Iowa Energy Efficiency Statewide Technical Reference Manual Version 6.0

Volume 3: Nonresidential Measures

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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 CFM[1]/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 Labs[2] with fan diameters above 12 inches that meet program minimum efficiency requirements.

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

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

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

[1] Cubic Feet per Minute

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

[3] Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,259 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

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

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

If actual costs are not available, assume an incremental total installed cost of$150.[5]

LOADSHAPE

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts\_base - Watts\_ee}{1000} * Hours * Nfans$$

Where:

Watts_base[6] = Demand (W) of baseline fan

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

Watts_ee[7] = Demand (W) of efficient fan

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

Hours = Actual hours of operation. Typically, the fans will be operated above certain temperature thresholds, and therefore the operating hours can be reasonably estimated using the Ag Ventilation Operating Hours Calculator if temperature setpoints are known. If not, the following table[8] can be used to establish operating hours by facility type (hog, poultry, or dairy). For dairy facilities the typical temperature setpoint can be assumed to be 67°F, for poultry and hog facilities it can be assumed to be 65°F and 60°F, respectively, as these are the recommended temperatures above which comfort cooling should be

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

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

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

[8] Based on TMY3 data for Des Moines. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa. For more information on the weighting, see: “Ventilation Op Hours_2020.xlsx”.

provided for livestock.[9]

Facility Type	Annual Hours of Operation
Hog	3597
Poultry	2,862
Dairy	2,578
Unknown/Other	3,249

Nfans = Number of circulation fans

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts\_base - Watts\_ee}{1000} * CF * Nfans$$

Where:

CF = Summer Peak Coincidence Factor

= 100%[10]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-CIRC-V04-210101

SUNSET DATE: 1/1/2024

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

[10] Industrial Ventilation CF from eQuest.

3.1.2. Ventilation Fans

Description

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

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

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment must be certified by BESS Labs[11] with fan diameters above 14 inches that meet program minimum efficiency requirements.

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

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years.[13]

Deemed Measure Cost

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

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

[11] University of Illinois, Department of Agricultural and Biological Engineering. http://bess.illinois.edu/
[12] Static Pressure in units of inches of water
[13] Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 4,800 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.
[14] Baseline full installed costs from Act on Energy Commercial Technical Reference Manual No. 2010-4. Cost for 14-23” diameter fans determined through extrapolation of costs for other fan sizes.

If actual cost not available, assume an incremental total installed cost of $150.[15]

Loadshape

Loadshape NREV06-Industrial Ventilation

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \frac{Watts\_base - Watts\_ee}{1000} * hours * Nfans$$

Where:

Watts_base[16] = 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_ee[17] = Demand (W) of efficient fan

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

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

Facility Type	Annual EFLH
Hog	4,923
Poultry	4,794
Dairy	4,205

[15] Act on Energy Commercial Technical Reference Manual No. 2010-4.
[16] BESS fan database downloaded on 7/1/2015. Average watts from models below standard (minimum efficiency requirement detailed in the efficient equipment definition). For more detail, see: "AgVentilationFans.xls"
[17] BESS fan database downloaded on 7/1/2015. Average watts from models above standard (minimum efficiency requirement detailed in the efficient equipment definition). For more detail, see: "AgVentilationFans.xls"
[18] See "Ventilation Op Hours_2020.xlsx" workbook for a complete description and derivation of default operating hours. EFLH based on TMY3 data for Des Moines. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

Facility Type	Annual EFLH
Unknown/Other	4,800

Nfans = Number of ventilation fans

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts\_base - Watts\_ee}{1000} * CF * Nfans$$

Where:

CF = Summer Peak Coincidence Factor

= 100%[19]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-VENT-V03-210101

SUNSET DATE: 1/1/2026

[19] Industrial Ventilation CF from eQuest.

3.1.3. High Volume Low Speed Fans

Description

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

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment must be a fan with a diameter above 16 feet that meets program minimum efficiency requirements.

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Measure Cost

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

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

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

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

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

[20] Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,259 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

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

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

LOADSHAPE

Loadshape– NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

N_{base} = Number of baseline (conventional) fans being replaced (of equivalent wattage)

= Actual (for Retrofit projects). For new construction projects, the number of baseline fans should be set equivalent to the number of HVLS fans being installed.

$Watts_{base}$ = Operating demand (W) of baseline fan

=Actual (Retrofit). For new construction projects refer to the New Construction HVLS connected load savings table below.

N_{ee} = Number of efficient fans installed (of equivalent wattage)

= Actual

$Watts_{ee}$ = Operating demand (W) of efficient fan

= Actual (Retrofit). For new construction projects refer to the New Construction HVLS connected load savings table below.

New Construction HVLS Connected Load Savings[23]

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 table[24] can be used to establish operating hours. For dairy facilities the typical temperature setpoint can be assumed to be 67°F, for poultry and hog facilities it can be assumed to be 65°F and 60°F, respectively, as these are the recommended temperatures above which comfort cooling should be provided for

[23] KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, Group 1 Programs, Volume 2 (Table 17). Typically, the number of baseline conventional circulation fans the HVLS fan is off-setting is not a one for one replacement scenario. Due to their more efficient design, a single HVLS fan can move and displace as much air as multiple conventional circulation fans. The baseline wattage represents the equivalent quantity of baseline fans and their wattages to match that of a single HVLS fan.
[24] Based on TMY3 data for Des Moines. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa. For more information on the weighting, see: "Ventilation Op Hours_2020.xlsx".

livestock.[25]

Facility Type	Annual Hours of Operation
Hog	3597
Poultry	2,862
Dairy	2,578
Unknown/Other	3,259

Summer Coincident Peak Demand Savings

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

Where:

CF = Summer Peak Coincidence Factor

= 100%[26]

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-HVLS-V03-210101

Sunset Date: 1/1/2026

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

[26] Industrial Ventilation CF from eQuest.

3.1.4. Temperature Based On/Off Ventilation Controller

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years.[27]

Deemed Measure Cost

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

Loadshape

Loadshape NREV06-Industrial Ventilation

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \frac{Watts\_fan}{1000} * (Hours_{control})$$

[27] Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 4,800 hours.

Where:

Watts_fan = Total wattage of controlled fans

= Actual - If unknown, the following table can be used to estimate:[28]

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

$Hours_{control}$ = Reduction in fan run hours due to controller[29]

Facility Type	$Hours_{control}$
Hog	1,384
Poultry	877
Dairy	624
Unknown/Other	1,137

Summer Coincident Peak Demand Savings

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

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-VCON-V02-210101

Sunset Date: 1/1/2026

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

[29] Refer to "Ventilation Op Hours_2020.xlsx" workbook for a complete derivation. Reduced run time as a result of the installation of a thermostatic controller is based on TMY3 weather data for Des Moines, Iowa. Additional factors are incorporated into the analysis such as fan temperature settings and staging's. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

3.1.5. Automatic Milker Take Off

Description

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

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

Retrofit measure, actual costs will be used.

Loadshape

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

Calculation of Savings

Electric Energy Savings**:**

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

Where:

kWh/cow/milking = 50[32]

Nmilkings = Number of milkings per day

= Actual, if unknown use 2[33]

Ncows = Number of milking cows per farm

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

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

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

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

= Actual; if unknown use 140[34]

SUMMER COINCIDENT PEAK DEMAND SAVINGS:

$$\Delta kW = \frac{\Delta kWh}{FLH} \, x \, CF$$

Where:

FLH = Full Load Hours

= 2,703[35]

CF = Coincidence Factor

= 0.793[36]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-AMTO-V04-210101

SUNSET DATE: 1/1/2024

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

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

[36] Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

3.1.6. Dairy Scroll Compressor

Description

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

This measure applies to the following program types: RF.

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

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

Loadshape

Loadshape NRE01 - Non-Residential Refrigeration - Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

EER_{Base} = Cooling efficiency of existing compressor in Btu/watt-hour

= Actual, if unknown use values from table below[38]

EER_{ee} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour

= Actual, if unknown use values from table below[39]

[37] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, "Effective/Remaining Useful Life Values", California Public Utilities Commission, February 4, 2014 (http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx)

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

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

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

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

= 6[40]

$Days_{yr}$ = Number of days per year

= 365.25

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

= 0.93[41]

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

= 8.6

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

= 19[42]

Required change in temperature (without precooler) in °F

= 59[43]

1000 =Conversion factor from watts to kilowatts

N_{Cows} = Number of cows

= Actual, if unknown use 140 cows[44]

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

ΔkWh = (1/11.12 - 1/12.39) * 6 * 365.25 * 0.93 * 8.6 * 19 * 1/1000 * 90

= 276.3 kWh

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

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

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

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

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

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh}{FLH} \; x \; CF$$

Where:

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

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

> **For example,** for a 5 HP efficient scroll compressor (with precooler) replacing an existing reciprocating compressor, serving 90 cows:
>
> ΔkW = (276.3/3910) * 0.964
>
> = 0.0681 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-AGE-SCROL-V04-210101

Sunset Date: 1/1/2021*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

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

3.1.7. Heat Lamp

Description

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is 1 year.[46]

Deemed Measure Cost

Incremental cost is assumed to be $0.[47]

Loadshape

Loadshape C04 - Nonresidential Electric Heating

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

W_{Base} = Wattage of baseline heat lamp

= 175 watts[48]

W_{eff} = Wattage of reduced wattage heat lamp

= Actual if known, otherwise assume 125 watts[49]

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

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

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

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

Hours = Annual heat lamp operating hours[50]

= 5,105 hours

1,000 = Conversion factor from watts to kilowatts

= 1,000

Nunits = Number of units installed

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings for heating measures

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-HTLP-V02-210101

SUNSET DATE: 1/1/2024

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

3.1.8. Heat Reclaimer

Description

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

This measure applies to the following market: RF.

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

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

Loadshape

Loadshape C04 - Nonresidential Electric Heating

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

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

= 51.6 lbs of milk per cow per day[52]

$C_{P,Milk}$ = Specific heat of milk

= 0.93 Btu/(lb-°F)

ΔT_{Milk} = Change in milk temperature (°F)

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

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

= 59°F without precooler installed; 19°F with precooler installed

Days = Number of milking days per year

= 365 days

Heat Available = 1,033,422 Btu/h per cow per year without precooler

= 332,797 Btu/h per cow per year with precooler

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

Where:

Hot Water = Gallons of hot water needed per cow per day

= 2.2 gallons per cow per day

P_{Water} = Density of water

= 8.33 lbs/gallon

$C_{P,Water}$ = Specific heat of water

= 1 Btu/(lb-°F)

ΔT_{Water} = Change in water temperature between the incoming water and the hot water leaving the hot water heater

= 70°F

Heat Storage = 468,229 Btu/h per cow per year

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

Table 1 - Reclaimable Heat

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

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

Where:

EF_{elec} = Energy factor of the electric water heater

= Actual, if unknown use 0.90[53]

Reclaimable Heat = Values shown in Table 1 in Btu/h per cow per year

3,412 = Btu to kWh electric conversion factor

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

Table 2 – Heat Reclaimer Savings

Case	kWh/Cow
No precooler installed	152.5
Precooler installed	108.4

This method requires the program to collect information on existing precooler installation. When rebating a precooler and heat reclaimer at the same time, KEMA recommends that IPL follows the installation order discussed above. This measure should be limited to electric 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

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-HTRE-V04-210101

Sunset Date: 1/1/2024

3.1.9. Heat Mat

DESCRIPTION

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline is standard wattage heat lamps.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Incremental cost is assumed to be $225.[55]

LOADSHAPE

Loadshape C04 - Non-Residential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS[56]

ELECTRIC ENERGY SAVINGS

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

Where:

$Mats_{Single}$ = Number of single mats at 90 watts or less, actual

$Mats_{Double}$ = Number of single mats at 180 watts or less, actual

$Savings_{SingleMat}$ = Default energy savings per single mat, dependent on baseline heat lamp (kWh/mat)

[54] Professional judgement

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

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

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

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

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

Controller = Number of Controllers, actual

Controller Impact = 383 kWh/usage per controller

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

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

Where:

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

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

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

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

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

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

Where:

Crates$_{Total}$ = Number of crates

= 234

Hours$_{Yr}$ = Annual hours of operation

=5,105 hours[57]

Fixture$_{Crate}$ = Number of heat lamp fixtures per crate

=Actual. If unknown, use 1.25

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

$Lamp_{Fixture}$ = Number of heat lamps per fixture

=1

$Wattage_{Lamp}$ = Wattage of heat lamp

= Actual. If unknown, use 175 watts

1000 Watts/kW = Constant, conversion factor for watts to kW

$Controller_{Adv}$ = Controller advantage

=1

Rooms = Number of rooms per farrowing barn

= Actual. If unknown, use 9

MSU_{Room} = Number of master sensor units (MSU) per room

=1

$MSU_{Wattage}$ = Wattage of master sensor unit

=75W

$Crates_{Single\text{-}Row}$ = Number of single crates per row

= Actual. If unknown, use 1

$Single_{Wattage}$ = Wattage of a 14” x 60” farrowing heat mat

= 90W

$Single_{Mat}$ = Number of 14” x 60” farrowing heat mats per single crate

= Actual. If unknown, use 1

Rows = Number of rows per room

= Actual. If unknown, use 2

$Crates_{Double\text{-}Row}$ = Number of Double Crates per Row

= Actual. If unknown, use 12

$Double_{Wattage}$ = Wattage of a 24” x 60” farrowing heat mat

=180W

$Double_{Mat}$ = Number of a 24” x 60” farrowing heat mat

=0.5

Summer Coincident Peak Demand Savings

No summer coincident peak demand savings for heating measures

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-HTMT-V03-210101

SUNSET DATE: 1/1/2024

3.1.10. Grain Dryer

Description

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

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

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

Loadshape

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

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

58 Estimate based on professional judgment

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

= Actual, if unknown use table:[60]

Savings Tier (Bushels/hr) from manufacturer	Savings Tier (Bushels/yr)	Average Bushels/yr
< 500	$< 170{,}000$	85,000
≥ 500 *and* $< 1{,}000$	$\geq 170{,}000$ *and* $< 330{,}000$	225,000
$\geq 1{,}000$ *and* $< 2{,}000$	$\geq 330{,}000$ *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

= 0.075[61]

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

= 0.035[62]

Summer Coincident Peak Demand Savings

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

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-GNDR-V02-200101

Sunset Date: 1/1/2025

[60] Alliant Energy Custom Rebate project data from 2012-2014

[61] Alliant Energy Custom Rebate project data from 2012-2014

[62] Alliant Energy Custom Rebate project data from 2012-2014

3.1.11. Live Stock Waterer

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

Actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, assume an incremental capital cost of $787.50.[64]

Loadshape

Loadshape C04 - Nonresidential Electric Heating

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

kWh/Waterer = 1104[65]

N_{Units} = Number of waterers installed per farm

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

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

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

Summer Coincident Peak Demand Savings

No summer coincident peak demand savings for heating measures

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-LSWT-V02-180101

Sunset Date: 1/1/2024

3.1.12. Low Pressure Irrigation

Description

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The baseline for this measure is the existing irrigation system.

Deemed Lifetime of Efficient Equipment

The expected measure life is 5 years.[66]

Deemed Measure Cost

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

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

Hours = hours irrigation system runs per season

= 864 hr/yr[67]

Pressure = reduction in pump pressure resulting from retrofit

= Actual (PSI)

Acres = Actual

Flow per Acre = 5 gallons/minute/acre[68]

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

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

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

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

$Pump_{eff}$ = Actual, if unknown use 0.70[69]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

FLH = Full Load Hours

= 6768[70]

CF = Summer System Peak Coincidence Factor 79.3%[71]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-LIRR-V02-200101

SUNSET DATE: 1/1/2021*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

[69] Appendix F Program Evaluations Group 1 Vol 2; page 354
[70] Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls
[71] IA_Electric_Loadshapes.xls

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

Description

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

This measure applies to the following markets: RF.

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The baseline is an existing pump without a VFD.

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

Actual material and labor costs should be used.

Loadshape

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

16 = Annual energy savings per cow per milking from VSD dairy vacuum pump (kWh/cow/milking)

= 16[73]

$N_{Milking}$ = Number of milkings per cow per day

= Actual, if unknown use 2[74]

---

[72] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014 (http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

[73] 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.

[74] Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy

N_{Cows} = Number of milking cows per farm

= Actual, if unknown use 140[75]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH = Full Load Hours

= 2,703[76]

CF = coincidence factor

= 0.793[77]

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-V03-210101

SUNSET DATE: 1/1/2023

savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

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

[76] The full load hours are based on an average number of milkings per day of 2, and assumptions on the average hours per milking of 3.7 hours, with milking occurring 365.25 days a year.. Source Milking System Air Consumption When Using a Variable Speed Vacuum Pump. Paper Number: 033014 An ASAE Meeting Presentation. July 2003

[77] 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 precooler 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 precooler.

Deemed Lifetime of Efficient Equipment

The expected measure life of a plate cooler is 15 years.[78]

Deemed Measure Cost

Actual material and labor costs should be used.

If the actual installed cost is unknown, the default equipment cost of a plate cooler is $2,950 with an installation cost of $494, for a total incremental installed cost of $3,444.[79]

Loadshape

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

kWh/Cow = Per cow annual energy savings from plate-style milk precooler in kWh/cow/yr.[80]

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

[78] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, "Effective/Remaining Useful Life Values", California Public Utilities Commission, February 4, 2014
[79] The equipment and labor costs are sourced from the PG&E Workpaper – Milk Pre Cooler (PGE3PAGR114), February 2013.
[80] IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

Equipment Type	kWh/cow/year
scroll compressor installed	
Default if type not know [81]	66.5

NCows = Number of milking cows per farm

= Actual, if unknown use 140[82]

Savings Analysis:

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

Where:

Days = Number of milking days per year

= 365 days[83]

$C_{P,Milk}$ = Specific heat of milk[84]

= 0.93 Btu/(lb-°F)

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

= 51.6 lbs of milk per cow per day[85]

ΔT = Temperature reduction of the milk across precooler

= 40°F[86]

Btuh of Heat Recovery = Difference in Btu/h per cow per year recovered by heat reclaimer system with and without precooler

= 0 Btu/h per cow per year if non-electric water heater

= 131,562 Btu/h per cow per year if electric water heater and a heat reclaimer are present on-site[87]

1000 = Conversion factor from watts to kilowatts[88]

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

[81] 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.

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

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

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

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

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

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

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

= if installed with reciprocating compressor, use EER of 8.4[89]

= if installed with unknown compressor type, use EER of 9.3[90]

= if installed with scroll compressor, use EER of 10.9[91]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH =Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are based on the run time of compressors for medium temperature refrigeration applications.[92]

= 3,910

CF = Coincidence factor

= 0.79[93]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-DYPC- V05-210101

SUNSET DATE: 1/1/2026

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

[90] 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.

[91] Typical milk precooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.9 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

[92] 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

[93] Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

3.1.15. LED Grow Lights

Description

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

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

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

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

Definition of Efficient Equipment

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

- Third-party tested and UL listed
- Power factor (PF) ≥ 0.90
- Photosynthetic photon efficacy (PPE) of no less than 1.9 micromoles per joule
- Minimum rated lifetime of 50,000 hours and a minimum warranty of 5 years
- LED fixture must be on the Design Lights Consortium qualifying products list[94]

Definition of Baseline Equipment

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

Crop Type	Baseline Technology Type	Baseline PPE (µmol/J)[95]	Baseline Watts per Square Foot[96]	Baseline Fixture Wattage[97]
Flowering Crops (Tomatoes and Peppers)	High Pressure Sodium	1.7	52.5	750 W
Vegetative Growth	Metal Halide	1.25[98]	40	640 W

[94] Design Light Consortium – Horticultural Lighting, Testing and Reporting Requirements of LED-Based Horticultural Lighting, version 2.0, effective March 31, 2021

[95] Erik Runkle and Bruce Bugbee "Plant Lighting Efficiency and Efficacy: µmols per joule". Accessed 4/21/2020.

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

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

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

Crop Type	Baseline Technology Type	Baseline PPE (µmol/J)[95]	Baseline Watts per Square Foot[96]	Baseline Fixture Wattage[97]
Microgreens[99]	T5 HO Fixture	0.84[100]	22.5	360 W
Propagation[101]	T5 HO Fixture	0.84[102]	15	240 W
Cannabis – Flowering Stage	High Pressure Sodium	1.7	68.8	1,100 W

Deemed Lifetime of Efficient Equipment

The expected measure life is 9.5 years.[103]

Deemed Measure Cost

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

Incremental cost[104] = (\$1.42 * $Watts_{LED}$) - \$65

Where:

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

\$65 = LED fixture wattage to incremental cost offset

$Watts_{LED}$ = LED fixture wattage

Loadshape

Loadshape NRE11 - Nonresidential Agricultural

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = (Watts_{Base} - Watts_{EE}) * Area * Hours * WHF_e / 1000 + \Delta kWh_{Heating\ Penalty}$$

Where:

ΔkWh = gross customer annual kWh savings

Area = Illuminated plant canopy, in square feet, of active and growing space.

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

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

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

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

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

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

Excludes all room area not associated with physical plants, such as room floor or aisles.

= Use actual if known. If unknown, default is 16 square feet per fixture[105]

Hours = Annual hours of operation

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

Crop Types	Annual Hours[106]
Flowering Crops	4,200
Vegetative/Propagation Crops	6,300
Microgreens	6,300
Cannabis – Flowering Stage	4,200
Other	3,650
Average	5,250

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

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting. Value is based on the Nonresidential Average building type as selected from the Lighting Reference Table in Section 3.4, and detailed in the table below.

HVAC Cooling Type	WHF_e
Cooling	1.06
No Cooling	1.00

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

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

= Actual. If crop type is unknown, default value is 36 watts per square foot[107]

HEATING PENALTY

If electrically heated building:

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

Where:

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

HVAC Heating Type	IFkWh
Gas Heating	0.00
Electric Resistance Heating	0.24
Electric Heat Pump Heating	0.10

[105] Default illuminated area is based on an average canopy grow area of 4 ft. x 4 ft.

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

[107] "Cannabis Energy Guidance", Massachusetts Department of Energy Resources, February 2019

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = 1.00

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings. Value is based on the Non-Residential Average building type as selected from the Lighting Reference Table in Section 3.4, and detailed in the table below.

HVAC Cooling Type	WHF_d
Cooling	1.28
No Cooling	1.00

NATURAL GAS SAVINGS

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

Where:

ΔTherms = gross customer annual therms savings

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

HVAC Heating Type	IFTherms
Gas Heating	0.01
Other Heating Type	0.00

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 197[108]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Any costs associated with moving the LED lighting fixture to different heights throughout the different growing

108 Number of days where HDD 55 >0.

phases should also be included as an O&M consideration. See table below for default replacement assumptions:[109]

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

MEASURE CODE: NR-AGE-GROW-V02-220101

SUNSET DATE: 1/1/2024

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

3.1.16 Grain Bin Fan Aeration Controls

Description

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

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

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

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

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

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

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is 7 years.[110]

Deemed Measure Cost

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

Loadshape

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Table: Default Annual kWh Savings Based on Bin Size

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
20	215	430	430	430	430	860	860	860	1,290	1,290	2,150
30	430	430	860	860	1,290	1,720	2,150	2,150	2,580	3,440	4,730
35	430	860	1,290	1,290	1,720	2,150	3,440	3,440	3,870	5,160	7,310
40	430	1,290	1,720	2,150	3,010	3,440	5,160	5,590	6,020	7,740	10,750
45	860	1,720	2,580	3,440	4,300	5,160	7,310	8,170	8,600	11,610	15,910
50	1,290	2,580	3,440	4,730	6,020	7,310	10,320	11,180	12,470	16,340	22,360
55	1,720	3,440	4,730	6,450	8,170	9,890	14,190	15,480	16,770	22,360	30,530
60	2,150	4,730	6,450	8,600	10,750	13,330	19,350	20,640	22,360	30,100	40,850
65	2,580	6,450	8,600	11,180	14,190	17,200	24,940	27,090	29,240	39,130	53,320
70	3,440	8,170	10,750	14,190	18,060	22,360	32,250	34,830	37,840	50,310	68,370
75	4,300	9,890	13,760	18,060	22,790	27,950	40,420	43,860	47,300	63,210	86,000
80	5,590	12,470	17,200	22,360	27,950	34,830	49,880	54,180	58,910	78,260	106,210
85	6,880	15,480	20,640	27,090	34,400	42,570	61,060	66,220	71,810	95,460	29,860
90	8,170	18,490	24,940	32,680	41,710	51,170	73,960	79,980	86,860	115,240	156,950
95	9,890	21,930	30,100	39,130	49,450	61,060	88,150	95,890	103,630	138,030	187,480
100	11,610	26,230	35,690	46,440	58,910	72,670	104,490	113,090	122,550	162,970	221,880

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

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

Where:

ΔkWh = gross customer annual kWh savings

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

Where:

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

= Default value is 430 kWh/hp

0.746 = Conversion factor from hp to kW

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

= 720 hours[111]

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

= 180 hours[112]

Eff_{Motor} = Efficiency of the fan motor

= 93.6%[113]

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

Where:

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

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

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

Eff_{Fan} = Efficiency of the fan

= 60%[114]

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

= 5%[115]

Static Pressure = The design static pressure of the stored grain required to be overcome by the aeration fan. Value as determined from the following polynomial where x is the bin eave height in feet, assuming the default value for CFM per Bushel of 0.17.[116]

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

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

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

[114] Typical rule of thumb for fans with high static pressure.

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

[116] Kansas State University Research and Extension, "Aeration of Grain", April 2012

$= ax^2 + bx + c$

a = 0.002142472

b = -0.0679226

c = 1.212104147

Table: Default Static Pressure

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

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

Where:

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

CFM per Bushel = CFM required per bushel for effective aeration

= 0.17 CFM per bushel[117]

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

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

= See table below for Bushel Capacity default values

Table: Bushel Capacity

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
20	7,274	16,367	22,278	29,098	36,827	45,465	65,470	71,039	76,836	102,297	139,237
30	10,912	24,551	33,417	43,647	55,240	68,198	98,205	106,559	115,254	153,445	208,855
35	12,730	28,643	38,986	50,921	64,447	79,564	114,572	124,319	134,463	179,019	243,665
40	14,549	32,735	44,556	58,195	73,654	90,930	130,940	142,079	153,672	204,593	278,474
45	16,367	36,827	50,125	65,470	82,860	102,297	147,307	159,838	172,881	230,167	313,283
50	18,186	40,919	55,695	72,744	92,067	113,663	163,674	177,598	192,090	255,741	348,092
55	20,005	45,010	61,264	80,019	101,274	125,029	180,042	195,358	211,299	281,315	382,902
60	21,823	49,102	66,834	87,293	110,480	136,395	196,409	213,118	230,508	306,890	417,711
65	23,642	53,194	72,403	94,567	119,687	147,762	212,777	230,878	249,717	332,464	452,520

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

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
70	25,460	57,286	77,973	101,842	128,894	159,128	229,144	248,637	268,926	358,038	487,329
75	27,279	61,378	83,542	109,116	138,100	170,494	245,512	266,397	288,135	383,612	522,139
80	29,098	65,470	89,112	116,391	147,307	181,861	261,879	284,157	307,344	409,186	556,948
85	30,916	69,562	94,681	123,665	156,514	193,227	278,247	301,917	326,553	434,760	591,757
90	32,735	73,654	100,251	130,940	165,720	204,593	294,614	319,677	345,762	460,334	626,566
95	34,553	77,745	105,820	138,214	174,927	215,959	310,981	337,437	364,971	485,909	661,376
100	36,372	81,837	111,390	145,488	184,134	227,326	327,349	355,196	384,180	511,483	696,185

Diameter = Diameter of the storage bin, in feet

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

Bushels per ft^3 = Bushels per cubic foot (for storage)

= If unknown, default is 0.804 Bu/ft^3

Table: Fan BHP Based on Bin Size

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
20	0.5	1	1	1	1	2	2	2	3	3	5
30	1	1	2	2	3	4	5	5	6	8	11
35	1	2	3	3	4	5	8	8	9	12	17
40	1	3	4	5	7	8	12	13	14	18	25
45	2	4	6	8	10	12	17	19	20	27	37
50	3	6	8	11	14	17	24	26	29	38	52
55	4	8	11	15	19	23	33	36	39	52	71
60	5	11	15	20	25	31	45	48	52	70	95
65	6	15	20	26	33	40	58	63	68	91	124
70	8	19	25	33	42	52	75	81	88	117	159
75	10	23	32	42	53	65	94	102	110	147	200
80	13	29	40	52	65	81	116	126	137	182	247
85	16	36	48	63	80	99	142	154	167	222	302
90	19	43	58	76	97	119	172	186	202	268	365
95	23	51	70	91	115	142	205	223	241	321	436
100	27	61	83	108	137	169	243	263	285	379	516

Table: Design CFM

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
20	1,237	2,782	3,787	4,947	6,261	7,729	11,130	12,077	13,062	17,390	23,670
30	1,855	4,174	5,681	7,420	9,391	11,594	16,695	18,115	19,593	26,086	35,505
35	2,164	4,869	6,628	8,657	10,956	13,526	19,477	21,134	22,859	30,433	41,423
40	2,473	5,565	7,574	9,893	12,521	15,458	22,260	24,153	26,124	34,781	47,341
45	2,782	6,261	8,521	11,130	14,086	17,390	25,042	27,173	29,390	39,128	53,258
50	3,092	6,956	9,468	12,367	15,651	19,323	27,825	30,192	32,655	43,476	59,176
55	3,401	7,652	10,415	13,603	17,217	21,255	30,607	33,211	35,921	47,824	65,093

	Bin Diameter (ft)										
Bin Eave Height (ft)	24	36	42	48	54	60	72	75	78	90	105
60	3,710	8,347	11,362	14,840	18,782	23,187	33,390	36,230	39,186	52,171	71,011
65	4,019	9,043	12,309	16,076	20,347	25,119	36,172	39,249	42,452	56,519	76,928
70	4,328	9,739	13,255	17,313	21,912	27,052	38,955	42,268	45,717	60,866	82,846
75	4,637	10,434	14,202	18,550	23,477	28,984	41,737	45,288	48,983	65,214	88,764
80	4,947	11,130	15,149	19,786	25,042	30,916	44,519	48,307	52,249	69,562	94,681
85	5,256	11,825	16,096	21,023	26,607	32,849	47,302	51,326	55,514	73,909	100,599
90	5,565	12,521	17,043	22,260	28,172	34,781	50,084	54,345	58,780	78,257	106,516
95	5,874	13,217	17,989	23,496	29,738	36,713	52,867	57,364	62,045	82,604	112,434
100	6,183	13,912	18,936	24,733	31,303	38,645	55,649	60,383	65,311	86,952	118,351

Summer Coincident Peak Demand Savings

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

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-GRAIN-V01-210101

Sunset Date: 1/1/2026

3.1.17. Dairy Refrigeration Tune-Up

Description

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

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

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

Definition of Efficient Equipment

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

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is 3 years.[118]

Deemed Measure Cost

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used. If unknown, the default incremental cost is estimated to be $194.[119]

Loadshape

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

Algorithm

Calculation of Energy Savings

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

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

Electric Energy Savings

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

Where:

Days	= Number of milking days per year
	= 365 days[120]
$C_{P,Milk}$	= Specific heat of milk[121]
	= 0.93 Btu/(lb-°F)
Lbs of Milk	= The pounds of milk produced per day per cow that needs to be cooled
	= 51.6 lbs of milk per cow per day[122]
Cows	= Number of cows
	= Actual, if unknown use 140 cows[123]
ΔT	= Temperature differential of milk this is mechanically cooled
	= 59°F if no pre-cooler is in operation
	= 29°F if a milk pre-cooler is in operation
	= 19°F if a milk pre-cooler is in operation with a milk transfer pump VFD
1000	= Conversion factor from watts to kilowatts[124]
EER	= Energy Efficiency Ratio; efficiency of the existing compressor on the milk refrigeration system (Btu/Wh)
	= if tune-up with reciprocating compressor, use EER of 8.4[125]
	= if tune-up with unknown compressor type, use EER of 9.3[126]
	= if tune-up with scroll compressor, use EER of 10.9[127]
SF	= Energy savings factor
	= 5%[128]

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

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

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

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

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

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

[126] 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.

[127] Typical milk precooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.9 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

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

Summer Coincident Peak Demand Savings

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

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-AGE-TUNE-V01-220101

Sunset Date: 1/1/2026

3.1.18. ECM Ventilation Fan and Staging Controls

Description

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

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

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

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

Definition of Efficient Equipment

In order for this characterization to apply, a new ventilation controller is installed on new or existing ventilation fans. The fans must have ECM motors to fully realize the control savings.

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years.[129]

Deemed Measure Cost

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

Loadshape

Loadshape NREV06-Industrial Ventilation

[129] Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 4,800 hours.

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

$Watts_{base}$ = Connected load of baseline ventilation fans (watts)[130]

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

$hours_{Total}$ = Actual hours of operation. Typically, the fans will operate in a staged fashion such that only a fraction of total fans are operating in conditions that do not require maximum installed capacity. Accordingly, effective full load hours (EFLH) should be determined based on operating schedule and considering factors such as number of fans, stages, and temperature band definitions. If this information is unavailable, the table below may be used to reasonably estimate EFLH for hog, poultry, and dairy facilities, based on typical control schedules.[131]

Facility Type	Annual EFLH
Hog	4,923
Poultry	4,794
Dairy	4,205
Unknown/Other	4,800

$Nfans$ = Number of ventilation fans

= Actual

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

= Actual

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

[131] See “Ventilation Op Hours_2020.xlsx” workbook for a complete description and derivation of default operating hours. EFLH based on TMY3 data for Des Moines. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

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

= Actual

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

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

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

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

= 46,806 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-ECMV-V01-220101

SUNSET DATE: 1/1/2023

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)[132] or less. Savings are calculated on an average savings per faucet fixture basis.

Definition of Baseline Equipment

The baseline condition is assumed to be a standard faucet aerator rated at 2.2 GPM[133] 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.[134]

Deemed Measure Cost

The incremental installed cost for this measure is $16,[135] or program actual cost.

Loadshape

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

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

Algorithm

Calculation of Savings

Electric Energy Savings

Note these savings are per faucet retrofitted.[136]

[132] IPL program product data for 2014 Iowa Residential Energy Assessments.
[133] DOE Energy Cost Calculator for Faucets and Showerheads: (http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html#output)
[134] 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"
[135] 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)).
[136] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.

$$\Delta kWh = \%ElectricDHW * \frac{GPM\_base - GPM\_low}{GPM\_base} * Usage * EPG\_electric * ISR$$

Where:

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

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	53%[137]

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

= Measured full throttle flow * 0.83 throttling factor[138]

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

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

= Rated full throttle flow * 0.95 throttling factor[139]

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[140] (A)	Unit	Estimated % total building hot water use from Faucets[141] (B)	Multiplier[142] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Rest	0.7	meal/day	50%	75	meals per faucet	365.25	9.588
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365.25	15,779
Retail	2	employee	100%	5	employees per faucet	365.25	3,653
Grocery	2	employee	100%	5	employees per faucet	365.25	3,653

137 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.

138 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

139 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

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

141 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

142 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[140] (A)	Unit	Estimated % total building hot water use from Faucets[141] (B)	Multiplier[142] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365.25	16,436
Motel	20	room	25%	1	faucet per room	365.25	1,826
Hotel	14	room	25%	1	faucet per room	365.25	1,278
Other	1	employee	100%	20	employees per faucet	250	5,000

EPG_electric = Energy per gallon of mixed water used by faucet (electric water heater)

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

= 0.0822 kWh/gal if resistance tank (or unknown) [143]

= 0.0403 kWh/gal if heat pump water heater

Where:

γWater = Specific weight of water (lbs/gallon)

= 8.33 lbs/gallon

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

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen

SupplyTemp = Assumed temperature of water entering building

= 56.5[144]

RE_electric = Recovery efficiency of electric water heater

= 98% for electric resistance (or unknown)[145]

= 200% for heat pump water heaters [146]

3412 = Converts Btu to kWh (Btu/kWh)

143 Assumes 50:50 kitchen and bathroom usage.

144 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.

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

146 200% represents a reasonable estimate of the weighted average event recovery efficiency for heat pump water heaters, including those that are set to Heat Pump only mode (and so have a recovery efficiency >250%) and those that are set in hybrid mode where a larger draw would kick the unit in to resistance mode (98%), or where low total water consumption can result in lower COPs due to relatively high standby losses. Note that the AHRI directory provides recovery efficiency ratings, some of which are >250% but most are rated at 100%. This is due to the rating test involving a large hot water draw, consistent with multiple showers.

ISR = In service rate of faucet aerators

=Assumed to be 1.0

Based on defaults provided above:[147]

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

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = calculated value above on a per faucet basis

Hours = Annual electric DHW recovery hours for faucet use

= (Usage * 0.479[148])/GPH

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% for resistance (or unknown) and 200% for heat pump water tanks recovery efficiency, and typical 12kW electric resistance storage tank.[149]

= 68.8 if resistance tank, 140.4 if heat pump

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

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

[147] See "Commercial Faucet Aerator Calculations_06122019.xlsx" for details.
[148] 47.9% is the proportion of hot 126.5F water mixed with 56.5F supply water to give 90°F mixed faucet water.
[149] See "Calculation of GPH Recovery_06122019.xlsx" for more information.

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

CF = Coincidence Factor for electric load reduction

= Dependent on building type[150]

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:[151]

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

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

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

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * \frac{GPM\_base - GPM\_low}{GPM\_base} * Usage * EPG\_gas * ISR$$

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	47%[152]

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)

= (8.33 * 1.0 * (WaterTemp[153] - 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% [154]

= 78% for buildings with storage tank, 59% if hot water through central boiler, or 69% if unknown[155]

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

Other variables as defined above.

Based on defaults provided above:[156]

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

152 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.
153 Assumes 50:50 kitchen and bathroom usage.
154 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.
155 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.
156 See "Commercial Faucet Aerator Calculations_06122019.xlsx" for details.

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

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

Based on defaults provided above:[157]

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

$$\Delta Gallons = \frac{GPM\_base - GPM\_low}{GPM\_base} * Usage * ISR$$

[157] See “Commercial Faucet Aerator Calculations_06122019.xlsx” for details.

Variables as defined above

Based on defaults provided above:[158]

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

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2026

[158] See "Commercial Faucet Aerator Calculations_06122019.xlsx" for details.

3.2.2. Low Flow Showerheads

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[159]

DEEMED MEASURE COST

The incremental installed cost for this measure is $20[160] or program actual.

LOADSHAPE

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture:

$$\Delta kWh = \%ElectricDHW * ((GPM\_base - GPM\_low) * L * SPD * Days) * EPG\_electric * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%

[159] 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.

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

DHW fuel	%ElectricDHW
Unknown	53%[161]

GPM_base = Flow rate of the baseline showerhead

= Actual measured flow rate - If not measured, assume 2.5 GPM[162]

GPM_low = Flow rate of the low-flow showerhead

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

(L * SPD * Days) = Minutes of use per showerhead annually. Ideally, this should be calculated using the following inputs (if unknown defaults are provided below:

L = Shower length in minutes with showerhead

= 7.8 min[163]

SPD = Showers Per Day for showerhead

= Input estimate (if unknown see table below)

Days = Days used per year, on average

= Actual (if unknown see table below)

If it is not possible to provide a reasonable custom estimate for annual showerhead minutes, the following defaults can be used:[164]

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

EPG_electric = Energy per gallon of hot water supplied by electric

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

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

161 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.

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

163 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.

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

Where:

γWater = Specific weight of water (lbs/gallon)

= 8.33 lbs/gallon

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

ShowerTemp = Assumed temperature of water

= 101F[165]

SupplyTemp = Assumed temperature of water entering house

= 56.5[166]

RE_electric = Average Recovery efficiency of electric water heater

= 98% for electric resistance (or unknown)[167]

= 200% for heat pump water heaters[168]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of showerhead

= 1.0

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

ΔkWh = 1 * ((2.5 - 1.5) * 7.8 * 3 * 365.25) * 0.111 * 1.0

= 948.7 kWh

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

= (GPM_base * L * SPD * 365.25 * 0.65[169])/ GPH

Where:

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

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

[166] 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.

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

[168] 200% represents a reasonable estimate of the weighted average event recovery efficiency for heat pump water heaters, including those that are set to Heat Pump only mode (and so have a recovery efficiency >250%) and those that are set in hybrid mode where a larger draw would kick the unit in to resistance mode (98%), or where low total water consumption can result in lower COPs due to relatively high standby losses. Note that the AHRI directory provides recovery efficiency ratings, some of which are >250% but most are rated at 100%. This is due to the rating test involving a large hot water draw, consistent with multiple showers.

[169] 65.0% is the proportion of hot 125F water mixed with 56.5F supply water to give 101F shower water.

56.5), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 12kW electric resistance storage tank.[170]

= 68.8 if resistance tank, 140.4 if heat pump

CF = Coincidence Factor for electric load reduction

= 1.6% [171]

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:

ΔkW = (948.7 / 202) * 0.016

= 0.075 kW

NATURAL GAS SAVINGS

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

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	47%[172]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0048 Therm/gal for buildings with storage tank, 0.0063 Therm/gal if hot water through central boiler or 0.0054 Therm/gal if unknown

Where:

RE_gas = Recovery efficiency of gas water heater

= 78% for buildings with storage tank, 59% if hot water through central boiler or 69% if unknown[173]

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

Other variables as defined above.

[170] See "Calculation of GPH Recovery_06122019.xlsx" for more information.

[171] 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.

[172] 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.

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

> **For example,** for a direct-installed 1.5 GPM showerhead in an office open every day with gas DHW (unknown system) where the number of showers is estimated at 3 per day:
>
> ΔTherms = 1.0 * (2.5 – 1.5) * 7.8 * 3 * 365.25 * 0.0054 * 1.0
>
> = 46.2 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:

ΔTherms = Therm impact calculated above

365.25 = Days per year

> **For example**, for a direct-installed 1.5 GPM showerhead in an office open every day with gas DHW where the number of showers is estimated at 3 per day:
>
> ΔPeakTherms = 46.2 / 365.25
>
> = 0.1265 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Gallons = (GPM\_base - GPM\_low) * L * SPD * Days * ISR$$

Variables as defined above

> **For example**, for a direct-installed 1.5 GPM showerhead in an office open every day with where the number of showers is estimated at 3 per day:
>
> ΔGallons = (2.5 - 1.5) * 7.8 * 3 * 365.25 * 1.0
>
> = 8,547 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2026

3.2.3. Hot Water Heater

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

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

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

Equipment Type	Sub Category	Draw Pattern	Federal Standard[174]
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h	≤120 gallon tanks	Very small	UEF = 0.2674 – (0.0009 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5362 – (0.0012 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6002 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 0.6597 – (0.0009 * Rated Storage Volume in Gallons)
Commercial Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h	>120 gallon tanks	All	80% $E_{thermal}$, Standby Losses = (Q /800 + 110√Rated Storage Volume in Gallons)
Commercial Gas Storage Water Heaters >155,000 Btu/h		All	
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% $E_{thermal}$
	≥10 gal	All	80% $E_{thermal}$
Residential Sized Electric Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	Very small	UEF = 0.8808 – (0.0008 * Rated Storage Volume in Gallons)
		Low	UEF = 0.9254 – (0.0003 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.9307 – (0.0002 * Rated Storage Volume in Gallons)
		High	UEF = 0.9349 – (0.0001 * Rated Storage Volume in Gallons)
	>55 gallon and ≤120 gallon tanks[175]	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)

[174] Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.

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

Equipment Type	Sub Category	Draw Pattern	Federal Standard[174]
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)

Residential-duty Commercial Water Heaters meet the following criteria:

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

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[176]

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

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

Deemed Lifetime of Efficient Equipment

The expected measure life for water heaters is assumed to be 15 years for storage heaters and 20 years for tankless water heaters.[177]

Deemed Measure Cost

Actual costs should be used where available and if associated baseline costs can also be estimated for the application. If actual costs are unknown full install costs and incremental cost assumptions are provided below:[178]

[176] Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

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

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

Equipment Type	Category	Install Cost	Incremental Cost
Gas Storage Water Heaters ≤ 75,000 Btu/h, ≤55 Gallons	Baseline	$616	N/A
	Efficient	$1,055	$440
Gas Storage Water Heaters > 75,000 Btu/h	0.80 Et	$4,886	N/A
	0.83 Et	$5,106	$220
	0.84 Et	$5,299	$413
	0.85 Et	$5,415	$529
	0.86 Et	$5,532	$646
	0.87 Et	$5,648	$762
	0.88 Et	$5,765	$879
	0.89 Et	$5,882	$996
	0.90 Et	$6,021	$1,135
Gas Tankless Water Heaters >50,000 Btu/h and <200,000 Btu/h	Tankless Baseline	$593	N/A
	Efficient	$1,080	$487
	Incremental using Storage Baseline		$465
Gas Tankless Water Heaters ≥200,000 Btu/h	Tankless Baseline	$1,148	N/A
	Efficient	$1,427	$278
	Incremental using Storage Baseline		-$3,459
Electric Heat Pump Water Heaters ≤55 gallons	Baseline	$1,032	N/A
	<2.6 UEF	$2,062	$1,030
	≥2.6 UEF	$2,231	$1,199
Electric Heat Pump Water Heaters >55 gallons	Baseline	$1,319	N/A
	<2.6 UEF	$2,432	$1,113
	≥2.6 UEF	$3,116	$1,797

LOADSHAPE

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

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

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

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

T_{out} = Unmixed Outlet Water Temperature

= custom, otherwise assume 140[179]

T_{in} = Inlet Water Temperature

= custom - otherwise assume 56.5[180]

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

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

   Where:

   Capacity = Usable capacity of hot water storage tank in gallons

   = Actual[181]

   Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:[182]

Building Type[183]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788

179 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.

180 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.

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

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

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

Building Type[183]	Consumption/Cap
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894

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

Where:

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

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[184]

Building Type[185]	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

γWater = Specific weight capacity of water (lb/gal)

= 8.33 lbs/galAA

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

[185] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

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

$UEF_{elecbase}$ = Rated efficiency of baseline water heater expressed as Uniform Energy Factor (UEF);

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

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[186]
Residential Electric Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	Very small	UEF = 0.8808 – (0.0008 * Rated Storage Volume in Gallons)
		Low	UEF = 0.9254 – (0.0003 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.9307 – (0.0002 * Rated Storage Volume in Gallons)
		High	UEF = 0.9349 – (0.0001 * Rated Storage Volume in Gallons)
	>55 gallon and ≤120 gallon tanks [187]	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[188]

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

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

UEF_{eff} = Rated efficiency of efficient water heater expressed as Uniform Energy Factor (UEF)

= Actual

3412 = Converts Btu to kWh

kWh_{cool} = Cooling savings from conversion of heat in building to water heat[189]

---

[186] All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.

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

[188] Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

[189] This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling, and latent cooling demands.

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

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location[190]

= 0.0 for installation in an unconditioned space

18% = Portion of reduced waste heat that results in cooling savings[191]

COP_{COOL} = COP of Central Air Conditioner

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

LM = Latent multiplier to account for latent cooling demand

= 1.33 [192]

Cool = 1 if building has central cooling, 0 if not cooled

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

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

Where:

24% = Portion of reduced waste heat that results in increased heating load[193]

COP_{HEAT} = COP of electric heating system

= Actual system efficiency including duct loss - If not available, use:[194]

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

[191] This is estimated based on the percentage of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar). This is based on the average WHFe for non-residential buildings (1.06) and assuming an average cooling COP of 3.08 (1.06 = 1 + 0.1848/3.08).

[192] A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of "Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers" by M. A. Andrade and C. W. Bullard, 1999: www.ideals.illinois.edu/bitstream/handle/2142/11894/TR151.pdf

[193] This is estimated based on the percentage of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar). The average WHFh for non-residential buildings is 24%.

[194] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

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

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

For example, an 100 gallon 4.3 UEF Heat Pump Water heater is installed in place of a failed 100 gallon resistance tank, in a 1500 ft^2 restaurant with high draw rate. Unit is installed in conditioned, cooled space with gas heat:

$UEF_{elecbase}$ = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)

= 2.2418 – (0.0011 * 50)

= 2.187

kWh_{cool} = ((140 – 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1 - 1/4.3) * 1 * 0.18 * 1.33)/(3.08 * 3412) * 1

= 491 kWh

kWh_{heat} = 0 kWh

ΔkWh = ((140 – 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/2.187 - 1/4.3))/3412 + 491 - 0

= 2,341 kWh

Summer Coincident Peak Demand Savings

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

Where:

Hours = Full load hours of water heater

= 2,791[195]

CF = Summer Peak Coincidence Factor for measure

= 41%[196]

Natural Gas Savings

$$\Delta Therms = \Delta Therms_{Unit} + \Delta Therms_{Standby}$$

$$\Delta Therms_{Unit} = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma Water * 1 * \left(\frac{1}{\mu_{base}} - \frac{1}{\mu_{Eff}}\right)}{100{,}000}$$

Where:

[195] Water heater full load hour assumption is based on loadshape information provided by Cadmus.
[196] Water heater coincidence factor assumption is based on loadshape information provided by Cadmus.

μ_{base} = Rated efficiency of baseline water heater

Equipment Type	Sub Category	Draw Pattern	μ_{base} [197]
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h	≤120 gallon tanks	Very small	UEF = 0.2674 – (0.0009 * V)
		Low	UEF = 0.5362 – (0.0012 * V)
		Medium	UEF = 0.6002 – (0.0011 * V)
		High	UEF = 0.6597 – (0.0009 * V)
Commercial Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h	>120 gallon tanks	All	80% $E_{thermal}$, Standby Losses = (Q /800 + 110√V)
Commercial Gas Storage Water Heaters >155,000 Btu/h		All	
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% $E_{thermal}$
	≥10 gal	All	80% $E_{thermal}$

Where:

V = Rated storage volume of new water heater in gallons

= Actual

Draw Pattern = Draw profile based on actual water heater size and capacity [198]

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

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

= Actual

100,000 = Converts Btu to Therms

Additional Standby Loss Savings

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

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

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

Where:

SL_{base} = Standby loss of baseline unit

[197] Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.

[198] 10 CFR 430, Subpart B, Appendix E, Section 5.4.1

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

Q =Nameplate input rating in Btu/h

V = Rated volume in gallons

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

8766 = Hours per year

Example - Commercial Water Heater: for a 95% Thermal Efficiency, 130,000 Btu/hr, 100 gallon storage unit with rated standby loss of 1,079 Btu/h installed in a 1,500 ft^2 restaurant:

$\Delta Therms_{Unit}$ = ((140 – 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/0.8 - 1/0.95))/100,000

= 55.4 Therms

$\Delta Therms_{Standby}$ = (((130,000/800 + 110 * √100) – 1,079) * 8,766)/100,000

= 16.1 Therms

ΔTherms = 55.4 + 16.1

= 71.5 Therms

Example - Residential-Duty Commercial Water Heater: for a 0.86 Uniform Energy Factor (UEF), 100,000 Btu/hr, 74 gallon storage unit with first hour rating of 130 gallons installed in a 6,000 ft^2 multifamily apartment building:

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

UEF_{Base} = 0.6597–(0.0009 × 74)

= 0.5931

$\Delta Therms_{Unit}$ = ((140 – 56.5) * ((6,000/1,000) * 13,133) * 8.33 * 1 * (1/0.5934 - 1/0.86))/100,000

= 286.3 Therms

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

ΔTherms = 286.3 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:

ΔTherms = Therm impact calculated above

365.25 = Days per year

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

ΔPeakTherms = 71.5 / 365.25

= 0.1958 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.[199]

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

SUNSET DATE: 1/1/2025

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

3.2.4. Controls for Central Domestic Hot Water

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years.[200]

DEEMED MEASURE COST

Actual material and labor costs should be used if available. If actual costs are unknown, the assumed measure cost is $1,200 per pump.[201]

LOADSHAPE

Loadshape NREW08 – Nonresidential Electric Hot Water – Multifamily

Loadshape NRGW08 – Nonresidential Gas Hot Water - Multifamily

Algorithm

CALCULATION OF ENERGY SAVINGS[202]

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh.[203]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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[200] 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.

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

[202] See Illinois_Statewide_TRM_Workpaper_Demand Control Central DHW for more details.

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

Summer coincident peak demand savings are expected to be negligible.

Natural Gas Savings[204]

ΔTherms = 55.9 * number of dwelling units

For example, an apartment building with 53 units:

ΔTherms = 55.9 * 53

= 2,962.7 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:

ΔTherms = Therm impact calculated above

365.25 = Days per year

For example, an apartment building with 53 units:

ΔPeakTherms = 2,962.7 / 365.25

= 8.11 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-HWE-DHWC-V02-180101

Sunset Date: 1/1/2023

[204] 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.[205]

Deemed Measure Cost

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

$ / Sqft[206]	
Manually Operated	Automatic
$1.50	$6.50

Loadshape

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

Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

[205] 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

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

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

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

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

Where

Savings Factor = dependant on season and location:[207]

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 ft^2

= 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:

ΔTherms = Therm impact calculated above

Days = Days in operating season

= Actual

Water Impact Descriptions and Calculation

Water savings result from a reduction in evaporative losses:

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

Where:

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

Sqft = surface area of the pool in ft^2

= Actual

h_{makeup} = Height, in inches, the pool is typically filled when make-up water is added

= Actual

Freq = Total number of water make-up events throughout the operating season

= Actual

7.48052 = gallons of water per ft^3

12 = inches per foot

0.3[208] = conservative estimate for the reduction of make-up water required

DEEMED O&M COST ADJUSTMENT CALCULATION

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

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

SUNSET DATE: 1/1/2023

[208] 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.[209]

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 140[210]

[209] Conservative estimate based on product manufacturer published expected lifetime.

[210] 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 to the DHW system

= Actual, otherwise assume 56.5[211]

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

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

   Where:

   Capacity = Usable capacity of hot water storage tank in gallons

   = Actual

   Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:[212]

Building Type[213]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894

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

   Where:

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

   = Actual

   Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000

---

[211] 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.

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

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

sq.ft. based on building type:[214]

Building Type[215]	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

γWater = 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%.[216] 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 difinitely 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:

---

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

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

216 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

= 0.98 [217]

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

ΔkWh = (140 – 56.5) * (377 * 100) * 8.33 * 1 * 0.25 / (3,412 * 0.98)

= 1,960.5 kWh

Summer Coincident Peak Demand Savings

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

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:

ΔkW = 1,960.5 / 8,766 * 1

= 0.22 kW

Natural Gas Savings

For sites with natural gas DHW:

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

Where:

100,000 = Converts Btu to Therms

RE_{gas} = Recovery efficiency of gas DHW system

= Actual if known - if not, assume:

= 78%[218]

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:

ΔTherms = (140 – 56.5) * (377 * 100) * 8.33 * 1 * 0.25 / (100,000 * 0.85)

= 77.1 Therms

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

[218] 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%.

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

> **For example**, for a natural gas DHW system with a 100 gallon storage unit and a recovery efficiency of 85% installed in a restaurant:
>
> ΔPeakTherms =77.1 / 365.25
>
> = 0.2111 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-V03-190101

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. Values for both existing and new construction buildings are provided.

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

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

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

Existing Building

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average[219]	Model Source
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Education	1298	1073	1529	848	1351	928	9%	OpenStudio
Grocery	1493	320	1754	221	1601	356	0%	OpenStudio
Health	1206	1449	1430	996	1346	1207	0%	OpenStudio
Hospital	1084	1792	940	1436	1082	1662	0%	OpenStudio
Lodging	1365	1464	1464	1252	1494	1460	0%	OpenStudio
Multifamily	1521	1472	1846	1045	1694	1349	0%	OpenStudio
Office - Large	1457	1141	1748	843	1549	1084	0%	OpenStudio
Office - Small	1250	986	1435	667	1358	882	26%	OpenStudio
Restaurant	1040	1397	1324	937	1173	1249	7%	OpenStudio
Retail - Large	1255	846	1523	616	1348	845	5%	OpenStudio
Retail - Small	1172	891	1471	531	1372	780	11%	OpenStudio

[219] 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. Vales rounded in table, see model reference files for exact values.

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average[219]	Model Source
Warehouse	1277	1032	1589	539	1443	864	26%	OpenStudio
Convenience	785	1477	1224	1128	1071	1351	0%	eQuest
Industrial	849	1185	1275	856	1183	1063	0%	eQuest
Religious	1322	1109	1873	797	1796	1031	16%	eQuest
Nonresidential Average	1251	1034	1555	669	1438	915	N/A	N/A

New Construction

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average[220]	Model Source
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Education	510	776	683	464	591	645	11%	OpenStudio
Health	778	1482	972	1073	864	1328	0%	OpenStudio
Hospital	1799	1422	1520	946	2196	1356	0%	OpenStudio
Lodging	1080	1204	1491	813	1471	1105	0%	OpenStudio
Office - Large	710	816	917	641	862	823	0%	OpenStudio
Office - Small	450	616	590	448	492	542	31%	OpenStudio
Restaurant	896	915	1192	572	1048	825	8%	OpenStudio
Retail - Large	709	764	906	504	839	711	6%	OpenStudio
Retail - Small	785	749	1036	486	986	744	13%	OpenStudio
Warehouse	886	223	1238	35	1116	148	31%	OpenStudio
Convenience	N/A[221]							
Industrial								
Religious								
Grocery								
Multifamily								
Nonresidential Average	690	560	930	338	830	488	N/A	N/A

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

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

3.3.1. Boiler

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The baseline efficiency source is a natural gas non-condensing boiler used for space heating, not process, meeting the federal equipment standards. The current Federal Standard minimum AFUE rating is 84% for boilers <300,000 Btu/hr capacity,[222] 80% E_T for boilers ≥300,000 Btu/h and ≤2,500,000 Btu/h, and 82% E_C for boilers >2,500,000 Btu/h.[223]

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[224]

Deemed Measure Cost

The incremental install cost for boilers with <300,000 Btu/hr input capacity is provided in the table below and is dependent on AFUE efficiency.[225] Any boiler ≥300,000 Btu/h input capacity shall use a custom cost input.

AFUE	Full Install Cost	Incremental Install Cost
84%	$4,053	n/a
85%	$4,468	$415
86%	$5,264	$1,211
87%	$5,276*	$1,223
88%	$5,397*	$1,344
89%	$5,518*	$1,465
90%	$5,638*	$1,585

[222] 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.

[223] Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

[224] 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

[225] 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_Commercial.xls" for more information.

AFUE	Full Install Cost	Incremental Install Cost
91%	$5,583	$1,530
92%	$5,734*	$1,681
93%	$5,885*	$1,832
94%	$6,036*	$1,983
95%	$6,188*	$2,135
96%	$6,339*	$2,286
97%	$6,490*	$2,437
98%	$6,641*	$2,588
99%	$6,792	$2,739

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

Loadshape

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

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

Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

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

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

Capacity = Nominal Heating Input Capacity Boiler Size (Btu/hr) for efficient unit, *not existing unit*

= Actual

EfficiencyRating(base) =Baseline equipment efficiency rating, depending on boiler input capacity.

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE[226]
≥300,000 Btu/h and ≤2,500,000 Btu/h	80% E_T[227]

[226] 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.
[227] Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

Boiler Input Capacity	Efficiency Rating
>2,500,000 Btu/h	82% E_C[228]

EfficiencyRating(EE) = Efficent equipment efficiency rating

= Actual

100,000 = Conversion of Btu to Therms

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

ΔTherms = 1549 * 150,000 * ((0.90/0.84)-1) / 100,000

= 166.0 Therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[229]	Model Source
Convenience	0.01631	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014240	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011745	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[230]	0.014623	N/A

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

ΔPeak Therms = 166.0 * 0.013082

= 2.1711 Therms

[228] Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87

[229] Calculated as the percentage of total savings in the maximum saving day, from models.

[230] For weighting factors, see HVAC variable table in section 3.3.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-BOIL-V04-210101

SUNSET DATE: 1/1/2023

3.3.2. Furnace

Description

This measure covers the installation of a high efficiency gas furnace in a nonresidential or multifamily application. High efficiency condensing gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy. ECM furnace fan is a separate measure.

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

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

Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a condensing furnace with input energy <225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

Definition of Baseline Equipment

The baseline for this measure is a non-condensing furnace with input energy <225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating of 85%.[231]

Definition of Measure Life

The expected equipment measure life is assumed to be 18 years.[232]

Deemed Measure Cost

The incremental capital cost for this measure depends on efficiency as listed below:[233]

AFUE	Full Install Cost	Incremental Install Cost
85%	$4,030	N/A
86%	$4,086	$56
87%	$4,143	$113
88%	$4,199	$169
89%	$4,256	$226
90%	$4,312	$282
91%	$4,369	$339
92%	$4,425	$395
93%	$4,482	$452
94%	$4,538	$508
95%	$4,595	$565

[231] 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.

[232] Based on 'ASHRAE Equipment Life Expectancy chart'.

[233] Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers. Full install costs are interpolated from data provided in the 2018 MA 'Water Heating, boiler and Furnace Cost Study' and adjusted from MA to IA costs using the 2016 implicit regional price deflators from the Bureau of Economic Analysis. See "Iowa Incremental Cost Study2_Adjusted.xls" for more information.

AFUE	Full Install Cost	Incremental Install Cost
96%	$4,888	$858
97%	$5,181	$1,151
98%	$5,474	$1,444
99%	$5,768	$1,738

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

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{eff}}{AFUE_{base}} - 1\right)}{100{,}000}$$

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit, not existing unit

= Actual

$AFUE_{eff}$ = Annual Fuel Utilization Efficiency Rating (AFUE) of Energy Efficient equipment.

= Actual

$AFUE_{base}$ = Annual Fuel Utilization Efficiency Rating (AFUE) of Baseline equipment

= 85%

100,000 = Conversion of Btu to Therms

For example, for a 150,000 Btu/hr 92% efficient furnace installed at an existing small office building in unknown location:

ΔTherms = (1358 * 150,000 * (0.92/0.85 – 1)) / 100,000

= 167.8 Therms

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[234]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[235]	0.014658	N/A

For example, for a 150,000 Btu/hr 92% efficient furnace installed stallation at an existing small office building in unknown location:

ΔPeakTherms = 167.8 * 0.0167180

= 2.8053 Therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-HVC-FRNC-V05-220101

Sunset Date: 1/1/2025

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

235 For weighting factors see HVAC variable table in section 3.3.

3.3.3. Furnace Blower Motor

Description

A furnace is purchased, or retrofitted, with a brushless permanent magnet (BPM) blower motor installed instead of one with a lower efficiency motor. This measure characterizes only the electric savings associated with the fan during the heating season. Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation too. If the customer runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM motor that way, savings are near zero and possibly negative.

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

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

Definition of Efficient Equipment

A furnace with a brushless permanent magnet (BPM) blower motor, also known by the trademark ECM, BLDC, and other names.

Definition of Baseline Equipment

A furnace with a non-BPM blower motor. NOTE: Code of Federal Regulations applying to furnaces having a heat input rate of less than 225,000 Btu/hr and meeting definitions of the Residential Product Class effectively prohibits the manufacture of equipment utilizing non-BPM motors on and after July 3, 2019. By January 1, 2020 it shall be assumed that all equipment available for sale conforms to this regulation and therefore ineligible to claim savings for this measure. Given that the expected market for this measure could potentially rely on the Residential Product Class of furnaces for heating, care should be taken to ensure savings are claimed only for eligible equipment, i.e., furnaces that fall into the Commercial Product Class.

Deemed Lifetime of Efficient Equipment

Measure life is deemed to be the remaining useful life of the furnace, as calculated by 20 years[236] minus furnace age.

Deemed Measure Cost

If this measure is coupled with 3.3.2 Furnace, the cost of the efficient fan is assumed to be included in the cost of the furnace and can therefore be taken as $0. As a stand-alone measure, cost is calculated as follows:

For TOS and NC projects, the incremental cost is calculated as follows:

Cost = $0.29 * Watts +$36.5[237]

Where:

Watts = Nominal wattage of the efficient motor

For retrofit applications, the actual cost of labor plus materials should be used for screening purposes.

[236] 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

[237] Incremental costs established by comparing prices as listed on grainger.com 10/25/2015. See "ECM costs.xlsx" for complete analysis methodology.

Loadshape

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

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = \frac{HP * 0.746 * LF_{base} * Hours * SF}{\eta_{basemotor}}$$

Where:

HP = Nominal horsepower of efficient motor

= Actual

0.746 = converts HP to kW

LF_{base} = Load Factor of baseline motor at fan design CFM

= 65% [238]

Hours = Annual motor operating hours

= 4000 [239]

SF = Savings factor

= 0.2 [240]

$\eta_{basemotor}$ = Efficiency rating of the baseline motor

= 0.85 [241]

Summer Coincident Peak Demand Savings

There are no expected summer coincident peak demand savings for this measure.

Natural Gas Savings

N/A

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[238] 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.

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

[240] 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.

[241] 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.

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FBLM-V03-200101

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 set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, or water source that meets the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Note: New Federal Standards affecting heat pumps become effective January 1, 2023.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[242]

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for air-cooled units is assumed to be $467.99 per ton for up to and including CEE Tier 1 class products,[243] and $935.98 per ton for CEE Tier 2 and higher class products.[244] The incremental cost for all other equipment types should be determined on a site-specific basis.

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

Note: The Code of Federal Regulations mandates that manufacturers comply with minimum efficiency standards for certain types of heat pump equipment. Due to the fact that all equipment available for purchase must comply with this regulation, the Code of Federal Regulation shall be taken as the principle authoritative source for specification of baseline efficiency where applicable. Only in instances where equipment types or efficiency values are not specified by the Code of Federal Regulations shall they be sourced from IECC 2012.

[242] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[243] For specification details see; https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0
[244] NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [\text{Annual kWh Savings}_{cool}] + [\text{Annual kWh Savings}_{heat}]$$

For units with cooling capacities less than 65 kBtu/hr:

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

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.[245]

$SEER_{ee}$ = 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:

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

Where:

E_{base} = Baseline equipment efficiency. Use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio (EER) shall be used; see the table below for values.

E_{ee} = Efficient equipment efficiency.

= Actual installed. Use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio (EER) shall be used.

3,412 = kBtu per kWh.

[245] Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

COP_{base} = coefficient of performance of the baseline equipment; see table below for values.

COP_{ee} = coefficient of performance of the energy efficient equipment.

= Actual installed

All other variables as defined above.

Reminder: IECC 2012 shall only source minimum efficiency requirements when not specified by the Code of Federal Regulations.

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment and Table 4 to §431.97—Updates to the Minimum Heating Efficiency Standards for Air-Cooled Air Conditioning and Heating Equipment [Heat Pumps]

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.2	N/A	1/1/2018
		All Other Types of Heating	IEER = 12.0	COP = 3.3	1/1/2018
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6	N/A	1/1/2018
		All Other Types of Heating	IEER = 11.4	COP = 3.2	1/1/2018
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 10.6	N/A	1/1/2018
		All Other Types of Heating	IEER = 10.4	COP = 3.2	1/1/2018
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER = 14.0	HSPF = 8.2	1/1/2017
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER = 14.0	HSPF = 8.0	1/1/2017
Small Commercial Packaged Air-Conditioning and Heating Equipment (Water Source: Water-to-Air, Water-Loop)	<17,000 Btu/h	All	EER = 12.2	COP = 4.3	10/9/2015
	≥17,000 Btu/h and <65,000 Btu/h	All	EER = 13.0	COP = 4.3	10/9/2015
	≥65,000 Btu/h and <135,000Btu/h	All	EER = 13.0	COP = 4.3	10/9/2015

IECC 2012 Specifications:

TABLE C403.2.3(2)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[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	AHRI 340/360
		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	ISO 13256-2
			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[a]
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO 13256-1
Ground water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.1 COP	
Water-source water to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

For example, a single package 5 ton cooling unit at an existing restaurant in unknown location with 60,000 Btu/h heating capacity with a SEER of 15 and an HSPF of 9 saves

= [(60,000) * [(1/14) – (1/15)] * 1249] + [(60,000) * [(1/8) – (1/9)] * 1173]/1000

= 1334 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 tables above for values. Since EER requirements for air-cooled heat pumps < 65 kBtu/hr are not specified, assume the following conversion from SEER to EER: EER = -0.02 x $SEER^2$ + 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 EERee is unknown, assume the following conversion from SEER to EER: EER = –0.02 × $SEER^2$ + 1.12 × SEER.

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

Building Type	CF[246]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[247]	92.3%	N/A

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

ΔkW = [(60,000) * [(1/11.76) – (1/12.3)]/1000 *.996

= 0.22 kW

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-V04-220101

Sunset Date: 1/1/2023

[246] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
[247] For weighting factors, see HVAC variable table in section 3.3.

3.3.5. Geothermal Source Heat Pump

Description

This measure characterizes the installation of an ENERGY STAR qualified Geothermal Source Heat Pump (GSHP) either during new construction or at Time of Sale/Replacement of an existing system(s). The baseline is always assumed to be a new baseline Air Source Heat Pump. Savings are calculated due to the GSHP providing heating and cooling more efficiently than a baseline ASHP, plus savings hot water loads utilizing a desuperheater when installed.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment must be a Geothermal Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed below:

ENERGY STAR Requirements (Effective January 1, 2012)

Product Type	Cooling EER	Heating COP
Water-to-air		
Closed Loop	17.1	3.6
Open Loop	21.1	4.1
Water-to-Water		
Closed Loop	16.1	3.1
Open Loop	20.1	3.5
DGX	16	3.6

Definition of Baseline Equipment

The baseline equipment is assumed to be a commercially rated Air Source Heat Pump meeting the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.[248]

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment and Table 4 to §431.97—Updates to the Minimum Heating Efficiency Standards for Air-Cooled Air Conditioning and Heating Equipment [Heat Pumps][249]

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-	<65,000 Btu/h	All	SEER = 14.0 EER = 11.8	HSPF = 8.2	1/1/2017

[248] The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: EER = IEER/F where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).

[249] The new compliance standards set by the Code of Federal Regulations for commercial air source heat pumps are more aggressive and have a higher minimum cooling and heating efficiency requirements as compared to IECC 2012. In this instance, federal standards supersede state code conservation requirements and the baseline equipment is defined as an air source heat pumping meeting the minimum qualifying criteria as detailed in the Code of Federal Regulations.

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Phase, Split-System)					
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER = 14.0 EER = 11.8	HSPF = 8.0	1/1/2017
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.2 EER = 12.0	N/A	1/1/2018
		All Other Types of Heating	IEER = 12.0 EER = 11.8	COP = 3.3	1/1/2018
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6 EER = 11.4	N/A	1/1/2018
		All Other Types of Heating	IEER = 11.4 EER = 11.2	COP = 3.2	1/1/2018
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 10.6 EER = 10.5	N/A	1/1/2018
		All Other Types of Heating	IEER = 10.4 EER = 10.3	COP = 3.2	1/1/2018

Note: New Federal Standards affecting heat pumps become effective January 1, 2023.

Deemed Lifetime of Efficient Equipment

The expected equipment measure life for Time of Sale or New Construction is assumed to be 25 years.[250]

Deemed Measure Cost

The actual installed cost of the Geothermal Source Heat Pump should be used (default of $4,081per ton)[251], minus the assumed installation cost of the baseline equipment ($1,867 per ton for ASHP).[252] Note if replacing an existing Geothermal Source Heat Pump with a functioning ground or water loop, it should be assumed that the indoor components of the Geothermal Source Heat Pump are consistent with the incremental cost of an efficient ASHP over the baseline ASHP. For this scenario only, the incremental capital cost for air-cooled units is assumed to be $467.99 per ton for up to and including CEE Tier 1 class products,[253] and $935.98 per ton for CEE Tier 2 and higher class products.[254]

An estimate of additional cost required for a desuperheater is $1,500.[255]

[250] The expected system life of indoor components is assumed to be 25 years as per U.S. Department of Energy (DOE) estimates from the Office of Energy Efficiency & Renewable Energy, Energy Saver Articles on Heat Pump Systems – Geothermal Heat Pumps. The ground loop life is estimated at 50 years (based on U.S. DOE Office of Energy Efficiency & Renewable Energy, Energy Saver details and descriptions for Geothermal Heat Pumps).

[251] Based on data provided on Home Advisor website, providing national average GSHP costs based on actual project quotes from 132 Home Advisor members and contractors. Equipment and material cost of $2,581 per ton plus an added $1,500 per ton installation cost (assuming vertical looping).

[252] Based on data provided on Home Advisor website, providing national average ASHP costs based on actual project quotes from 3,523 Home Advisor members and contractors.

[253] For specification details see; https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0

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

[255] Based on web review, e.g. https://www.123zeroenergy.com/geothermal-desuperheater.html.

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings\ if\ displacing\ electric\ DHW]$$

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

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

$$+ \left[\frac{ElecDHW * \%DHW * \frac{1}{EF_{elecbase}} * HotWaterUseGallon * \gamma Water * (T_{Out} - T_{In})}{3412}\right]$$

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

= 0.85 if variable speed GSHP[256]

= 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} = Energy Efficiency Ratio (EER) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in 'Definition of Baseline Equipment'

[256] 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.

section[257]

EER_{EE-PL} = Part Load EER Efficiency of efficient GSHP unit

= Actual installed with adjustment for pumping energy:[258]

Adjusted EER (closed loop) = 0.0000315*EER^3 - 0.0111*EER^2 + 0.959*EER
Adjusted EER (open loop) = 0.00005*EER^3 - 0.0145*EER^2 + 0.93*EER

EER_{EE-FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit

= Actual installed with adjustment for pumping energy described above

$EFLH_{Heat}$ = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

$Capacity_{Heat}$ = Full Load Heating Capacity of Geothermal Source Heat Pump (Btu/hr)

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

PLF_{Heat} = Part load heating mode operation

= 0.5 if variable speed GSHP[259]

= 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); use minimum standard efficiencies as specified in the table in 'Definition of Baseline Equipment' section [260]

COP_{EE-PL} = Part Load Coefficient of Performance of efficient unit

= Actual Installed with adjustment for pumping energy:[261]

Adjusted COP (closed loop) = 0.000416*COP^3 - 0.041*COP^2 + 1.0086*COP
Adjusted COP (open loop) = 0.00067*COP^3 - 0.0531*COP^2 + 0.976*COP

COP_{EE-FL} = Full Load Coefficient of Performance of efficient unit

= Actual Installed with adjustment for pumping energy described above

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

$Elec_{DHW}$ = 1 if building has electric DHW

[257] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: EER = IEER/F where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).
[258] The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps'; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf
[259] 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.
[260] Federal standards detail heating efficiency in terms of coefficient of performance (COP). In order to convert HSPF to COP, multiply by the constant, 3.412.
[261] The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps'; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf

= 0 if building has non electric DHW
= 0 if one to one replacement of existing Ground Source Heat Pump

%DHW = Percentage of total DHW load that the GSHP will provide
= Actual if known
= If unknown and if desuperheater installed, assume 44%[262]
= 0% if no desuperheater installed

$EF_{elecbase}$ = Energy Factor of baseline or existing electric DHW
= Actual. If unknown assume federal standard as defined in 3.2.3 Hot Water Heater measure

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

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

Where:

Capacity = Usable capacity of hot water storage tank in gallons

= Actual[263]

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:[264]

Building Type[265]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894

[262] Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.
[263] If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.
[264] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.
[265] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

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

Where:

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

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[266]

Building Type[267]	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

γWater = Specific weight capacity of water (lb/gal)

= 8.33 lbs/galAA

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

T_{out} = Unmixed Outlet Water Temperature

= custom, otherwise assume 140[268]

T_{in} = Inlet Water Temperature

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

[267] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

[268] 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.

= custom - otherwise assume 56.5[269]

For example, for a 5 ton closed loop GSHP with desuperheater unit with 24 Part Load EER, 18 Full Load EER and 4.2 Part Load COP, 3.8 Full Load COP installed in an existing school in Burlington, IA with an electric 0.95 UEF 80 gallon DHW tank:

Adjusted Part Load EER = 0.0000315*24^3 - 0.0111*24^2 + 0.959*24

= 17.1

Adjusted Full Load EER = 0.0000315*18^3 - 0.0111*18^2 + 0.959*18

= 13.8

Adjusted Part Load COP = 0.000416*4.2^3 - 0.041*4.2^2 + 1.0086*4.2

= 4.2

Adjusted Full Load COP = 0.000416*3.8^3 - 0.041*3.8^2 + 1.0086*3.8

= 3.3

ΔkWh = (1,073 * 60,000 * ((0.85 * (1/(11.8 – 1/17.1)) + (0.15 * (1/(11.8 – 1/13.8)))) / 1,000 + (968 * 60,000 * ((0.5 * (1/8.2 – 1/(4.2 *3.412))) + (0.5 * (1/8.2 – 1/(3.3*3.412)))) / 1,000 + ((1 * 0.44 * 1/0.95 * (100 * 568) * 8.33 * (140-56.5))/3412)

= 1,556.0 + 3,312.8 + 4290.3

= 9,159 kWh

Summer Coincident Peak Demand Savings

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

Where:

EERbase = Energy Efficiency Ratio (EER) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in 'Definition of Baseline Equipment' section.[270]

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit

= Actual

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

[269] 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.

[270] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: EER = IEER/F where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).

Building Type	CF[271]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[272]	92.3%	N/A

For example, for a 5 ton closed loop GSHP unit with 18 Full Load EER installed in an existing school in Burlington, IA.:

Adjusted Full Load EER = 0.0000315*18^3 - 0.0111*18^2 + 0.959*18

= 13.8

ΔkW = (60,000 * (1/11.8 – 1/13.8) / 1,000) * 0.967

= 0.7127 kW

NATURAL GAS SAVINGS

ΔTherm = [DHW savings if displacing gas DHW]

$$= \frac{Gas_{DHW} * \%DHW * \frac{1}{\mathrm{EF_{GasBase}}} * \mathrm{HotWaterUseGallon} * \gamma\mathrm{Water} * (\mathrm{T}_{Out} - \mathrm{T}_{In}) * 1.0)}{100{,}000}$$

Where:

Gas_{DHW} = 1 if building has gas DHW
= 0 if building has electric DHW
= 0 if one to one replacement of existing Ground Source Heat Pump

$EF_{GasBase}$ = Energy factor of baseline of existing natural gas DHW heater

= Actual. If unknown assume federal standard as defined in 3.2.3 Hot Water Heater measure

100,000 = Converts Btu to Therms

[271] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
[272] For weighting factors, see HVAC variable table in section 3.3.

Other variables as provided above.

PEAK GAS SAVINGS

It is assumed that savings from a desuperheater will occur throughout the year. The Peak Gas Savings is therefore assumed to be:

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

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR- HVAC-GSHP-V04-220101

SUNSET DATE: 1/1/2023

3.3.6. Single-Package and Split System Unitary Air Conditioners

DESCRIPTION

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiencies can save considerable amounts of energy. This measure could apply to the replacing of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively cooled air conditioner that exceeds the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively cooled air conditioner that meets the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[273]

DEEMED MEASURE COST

The incremental capital cost for this measure is based upon capacity and efficiency level (defined be CEE specifications),[274] as outlined in the following table:[275]

Capacity	Incremental cost ($/ton)	
	Up to and including CEE Tier 1 units	CEE Tier 2 and above
< 135,000 Btu/hr	$63.42	$126.84
135,000 Btu/hr to > 250,000 Btu/hr	$63.42	$126.84
250,000 Btu/hr and greater	$18.92	$37.83

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

Note: The Code of Federal Regulations mandates that manufacturers comply with minimum efficiency standards for certain types of heat pump equipment. Due to the fact that all equipment available for purchase must comply with

[273] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[274] For specification details see; https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0
[275] NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

this regulation, the Code of Federal Regulation shall be taken as the authoritative source for specification of baseline efficiency in instances where IECC 2012 requires less aggressive efficiency standards.

Electric Energy Savings

For units with cooling capacities less than 65 kBtu/hr:

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

For units with cooling capacities 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 values[276]

$SEER_{ee}$ = Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual installed

IEERbase = Integrated Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values[277]

IEERee = Integrated Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment

Equipment type	Cooling capacity	Heating type	Efficiency level	Compliance date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.9	1/1/2018
		All Other Types of Heating	IEER = 12.7	1/1/2018
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.4	1/1/2018
		All Other Types of Heating	IEER = 12.2	1/1/2018
Very Large Commercial Packaged Air	≥240,000 Btu/h	Electric Resistance	IEER = 11.6	1/1/2018

[276] Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

[277] Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

Equipment type	Cooling capacity	Heating type	Efficiency level	Compliance date
Conditioning and Heating Equipment (Air-Cooled)	and <760,000 Btu/h	Heating or No Heating		
		All Other Types of Heating	IEER = 11.4	1/1/2018
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER = 13.0	6/16/2008
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER = 14.0	1/1/2017

IECC 2012 Specifications:

TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, air cooled	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	13.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h[b]	All	Split System	10.0 SEER	10.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	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	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	12.5 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)

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 an existing small retail building in Burlington would save

ΔkWH = (60,000) * [(1/13) – (1/15)] / 1000 * 891

= 548.3 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:

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 EERee 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[278]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[279]	92.3%	N/A

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

EERbase $= -0.02 \times 13^2 + 1.12 \times 13$

$= 11.2$ EER

EERee $= -0.02 \times 15^2 + 1.12 \times 15$

$= 12.3$ EER

ΔkW $= (60{,}000 * [(1/11.2) - (1/12.3)] / 1000 * 1.00$

$= 0.4791$ kW

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Measure Code: NR-HVC-SPUA-V04-210101

Sunset Date: 1/1/2023

[278] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
[279] 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 years.[280]

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below:[281]

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	$137	$259	$350	$411
>= 50 and <100	$69	$129	$175	$206
>= 100 and <150	$46	$86	$117	$137
>= 150 and <200	$34	$65	$88	$103
>= 200	$17	$32	$44	$51

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	$311	$518	N/A	N/A
>= 50 and <100	$143	$246	N/A	N/A
>= 100 and <150	N/A	N/A	N/A	N/A

280 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008 .

281 NEEP incremental cost update for Version 7 of the Mid-Atlantic TRM. Original data and analysis sourced from Itron. Measure and baseline costs were calculated using hedonic models and data from Itron, 2010 –2012 WO017 Ex Ante Measure Cost Study, conducted for the California Public Utility
Commission in 2014 and adjusted for inflation. See supporting document "NEEP Chiller Incremental Cost_Recommendations_050917.xlsx"

Water cooled, electrically operated, positive displacement (rotary screw and scroll) ($/ton)				
Capacity (tons)	> .72 kW/ton	.72 and > .68 kW/ton	.68 and >.64 kW/ton	.64 kW/ton and less
>= 150 and <200	N/A	N/A	$52	$104
>= 200	N/A	N/A	N/A	$13

Water cooled, electrically operated, positive displacement (reciprocating) ($/ton)			
Capacity (tons)	> .60 kW/ton	.60 and > .58 kW/ton	.58 kw/ton and less
< 100	$88	$140	$244
>= 100 and <150	$59	$93	$162
>= 150 and <200	$44	$70	$122
>= 200 and <300	N/A	N/A	$31
>= 300	N/A	N/A	$13

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = TONS * ((IPLVbase) - (IPLVee)) * EFLH$$

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, Convertion Values' and 'Baseline Efficiency Values by Chiller Type' and Capacity in the Reference Tables section.

$IPLV_{ee}$[282] = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[283]

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller in an existing warehouse with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) in unknown location would save:

ΔkWH = 100 * ((0.96) – (0.86)) * 864

= 8,640 kWh

[282] 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.

[283] Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetI.org. http://www.ahrinet.org/

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = TONS * ((PEbase) - (PEee)) * CF$$

Where:

PE_{base} = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)

= See "FULL LOAD" values from 'Baseline Efficiency Values by Chiller Type and Capacity' in Reference Tables section.

PE_{ee} = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)

= Actual installed

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

Building Type	CF[284]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[285]	92.3%	N/A

For example, a 100 ton air-cooled electrically operated chiller in an existing warehouse with a full load efficiency of 12 EER (1 kW/ton) with baseline full load efficiency of 9.5 EER (1.26 kW/ton) in unknown location would save:

ΔkW = 100 * ((1.26) – (1.0)) * 0.779

= 20.25 kW

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

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

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

Deemed O&M Cost Adjustment Calculation

N/A

Reference Tables

Chillers Ratings - Chillers are rated with different units depending on equipment type as shown below.

Equipment Type	Unit
Air cooled, electrically operated	EER
Water cooled, electrically operated, positive displacement (reciprocating)	kW/ton
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	kW/ton

In order to convert chiller equipment ratings to IPLV, the following relationships are provided:

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

Baseline Efficiency Values by Chiller Type and Capacity[286]

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.

[286] International Energy Conservation Code (IECC)2012

TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS:
WATER CHILLING PACKAGES[a]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010[b]				TEST PROCEDURE[c]
					PATH A		PATH B		
			FULL LOAD	IPLV	FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA	NA	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 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-V02-200101

SUNSET DATE: 1/1/2024

3.3.8. Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and sometimes provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year round to heat or cool. In warm weather, it efficiently captures heat from inside your building and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into your home, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline conditions is provided in the Federal Baseline reference table provided below.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 8 years.[287]

Remaining life of existing equipment is assumed to be 3 years.[288]

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[289]

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume $1,047 per ton.[290]

The assumed deferred cost (after 3 years) of replacing existing equipment with new baseline unit is assumed to be

[287] Based on 2015 DOE Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018
[288] Standard assumption of one third of effective useful life.
[289] DEER 2008. This assumes that baseline shift from IECC 2006 to IECC 2012 carries the same incremental costs. Values should be verified during evaluation
[290] Based on DCEO – IL PHA Efficient Living Program data.

$1,039 per ton.[291] This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms.

ENERGY SAVINGS

Time of Sale:

PTAC ΔkWh[292] = Annual kWh Savings$_{cool}$

PTHP ΔkWh = Annual kWh Savings$_{cool}$ + Annual kWh Savings$_{heat}$

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

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

Early Replacement:

ΔkWh for remaining life of existing unit (1st 3 years) = Annual kWh Savings$_{cool}$ + Annual kWh Savings$_{heat}$

$$\Delta kWh\ Savings_{cool} = \left[\frac{EFLH_{cool} * \ Capacity_{Cool} * \left(\frac{1}{EER_{exist}} - \frac{1}{EER_{ee}}\right)}{1000}\right]$$

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

ΔkWh for remaining measure life (next 5 years) = Annual kWh Savings$_{cool}$ + Annual kWh Savings$_{heat}$

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

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

[291] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

[292] 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.

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 9.9 EER for PTAC and 9.7 EER for PTHP[293]

$EFLH_{heat}$ = 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 2.9 COP for PTHPs[294]

3,412 = kBtu per kWh.

Federal Equipment Standards, 10 CFR 431.97(c): Minimum Efficiency Requirements for PTAC and PTHP

Equipment Type	Category	Cooling Capacity	Minimum Efficiency
PTAC (Cooling mode)	Standard Size	< 7,000Btu/h	11.9 EER
		≥ 7,000 and ≤ 15,000 Btu/h	14.0 – (0.300 x Cap/1000) EER
		> 15,000 Btu/h	9.5 EER
	Non-Standard Size*	< 7,000Btu/h	9.4 EER
		≥ 7,000 and ≤ 15,000 Btu/h	10.9 – (0.213 x Cap/1000) EER
		> 15,000 Btu/h	7.7 EER
PTHP (Cooling mode)	Standard Size	< 7,000Btu/h	11.9 EER
		≥ 7,000 and ≤ 15,000 Btu/h	14.0 – (0.300 x Cap/1000) EER
		> 15,000 Btu/h	9.5 EER
	Non-Standard Size*	< 7,000Btu/h	9.3 EER
		≥ 7,000 and ≤ 15,000 Btu/h	10.8 – (0.213 x Cap/1000) EER
		> 15,000 Btu/h	7.6 EER
	Standard Size	< 7,000Btu/h	3.3 COP
		≥ 7,000 and ≤ 15,000 Btu/h	3.7 – (0.052 x Cap/1000) COP

[293] Estimated using the IECC building energy code up effective between IECC 2003 and IECC 2012. Assuming a 1 ton unit; PTAC: EER = 12.5 – (0.213 * 12,000/1,000) = 9.9 and PTHP: EER = 12.3 – (0.213 * 12,000/1,000) = 9.7.

[294]Estimated using the IECC building energy code up effective between IECC 2003 and IECC 2012. Assuming a 1 ton unit; COP = 3.2 – (0.026 * 12,000/1,000) = 2.9

Equipment Type	Category	Cooling Capacity	Minimum Efficiency
PTHP (Heating mode)		> 15,000 Btu/h	2.9 COP
	Non-Standard Size*	< 7,000Btu/h	2.7 COP
		≥ 7,000 and ≤ 15,000 Btu/h	2.9 – (0.026 x Cap/1000) COP
		> 15,000 Btu/h	2.5 COP

"Cap" = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

*Non-standard size applies only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

Time of Sale (assuming standard size baseline):

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

= [(12,000) * [(1/10.4) – (1/12)] / 1000 * 1,464

= 225 kWh

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

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

ΔkWh for remaining life of existing unit (1st 3 years)

= (12,000 * (1/8.1 – 1/12) * 1,173) / 1,000 + (12,000/3,412 * (1/1.0 – 1/3.0) * 1,249)

= 565 + 2,929

= 3,494 kWh

ΔkWh for remaining measure life (next 5 years)

= (12,000 * (1/8.3 – 1/12) * 1,173) / 1,000 + (12,000/3,412 * (1/1.0 – 1/3.0) * 1,249)

= 523 + 2,929

= 3,452 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

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

Early Replacement:

ΔkW for remaining life of existing unit (1st 3 years):

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

ΔkWh for remaining measure life (next 5 years):

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

Where:

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

Building Type	CF[295]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[296]	92.3%	N/A

Time of Sale:

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

ΔkW = (12,000 * (1/10.4 – 1/12) / 1,000 *0.974

= 0.15 kW

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

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

ΔkW for remaining life of existing unit (1st 3years):

ΔkW = 12,000 * (1/8.1 – 1/12) / 1,000 * 0.996

= 0.48 kW

ΔkW for remaining measure life (next 5 years):

ΔkW = 12,000 * (1/8.3 – 1/12) / 1,000 * 0.996

= 0.43 kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

[295] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

[296] For weighting factors, see HVAC variable table in section 3.3.

N/A

MEASURE CODE: NR-HVC-PTAC-V03-220101

SUNSET DATE: 1/1/2025

3.3.9. Guest Room Energy Management (PTAC)

DESCRIPTION

This measure applied to the installation of a temperature setback and lighting control system for individual guest rooms. The savings are achieved based on Guest Room Energy Management's (GREM's) ability to automatically adjust lighting levels and the guest room's set temperatures and control the packaged terminal air conditioner (PTAC) unit when the room is not occupied.

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

DEFINITION OF EFFICIENT EQUIPMENT

Guest room temperature set point must be controlled by automatic occupancy detectors or keycard that indicates the occupancy status of the room. During unoccupied periods the system sets heating and cooling to a minimum, and turns off lighting when the key card is removed. Once the guest returns and inserts the key card, the guest has full control of the room systems. This measure bases savings on improved HVAC controls and reduced lighting loads. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

DEFINITION OF BASELINE EQUIPMENT

Guest room energy management thermostats replace manual lighting controls and heating/cooling temperature set-point and fan On/Off/Auto thermostat controls for the PTAC.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for GREM is 15 years.[297]

DEEMED MEASURE COST

$260/unit

The incremental measure cost documented for this measure is $260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM.[298]

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape NREH07 – Nonresidential Electric Heat – Lodging

Loadshape NRECH07 – Nonresidential Cooling – Lodging

Loadshape NRGH07 – Nonresidential Gas Heating – Lodging

Algorithm

CALCULATION OF SAVINGS

Below are the annual kWh savings per installed energy management system for different climate zones. The savings

[297] DEER 2008 value for energy management systems

[298] This value was extracted from Smart Ideas projects in PY1 and PY2.

are achieved based on GREM's ability to automatically adjust the guest room's set temperatures and control the HVAC unit to maintain set temperatures for various occupancy modes. If the GREM is capable of controlling lighting, additional savings result. The basis of savings is the 2013 California Building Energy Standards, which used EnergyPro 5 simulation.[299] For PTACs that use gas for heating, separate gas savings are outlined.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Rooms * ([Heating\ savings] + [Cooling\ savings] + [Lighting\ savings])$$

Where:

Rooms = Number of rooms with a GREM system installed.

Other variables as listed in the table below:

Climate Zone	Heating savings [kWh/room/year]	Cooling savings [kWh/room/year]	Lighting savings [kWh/room/year]
Zone 5 (Burlington)	111.3	24.6	62.0
Zone 6 (Mason City)	151.5	17.8	62.0
Average / Unknown	135.8	22.2	62.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = Rooms * \frac{Cooling\ savings}{EFLH_{Cool}} * CF$$

Where:

$EFLH_{Cool}$ = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use

CF = Summer System Peak Coincidence Factor for Cooling,

= 97.4% (for Lodging)

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

For PTACs with gas heating:

$$\Delta Therms = Rooms * [Gas\ Savings]$$

Where:

Rooms = Number of rooms with a GREM system installed.

Gas Savings factor as listed in the table below:

Climate Zone	Gas Savings [300] [therms/room/year]
Zone 5 (Burlington)	4.7

[299] 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.
[300] Savings include the assumption that the thermal efficiency of the heating unit is 80%, per IECC2012 code.

Climate Zone	Gas Savings [300] [therms/room/year]
Zone 6 (Mason City)	6.5
Average / Unknown	5.8

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

= 0.681941for Lodging

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-GREM-V03-220101

SUNSET DATE: 1/1/2026

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 measure[301]

= Actual

100,000 = Converts Btu to therms

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

Δtherms = (200,000 * 1358 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 60.0 therms

[301] The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[302]	Model Source
Convenience	0.016310	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014240	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011745	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[303]	0.014623	N/A

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

ΔPeakTherms = 60.0 * 0.0167180

= 1.00031 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-V02-200101

Sunset Date: 1/1/2023

[302] Calculated as the percentage of total savings in the maximum saving day, from models.

[303] For weighting factors see HVAC variable table in section 3.3.

3.3.11. Furnace Tune-Up

Description

This measure is for a tune-up to a natural gas furnace that provides space heating in a nonresidential application. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation.

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

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

Definition of Efficient Equipment

The recommended tune-up requirements are listed below. It is recommended that utility programs require technicians performing the work are appropriately certified.

- Measure combustion efficiency using an electronic flue gas analyzer.
- Check and clean blower assembly and components per manufacturer's recommendations.
- Where applicable, lubricate motor and inspect and replace fan belt if required.
- Inspect for gas leaks.
- Clean burner per manufacturer's recommendations and adjust as needed.
- Check ignition system and safety systems and clean and adjust as needed.
- Check and clean heat exchanger per manufacturer's recommendations.
- Inspect exhaust/flue for proper attachment and operation.
- Inspect control box, wiring, and controls for proper connections and performance.
- Check air filter and clean or replace per manufacturer's recommendations.
- Inspect duct work connected to furnace for leaks or blockages.
- Measure temperature rise and adjust flow as needed.
- Check for correct line and load volts/amps.
- Check that thermostat operation is per manufacturer's recommendations.
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits.
- Check and adjust gas input.
- Check high limit and other safety controls.

Definition of Baseline Equipment

The baseline for a clean and check tune-up is a furnace assumed not to have had a tune-up in the past 2 years.

Deemed Lifetime of Efficient Equipment

The measure life of a clean and check tune-up is 2 years.[304]

Deemed Measure Cost

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

Loadshape

[304] Based on VEIC professional judgment.

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

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

Algorithms

Calculation of Energy Savings

Electric Energy Savings

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

Where:

ΔTherms = as calculated below

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

= 3.14%[305]

29.3 = kWh per therm

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:

EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr)

= Actual

Effbefore = Combustion Efficiency of the furnace before the tune-up

= Actual

Ei = Combustion Efficiency Improvement of the furnace tune-up measure[306]

= Actual

100,000 = Conversion of Btu to Therms

For example, for a 200 kBtu furnace in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

Δtherms = (200,000 * 1358 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 60.0 therms

[305] 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.

[306] The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[307]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[308]	0.014658	N/A

For example, for a 200 kBtu furnace in a small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

ΔPeakTherms = 60.0 * 0.0167180

= 1.0031 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-FTUN-V03-200101

Sunset Date: 1/1/2023

[307] Calculated as the percentage of total savings in the maximum saving day, from models.

[308] For weighting factors, see HVAC variable table in section 3.3.

3.3.12. Small Commercial Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable or Advanced Thermostat for reduced heating and cooling energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs,[309] as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. Therefore, use of this measure characterization is limited to select building types (such as convenience stores, small retail, low rise office, restaurants, religious facilities). This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a thermostat is assumed to be 8 years.[310]

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be $181.[311]

LOADSHAPE

NREC17 – Non-Residential Cooling – Small Programmable Thermostat

NREP01:16 – Non-Residential Electric Heat Pump (by Building Type)

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

[309] The square footage of the small office prototype building modeled in is 7,500 sf.

[310] 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.

[311] Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building:

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

If central cooling exists, the electric energy saved in annual cooling due to the thermostat is:

$$\Delta kWh_{cooling} = \frac{Sqft * Savings\ Factor_{cool}}{EfficiencyRating(exist)_{cool}}$$

Where:

Sqft = square footage of building controlled by thermostat

$EfficiencyRating(exist)_{cool}$ = efficiency rating of existing cooling equipment EER (btu hr/W)

If unknown assume code minimum

$Savings\ Factor_{cool}$ = cooling savings factor

= 0.53 kBtu/sf-yr[312]

If the building is heated with electric heat (heat pump), the electric energy saved in annual heating due to the thermostat is:

$$\Delta kWh_{heating} = \frac{Sqft * Savings\ Factor_{heat}}{3.412 * EfficiencyRating(exist)_{electric\ heat}}$$

Where:

$Savings\ Factor_{heat}$ = 0.85 kBtu/sf-yr[313]

3.142 = Conversion from kBtu to kWh

$EfficiencyRating(exist)_{electric\ heat}$ = efficiency rating of existing heating system

= Actual. If unknown assume code minimum. *Note: heat pumps will have an efficiency greater than 100%*

Other factors as defined above.

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to furnace fans operating fewer hours:

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

[312] 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.

[313] Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (7,500 sf) and converted to kBtu.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[314]

29.3 = Conversion from therms to kWh

Summer Coincident Peak Demand Savings

0.0[315]

Natural Gas Energy Savings

If building uses a gas heating system, the savings resulting from the thermostat is calculated with the following formula:

$$\Delta Therms \; = \frac{Sqft * Savings\ Factor_{heat}}{100 * EfficiencyRating(exist)_{heat}}$$

Where:

Sqft = square footage of building controlled by thermostat

$EfficiencyRating(exist)_{heat}$ = efficiency rating of existing heating equipment (AFUE)

If unknown assume code minimum

$Savings\ Factor_{heat}$ = 0.85 kBtu/sf-yr[316]

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[317]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest

314 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.

315 modeling work used to simulate savings for this measure showed no summer peak demand savings.

316 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.

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

Building Type	GCF[317]	Model Source
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[318]	0.014658	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-PROG-V05-220101

SUNSET DATE: 1/1/2026

[318] For weighting factors, see HVAC variable table in section 3.3.

3.3.13. Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

Description

This measure applies to variable frequency drives (VFDs) installed on HVAC chilled water and hot water distribution pumps (centrifugal pumps only) and cooling tower fans. There is a separate measure for HVAC supply and return fans. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VSD installation in existing cooling towers with 2-speed motors. (current code requires 2-speed motors for cooling towers with motors greater than 7.5 HP)
- VSD installation in new cooling towers with motors greater than 7.5 HP

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

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

Definition of Efficient Equipment

The VFD is applied to a pump motor 1-100 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 savings.[319]

Deemed Lifetime of Efficient Equipment

The expected measure life for HVAC application is 15 years.[320]

Deemed Measure Cost

Customer-provided costs will be used when available. Default incremental VFD costs are listed below for 1 to 100 HP motors.[321]

---

[319] 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".

[320] "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013."

[321] Incremental costs are sourced from the "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013" and adjusted to account for regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
1-9 HP	$2,177
10-19 HP	$3,123
20-29 HP	$4,280
30-39 HP	$5,023
40-49 HP	$5,766
50-59 HP	$6,591
60-69 HP	$7,550
70-79 HP	$8,173
80-89 HP	$8,796
90-100 HP	$9,576

LOADSHAPE

Loadshape NRE07 – VFD - Boiler feedwater pumps

Loadshape NRE08 – VFD - Chilled water pumps

Loadshape NRE09 – VFD - Boiler circulation pumps

Loadshape NRE18 - VFD - Cooling Tower Fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{BHP}{EFFi} * Hours * ESF$$

Where:

BHP = System Brake Horsepower

= (Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.[322] Custom load factor may be applied if known.

EFFi = Motor efficiency, installed.

= Actual

Hours = Default hours are provided for HVAC applications which vary by building type.[323] When available, actual hours should be used.

The type of hours to apply depends on the VFD application, according to the table below.

Application	Hours Type
Hot Water Pump	Heating
Chilled Water Pump	Cooling

[322] 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.

[323] Based on models developed in OpenStudio. Building types denoted with an asterisk indicate values were referenced from the ComEd TRM June 1, 2010 page 139.

Application	Hours Type
Cooling Tower Fan	Cooling

Building Type	Heating Run Hours	Cooling Run Hours
Convenience*	3628	2690
Education	6367	2796
Grocery	6499	2725
Health	8720	4770
Hospital	8289	8760
Industrial*	3977	3080
Lodging	5500	7909
Multifamily	5382	5084
Office - Large	5316	4596
Office - Small	1952	2138
Religious*	4763	2223
Restaurant	3027	2719
Retail – Large*	4218	2405
Retail - Small	3029	2266
Warehouse*	4100	1788
Nonresidential Average	3659	2182

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

Application	ESF[324]
Hot Water Centrifugal Pump	0.187
Chilled Water Centrifugal Pump	0.094
Cooling Tower Fan	0.382

For example, a 50-horsepower VFD operating 2386 hours annually driving a motor with 95% efficiency and a load factor of 70% on a chilled water pump would save:

ΔkWh = 50/0.95 * 0.70 * 2386 * 0.094

= 8,263 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

DSF = Demand Savings Factor varies by VFD application.[325] Units are kW/HP. Values listed below are based on typical peak load for the listed application.

Application	DSF
Hot Water Centrifugal Pump	0
Chilled Water Centrifugal Pump	0
Cooling Tower Fan	0.32

[324] Based on OpenStudio Large Office model, finding difference in energy use for each VSD application. See 'VSD Savings Factor Calc.xls'.

[325] Based on OpenStudio Large Office model, finding difference in maximum demand during peak period for each VSD application. See 'VSD Savings Factor Calc.xls'

For example, a 50-horsepower VFD operating 2386 hours annually driving a motor with 95% efficiency and a load factor of 70% on a chilled water pump would save:

$$\Delta kW = 50/0.95 * 0.7 * 0$$

$$= 0kW$$

Natural Gas Energy Savings

There are no expected fossil fuel impacts for this measure.[326]

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-V04-210101

Sunset Date: 1/1/2024

[326] Consider updating measure to include heating and cooling savings in future revisions.

3.3.14. Variable Frequency Drives for HVAC Supply and Return Fans

Description

This measure applies to variable frequency drives (VFDs) installed on HVAC supply fans and return fans. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is applicable to the following program types: TOS, RF.

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

Definition of Efficient Equipment

The VFD is applied to an HVAC fan motor 1-100 HP that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (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 savings.[327]

Deemed Lifetime of Efficient Equipment

The expected measure life for HVAC application is 15 years.[328]

Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.[329]

HP	Cost
1-9 HP	$2,177
10-19 HP	$3,123
20-29 HP	$4,4,280
30-39 HP	$5,5,023
40-49 HP	$5,766
50-59 HP	$6,591
60-69 HP	$7,550

[327] 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".

[328] "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013."

[329] Incremental costs are sourced from the "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013" and adjusted to account for regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
70-79 HP	$8,173
80-89 HP	$8,796
90-100 HP	$9,576

LOADSHAPE

Loadshape NRE04 – VFD - Supply fans

Loadshape NRE05 – VFD - Return fans

Loadshape NRE06 – VFD - Exhaust fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[330]

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

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

ΔkWh_{fan} = $kWh_{Base} - kWh_{Retrofit}$

ΔkWh_{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%)[331]

η_{motor} = Installed nominal/nameplate motor efficiency

= Actual

$RHRS_{Base}$ = Annual operating hours for fan motor based on building type

[330] 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.

[331] 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.

Default hours are provided for HVAC applications which vary by building type.[332] When available, actual hours should be used.

Building Type	Fan Run Hours
Convenience*	4630
Education	3544
Grocery	8743
Health	3478
Hospital	4570
Industrial*	2850
Lodging	3909
Multifamily	8760
Office - Large	2662
Office - Small	7667
Religious*	2412
Restaurant	7300
Retail - Large*	4065
Retail - Small	7410
Warehouse*	2920
Nonresidential Average[333]	4978

$\%FF$ = Percentage of run-time spent within a given flow fraction range:[334]

Flow Fraction (% of design cfm)	Percent of Time at Flow Fraction
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 39%	15.5%
40% to 49%	22.0%
50% to 59%	25.0%
60% to 69%	19.0%
70% to 79%	8.5%
80% to 89%	3.0%
90% to 100%	0.5%

PLR_{Base} = Part load ratio for a given flow fraction range based on the baseline flow control type (see table below)

$PLR_{Retrofit}$ = Part load ratio for a given flow fraction range based on the retrofit flow control type (see table below)

332 Based on outputs from OpenStudio modeling. Building types noted by an asterisk rely on values originally derived from eQuest modeling. In those instances, the fan hours are based on lighting hours by building type. For Fan based HVAC, fans generally operate full speed during building occupancy whether full speed is needed or not. The time VFDs will save energy is during building occupancy hours which corresponds most closely to lighting hours of use.
333 For weighting factors, see HVAC variable table in section 3.3.
334 Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

Control Type	Part Load Ratio for each Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, BI & Airfoil Fans	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
VFD with duct static pressure controls	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

Provided below are the resultant values based upon the defaults provided above:

Control Type	$\sum_{0\%}^{100\%}(\%FF \times PLR_{Base})$
No Control or Bypass Damper	1.00
Discharge Dampers	0.80
Outlet Damper, BI & Airfoil Fans	0.78
Inlet Damper Box	0.69
Inlet Guide Vane, BI & Airfoil Fans	0.63
Inlet Vane Dampers	0.53
Outlet Damper, FC Fans	0.53
Eddy Current Drives	0.49
Inlet Guide Vane, FC Fans	0.39
VFD with duct static pressure controls	0.30
VFD with low/no duct static pressure	0.27

IE_{energy} = HVAC interactive effects factor for energy (default = 15.7%)[335]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

ΔkW_{fan} = $kW_{Base} - kW_{Retrofit}$

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

[335] 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.

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%)

$PLR_{Retrofit,FFpeak}$ = 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.[336]

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-V03-200101

SUNSET DATE: 1/1/2023

[336] Consider updating measure to include heating and cooling savings in future revisions.

3.3.15. Duct Insulation

Description

Energy and demand saving are realized through reductions in the building cooling and heating loads by improving thermal resistance of ductwork in unconditioned areas. This measure was developed to be applicable to the following program types: RF.

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

Definition of Efficient Equipment

The efficient condition is ductwork in unconditioned areas with improved thermal resistance.

Definition of Baseline Equipment

The baseline condition is the existing ductwork in unconditioned areas.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[337]

Deemed Measure Cost

Actual project costs should be used since material and labor costs can vary greatly due to factors such as physical access and material costs (e.g., replacing ductwork versus adding insulation to existing).

Loadshape

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

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

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

Algorithm

Calculation of Energy Savings

Savings should only be claimed for ductwork that exists on the exterior of the building or in uninsulated spaces.

Electric Energy Savings

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

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

Where:

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

$R_{existing}$ = Duct heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]

= Actual, must be non-zero.

R_{new} = Duct heat loss coefficient with improved insulation [(hr-°F-ft²)/Btu]

= Actual

Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft²].

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature.[338]

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][339]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	20.4
Zone 6 (Mason City)	75.2	15.2
Average / Unknown	78.6	18.6

1,000 = Conversion from Btu to kBtu

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

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 115°F duct supply temperature.[340]

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][341]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	75.4

[338] 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.

[339] 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.

[340] 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.

[341] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][341]	$\Delta T_{AVG,heating}$ [°F]
Zone 6 (Mason City)	30.1	84.9
Average / Unknown	35.9	79.1

3,142 = Conversion from Btu to kWh.

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

= Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with 10.5 SEER central AC, and 1.92COP heat pump system, and the duct R-value with new insulation is 10.0:

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

$= ((1/3.5 – 1/10.0) * 100 * 780 * 18.6 / (1,000 * 10.5)) + ((1/3.5 – 1/10.0) * 100 * 1,372 * 79.1/ (3,412 * 1.92))$

$= 22.2 + 266.2$

$= 288.4$ kWh

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[342]

29.3 = Conversion from therms to kWh

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$\Delta kWh = 24.9 * 0.0314 * 29.3$

$= 22.9$ kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWhcooling}{EFLHcooling} * CF$$

Where:

$EFLH_{cooling}$ = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

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

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

Building Type	CF[343]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[344]	92.3%	N/A

For example, 100 ft^2 of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with 10.5 SEER central cooling, and the duct R-value with new insulation is 10.0:

ΔkW = 22.2 / 780 * 1.00

= 0.0280 kW

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 \ * \ \eta_{heat})}$$

Where:

$R_{existing}$ = Duct heat loss coefficient with existing insulation [(hr-^{o}F-ft^2)/Btu]

R_{new} = Duct heat loss coefficient with new insulation [(hr-^{o}F-ft^2)/Btu]

Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft^2].

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{o}F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

[343] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.
[344] For weighting factors, see HVAC variable table in section 3.3.

= Actual

For example, 100 ft^2 of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

ΔTherms = ((1/3.5 – 1/8.0) * 100 * 1,372 * 79.1/ (100,000 * 0.70))

= 24.9 therms

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[345]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[346]	0.014658	N/A

For example, 100 ft^2 of duct surface with a pre-insulation R-value of 3.5 is insulated in a small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

ΔPeakTherms = 24.9 * 0.0140550

= 0.3500 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

[345] Calculated as the percentage of total savings in the maximum saving day, from models.

[346] For weighting factors, see HVAC variable table in section 3.3.

N/A

MEASURE CODE: NR-HVC-DUCT-V03-220101

SUNSET DATE: 1/1/2026

3.3.16. Duct Repair and Sealing

DESCRIPTION

Air leaks in ductwork passing through exterior spaces are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured by qualified/certified HVAC professionals[347]. 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.[348]

DEEMED MEASURE COST

The actual labor and material cost for this measure should be used in screening.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

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

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

[347] In order for leakage rates to be considered accurate, performance testing must be carried out be a professional with a high level of experience in the C&I building sector.
[348] 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

$$\Delta \text{kWh} = \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}$$

Where:

$\Delta \text{kWh}_{\text{cooling}}$ = 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

= Actual[349]

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

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature:[350]

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][351]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	20.4
Zone 6 (Mason City)	75.2	15.2
Average / Unknown	78.6	18.6

0.018 = Specific Heat Capacity of Air (Btu/ft^3*°F)

LM = Latent multiplier to account for latent cooling demand

= dependent on location: [352]

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	5.0

[349] 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.

[350] 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.

[351] 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.

[352] The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads, again assuming outside makeup air. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015.

Climate Zone (City based upon)	LM
Zone 6 (Mason City)	5.9
Average/ unknown	5.2

1000 = Converts Btu to 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 temperature:[353]

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][354]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	75.4
Zone 6 (Mason City)	30.1	84.9
Average / Unknown	35.9	79.1

3,142 = Conversion from Btu to kWh.

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

= Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

For example, an existing small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

ΔkWh = $\Delta kWh_{cooling} + \Delta kWh_{heating}$

= [((40 – 25) * 60 * 780 * 18.6 * 0.018 * 5.2) / (1000 * 10.5)] +

[((40 – 25) * 60 * 13721608 * 79.1 * 0.018) / (1.92 * 3,412)]

= 116 + 268

= 384 kWh

<u>Conservative Deemed Approach</u>

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

Where:

[353] 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.

[354] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

SavingsPerUnit = Annual savings per linear foot installed airsealing material, dependent on heating / cooling equipment[355]

Note: savings factors are additive. For example, a building with both heating and cooling provided by heat pumps would save (1.64+3.27) = 4.91 kWh/ft

End Use	HVAC System	SavingsPerUnit (kWh/ft)
Cooling DX	Air Conditioning	1.64
Space Heat	Electric Resistance/Furnace	5.00
Heat Pump - Cooling	Heat Pump	1.64
Heat Pump - Heating	Heat Pump	3.27

L_{Duct} = Linear footage of airsealing material applied to exterior ductwork seams, closures or joints.

= Actual

Additional Fan savings

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[356]

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:

ΔkWh = 17.9 * 0.0314 * 29.3

= 16.5 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWhcooling}{EFLHcooling} * CF$$

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[357]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio

[355] 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.

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

[357] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF[357]	Model Source
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[358]	92.3%	N/A

For example, an existing small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

ΔkW = 116 / 780 * 1.00

= 0.15 kW

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, an existing restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

ΔTherms = ((40 – 25) * 60 * 1040 * 75.4 * 0.018) / (0.70 * 100,000)

= 17.9 therms

Conservative Deemed Approach

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

Where:

SavingsPerUnit = Annual savings per linear foot, dependent on heating / cooling equipment:[359]

[358] For weighting factors, see HVAC variable table in section 3.3.

[359] The values in the table represent estimates of savings from a 3% improvement in total usage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

End Use	HVAC System	SavingsPerUnit (Therms/ft)
Space Heat Boiler	Gas Boiler*	0.26
Space Heat Furnace	Gas Furnace	0.26

*Note: in instances where boilers supply heat to terminal units or VAV boxes that are already inside conditioned space, savings should not be claimed, as not conditioned air is not passing through exterior ductwork.

L_{Duct} = Linear footage of exterior ductwork sealed

= Actual

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[360]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[361]	0.014658	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

ΔPeakTherms = 17.9 * 0.0152620

= 0.2732 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[360] Calculated as the percentage of total savings in the maximum saving day, from models.
[361] For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-DCTS-V03-220101

SUNSET DATE: 1/1/2026

3.3.17. Chiller Pipe Insulation

Description

Energy and demand saving are realized through reductions in the building cooling loads by insulating supply and return chiller piping that passes through unconditioned areas.

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

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

Definition of Efficient Equipment

The efficient condition is chiller piping in unconditioned areas that has been insulated.

Definition of Baseline Equipment

The baseline condition is the existing chiller piping in unconditioned areas.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years.[362]

Deemed Measure Cost

The incremental measure cost for insulation is the full cost of adding insulation to the pipe. Actual installation costs should be used for the measure cost. For planning purposes, the following costs can be used to estimate the full cost of materials and labor, based on RS Means pricing.[363] The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

	Insulation Thickness	
	1 Inch	2 Inches
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.10.0156	220719.10.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	$9.40	$13.90
Jacket Cost per foot	$4.57	$7.30
Total Cost per foot	**$13.97**	**$21.20**

Loadshape

NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm

Calculation of Energy Savings

Savings should only be claimed for chiller piping that exists on the exterior of the building or in uninsulated spaces.

Electric Energy Savings

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

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[362] 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

[363] RS Means 2008. Mechanical Cost Data, pages 106 to 119

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

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 table:[364]

Insulation Thickness [in.]	Average Heat Gain [BTU/hr/ft]
Bare	47.100
0.5	14.413
1	9.063
1.5	6.973
2	5.798
2.5	5.038
3	4.450
3.5	4.068
4	3.768
4.5	3.475
5	3.288
5.5	3.130
6	2.990
6.5	2.875
7	2.770
7.5	2.680
8	2.600
8.5	2.523
9	2.455
9.5	2.398
10	2.340

[364] 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.

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Energy efficiency ratio (EER) of cooling system (kBtu/kWh)

= Actual. If not directly specified, EER may be calculated from other commonly listed efficiency ratings (kW/ton or COP):

EER = 12 / kW/ton

EER = COP x 3.412

For example, 3" thick insulation is installed on 100 feet of 2" diameter, bare straight pipe with 5 straight tee components in an existing industrial building in unknown location with a 12.0 EER cooling system:

ΔkWh = $\Delta kWh_{cooling}$

= ((100 + 3.2) * 1,063 * (47.100 - 4.450)) / (1,000 *12)

= 389.9 kWh

Summer Coincident Peak Demand Savings

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

Where:

$EFLH_{cooling}$ = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

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

Building Type	CF[365]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[366]	92.3%	N/A

[365] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

[366] For weighting factors, see HVAC variable table in section 3.3.

For example, 3" thick insulation is installed on 100 feet of 2" diameter, bare straight pipe with 5 straight tee components in an industrial building in unknown location with a 12.0 EER cooling system:

$$\Delta kW = 389.9/1{,}063 * 0.446$$

$$= 0.1636 \text{ kW}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-CPIN-V03-200101

SUNSET DATE: 1/1/2022*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.3.18. Hydronic Heating Pipe Insulation

DESCRIPTION

This measure provides rebates for installation of ≥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.[367]

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.[368]

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means[369] pricing reference materials may be used.[370] The following table summarizes the estimated costs for this measure per foot

[367] *ASHRAE Handbook—Fundamentals*, 23.14; Hart, G., “Saving energy by insulating pipe components on steam and hot water distribution systems”, *ASHRAE Journal*, October 2011

[368] 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

[369] RS Means 2008. Mechanical Cost Data, pages 106 to 119

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

of insulation added and include installation costs:

Insulation Thickness		
	1 Inch (Indoor)	2 Inches (Outdoor)
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.10.0156	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

$$\Delta Therms = \frac{(L_{SP} + L_{OC}) * EFLH_{heating} * (Q_{Base} - Q_{Eff}) * TRF}{(100{,}000 * \eta_{heat})}$$

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

$EFLH_{heating}$ = Equivalent Full Load Hours for heating [hr] are provided in Section 3.3, HVAC end use

$Q_{Base} - Q_{Eff}$ = Difference in heat loss rate due to the added insulation [BTU/hr/ft]

= Based on system type and location of the piping as shown in the following table:[371]

Pipe Location	System Type	Qbase – Qeff (Btu/hr/ft)
Indoor	Hot Water Space Heating - Without Outdoor Reset	90
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	61
	Hot Water Space Heating - With Outdoor Reset, Year-Round	45
	Low Pressure Steam	192
	High Pressure Steam	362
Outdoor	Hot Water Space Heating - Without Outdoor Reset	439
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	347
	Hot Water Space Heating - With Outdoor Reset, Year-Round	293
	Low Pressure Steam	678
	High Pressure Steam	1049

100,000 = Conversion from Btu to Therms

η_{heat} = Efficiency of heating system

= Actual. If unknown, assume the following:

= 82% for a hot water boiler or 80% for a steam boiler[372]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [373]

= 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.[374]

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

[371] 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.

[372] Code of Federal Regulations for gas-fired hot water and steam boilers < 300,000 Btu/h and manufactured after September 1, 2012 and before January 15, 2021 (10 CFR 430.32(e)(2)).. Effective January 15, 2021 the new federal compliance standard for boilers increases to an AFUE of 84%; however, because this is a retrofit measure, these standards are not applicable to the efficiency of the existing boiler..

[373] 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.

[374] Thermal Regain Factor_4-30-14.docx

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

For example, 1" thick insulation is installed on 100 feet of 1" diameter, bare straight pipe with 5 straight tee components distributing fluid in a low-pressure steam system and located in an indoor space heated with a steam boiler, in an industrial building in unknown location:

ΔTherms = ((100 + 1.9) * 1,183 * 192 * 0.15) / (100,000 * 0.80)

= 43.4 therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[375]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[376]	0.014658	N/A

For example, 1" thick insulation is installed on 100 feet of 1" diameter, bare straight pipe with 5 straight tee components distributing fluid in a low-pressure steam system and located in an indoor space heated with a steam boiler, in an industrial building in unknown location:

ΔTherms = 43.4 * 0.014296

= 0.6204 therms

[375] Calculated as the percentage of total savings in the maximum saving day, from models.
[376] For weighting factors, see HVAC variable table in section 3.3.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-HPIN-V03-210101

SUNSET DATE: 1/1/2024

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,[377] or for the remaining lifetime of the heating equipment, whichever is less.

DEEMED MEASURE COST

Given the variability in cost associated with differences in system specifications and design, as well as choice of measure technology, actual installed costs should be used as available or based on program-specific qualification requirements. When unavailable a deemed measure cost of $1,500 shall be assumed.[378]

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

[377] 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.

[378] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

N/A

Natural Gas Energy Savings

$$\Delta Therms = \mathrm{N_{gi}} * \mathrm{SF} * \mathrm{EFLH} / 100$$

Where:

N_{gi} = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%[379]

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:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[380]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio

[379] Based on internet review of savings potential;
"Up to 4%": Use of Automatic Vent Dampers for New and Existing Boilers and Furnaces, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency, Canada, 2002
"Up to 1%": Page 9, The Carbon Trust, "Steam and high temperature hot water boilers" http://www.carbontrust.com/media/13332/ctv052_steam_and_high_temperature_hot_water_boilers.pdf,
"1 - 2%": Page 2, Sustainable Energy Authority of Ireland "Steam Systems Technical Guide", see reference file "SEAI Technical Guide – Steam Systems."

[380] Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF[380]	Model Source
Warehouse	0.015677	eQuest
Nonresidential Average[381]	0.014658	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

A deemed, one-time Operations and Maintenance cost of $150 shall be included in cost-effectiveness calculations and occur in year 10 of the measure life to account for controller replacement.[382]

MEASURE CODE: NR-HVC-SODP-V02-200101

SUNSET DATE: 1/1/2024

[381] For weighting factors, see HVAC variable table in section 3.3.

[382] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

3.3.20. Room Air Conditioner (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 4.0 Volume 3: Nonresidential Measures; Final: August 2, 2019; Effective January 1, 2020 in which the measure was last active.

3.3.21. Room Air Conditioner Recycling

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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 years.[383]

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

$$DkWh = kWhexist - (\%replaced * kWhnewbase)$$

$$= \frac{Hours * BtuH}{\frac{EERexist}{1.01} * 1000} - (\%replaced * \frac{Hours * BtuH}{CEERNewBase * 1000})$$

Where:

Hours = Full Load Hours of room air conditioning unit[384]

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

[384] 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: see reference file "RoomAC_Calculator") is 31%. This ratio has been applied to the EFLH assumptions from Section 3.3 (modeling).

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown	
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH
Convenience	243	458	379	350	332	419
Education	300	328	464	221	403	290
Grocery	158	612	299	460	228	538
Health	317	362	474	278	438	330
Hospital	281	571	427	423	333	519
Industrial	263	367	395	265	367	330
Lodging	433	466	589	336	528	420
Multifamily	433	466	589	336	528	420
Office - Large	419	380	501	301	462	354
Office - Small	400	339	519	244	463	304
Religious	410	344	581	247	557	320
Restaurant	321	411	428	296	387	365
Retail - Large	277	375	432	267	404	334
Retail - Small	372	365	548	261	498	322
Warehouse	374	296	504	215	446	268
Nonresidential Average	371	337	513	241	464	303

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500.[385]

EERexist = Efficiency of recycled unit

= Actual if recorded - If not, assume 9.8.[386]

%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%[387]

CEERNewbase = Efficiency of baseline unit

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

[386] 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

[387] In the absence of empirical evidence for commercial Room AC replacement rates, the Residential assumption is used; Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% were replaced with ENERGY STAR units and 13% with non-ENERGY STAR. However, this formula assumes all are non-ENERGY STAR since the increment of savings between baseline units and ENERGY STAR would be recorded by the Efficient Products program when the new unit is purchased.

= 10.9[388]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption).[389]

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

ΔkWH = ((466 * 8500)/(9.8/1.01 * 1,000)) – (0.76 * (466 * 8500)/(10.9 * 1,000))

= 132.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[390]

Other variables as defined above

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

ΔkW = (132.0/466) * 0.3

= 0.0850 kW

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-APL-RACR-V02-180101

SUNSET DATE: 1/1/2023

[388] 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

[389] 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'.

[390] 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%20RAC.pdf)

3.3.22. Steam Trap Replacement or Repair

Description

This measure applies to the repair or replacement of failed steam traps on HVAC steam distribution systems. Faulty steam traps can allow excess steam to escape, wasting the energy used to generate steam and increasing the amount of steam generated. The measure is applicable to steam systems in commercial, industrial, and multifamily buildings.

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

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

Definition of Efficient Equipment

The efficient equipment is a repaired, rebuilt, or replaced steam trap.

Definition of Baseline Equipment

The baseline equipment is a failed steam trap that needs to be repaired, rebuilt, or replaced as confirmed by a steam trap survey. No minimum leak rate is required – qualifying failed steam traps may be failed closed, partially open, or completely open.

Deemed Lifetime of Efficient Equipment

The life of this measure is 6 years.[391]

Deemed Measure Cost

Measure cost depends on building type (commercial or industrial) and maximum steam system operating pressure (psig).

Steam System	Total Installed Cost (per Steam Trap)[392]
Commercial (all operating pressures)	\$177
Industrial, ≤ 15 psig	\$280
Industrial, > 15 ≤ 30 psig	\$300
Industrial, > 30 ≤ 125 psig	\$323
Industrial, > 125 ≤ 200 psig	\$415
Industrial, > 200 ≤ 250 psig	\$275
Industrial, > 250 psig	Custom

Loadshape

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

Algorithm

Calculation of Energy Savings

[391]Measure life from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

[392]Steam trap costs from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011. Measure cost includes installation cost of \$100 per trap, from Implement a Sustainable Steam-Trap Management Program, America Institute of Chemical Engineers, January 2014.

Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

$$\Delta Therms = LeakRate\ x\ H_{vap}\ x\ Hours_{Heat}\ x\ \%Leak/\ EFF_{Heat}\ /100{,}000$$

Where:

LeakRate = Average steam loss rate (lb/hr) per leaking trap

= 24.24 x (P_{Inlet} + 14.7) x D^2 x %Adjust

Where:

24.24 = Constant from Napier's equation (lb/(hr-psia-in^2)

P_{Inlet} = Steam trap inlet pressure (psig)

= Actual

14.7 = Atmospheric pressure (psia)

D = Diameter of steam trap orifice (in)

= Actual

%Adjust = Adjustment factor (%) to reduce the maximum theoretical steam flow to the average steam flow

= 50%[393]

H_{vap} = Heat of vaporization of steam (Btu/lb)

= Use values from table below, based on steam trap inlet pressure (psig):[394]

P_{Inlet} (psig)	H_{vap} (Btu/lb)
2	966
5	960
10	952
15	945
20	939
25	934
30	929
40	926
50	912
60	905
70	898
80	892
90	886

393 Enbridge adjustment factor, from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.
394 Heat of vaporization values from Steam Tables, Power Plant Service, Inc.

P_{Inlet} (psig)	H_{vap} (Btu/lb)
100	880
110	875
120	871
125	868
130	866
140	862
150	857
160	853
180	845
200	834
225	829
250	820

$Hours_{Heat}$ = Custom entry, annual operating hours of steam plant

%Leak = Percentage of leaking or blow-through steam traps

= 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, %Leak is applied to reflect the assumed percentage of steam traps that were actually leaking and in need of replacement. Use 27% for commerical customers and 16% for industrial customers.[395]

EFF_{Heat} = Boiler efficiency (%)

= Actual operating efficiency.

100,000 = Factor to convert Btus to therms

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

ΔTherms = $(24.24 * (30 + 14.7) * 0.125^2 * 0.5) * 929 * 4{,}500 * 1.0 / (0.75 * 100{,}000)$

= 471.8 Therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[396]	Model Source
Convenience	0.016310	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014240	eQuest

[395] % Leak values from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.
[396] Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF[396]	Model Source
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011745	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[397]	0.014623	N/A

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

ΔTherms = 471.8 * 0.0140550

= 6.6311 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-STRE-V03-220101

SUNSET DATE: 1/1/2026

[397] For weighting factors, see HVAC variable table in section 3.3.

3.3.23. Electric HVAC Tune-up

Description

This measure is for the tune-up of electric cooling equipment, such as a unitary or split system air conditioner or a central air source or geothermal heat pump. This should not be used for water based systems such as chillers. The tune-up will improve performance by inspecting, cleaning, and adjusting the system for correct and efficient operation. An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space. Heating savings are not currently characterized, however we hope to be able to add a much wider range of fault conditions based on NRELs recent modeling work through OpenStudio in a future cycle.

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a unitary or split system air conditioner at least 3 tons in capacity. The measure assumes that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Measure and record temperature drop at indoor coil
- Clean condensate drain line
- Clean outdoor coil and straighten fins
- Clean indoor and outdoor fan blades
- Clean indoor coil with spray-on cleaner and straighten fins
- Repair damaged insulation – suction line
- Change air filter
- Measure and record blower amp draw

Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be an AC system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 3 years.[398]

Deemed Measure Cost

A copy of contractor invoices that detail the work performed, as well as additional labor and parts to improve/repair air conditioner performance should be submitted to the program and used as the measure cost.

Loadshape

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

[398] 3 years is given for "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils". DEER2014 EUL Table.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWH = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1000}$$

Where:

Capacity$_{Cool}$ = capacity of the cooling equipment in Btu per hour (note 1 ton = 12,000Btu/hr)

= Actual

EERbefore = Energy Efficiency Ratio of the baseline equipment prior to tune-up

= Actual[399]

EERafter = Energy Efficiency Ratio of the baseline equipment after to tune-up

= Actual

EFLH = Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1000 * EER_{rated}) * EFLH * \%Savings$$

Where:

%Savings = Deemed percent savings per Tune-Up component. These are additive multiple components are performed (total provided below):[400]

Tune-Up Component	% savings
Correct Refrigerant Charge	2%
Clean condenser coils	1%
Clean evaporator coils	1%
If full tune up performed	5%

[399] In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer's performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state.

[400] Savings estimates are determined by applying each maintenance issue (high/low refrigerant charge, dirty condenser coil, dirty evaporator coil and all three combined) to the base maintained Office OpenStudio model and comparing electricity consumption.

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

ΔkWh = (60000 / (1000 * 12)) * 1,397 * 5%

= 349 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

Building Type	CF[401]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[402]	92.3%	N/A

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

ΔkW = 349 / 1397 * 0.996

= 0.2488 kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[401] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

[402] For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-ACTU-V01-210101

SUNSET DATE: 1/1/2025

3.3.24 Electric Chiller Tune-up

Description

This measure is for the tune-up of electric water-based chiller systems. Proper system tune-up and maintenance ensures refrigerant charges and airflows through evaporator coils have been properly tested and correctly adjusted. Restoring a chiller system so that it operates as originally designed can save energy and provide adequate cooling and comfort to the conditioned space. Note: air-based chiller systems should follow 3.3.23 Electric HVAC Tune-up.

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a chiller system at least 10 tons in capacity. The measure assumes that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Clean condenser and evaporator tubes
- Check oil level and pressure on all components
- Check pressure controls
- Inspect and clean/change air filter

Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be a chiller system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 3 years.[403]

Deemed Measure Cost

A copy of contractor invoices that detail the work performed, as well as additional labor and parts to improve/repair air conditioner performance should be submitted to the program and used as the measure cost.

Loadshape

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

[403] 3 years is given for "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils". DEER2014 EUL Table.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWH = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1000}$$

Where:

$Capacity_{Cool}$ = capacity of the chiller in Btu per hour (note 1 ton = 12,000Btu/hr)

= Actual, nameplate

EERbefore = Energy Efficiency Ratio of the chiller prior to tune-up (note EER = 12 / kW/ton)

= Actual, as measured[404]

EERafter = Energy Efficiency Ratio of the chiller after tune-up

= Actual, as measured

EFLH = Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1000 * EER_{rated}) * EFLH * \%Savings$$

Where:

EER_{rated} = Nameplate Energy Efficiency Ratio of the chiller

%Savings = Deemed percent savings per Tune-Up component.[405]

= 5%

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

ΔkWh = (600000 / (1000 * 12)) * 1,032 * 5%

= 2,580 kWh

Summer Coincident Peak Demand Savings

[404] In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer's performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state. ASHRAE Standard 184 is a recommended resource for field testing liquid chiller performance.

[405] Consistent with deemed approach in 3.3.23 and supported by literature review.

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

Where:

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

Building Type	CF[406]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[407]	92.3%	N/A

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

ΔkW = 2580 / 1032 * 0.779

= 1.9475 kW

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-HVC-CHTU-V01-220101

Sunset Date: 1/1/2026

[406] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

[407] For weighting factors, see HVAC variable table in section 3.3.

3.3.25 Gas-Fired Heat Pump

DESCRIPTION

A gas-fired heat pump (also commonly referred to a gas heat pump or GHP) is a type of heat pump whose primary input drive energy is natural gas, rather than an electrically-driven compressor. Gas heat pumps can typically be direct replacements or substitutes for conventional space heating boilers. Additionally, some are capable of providing cooling and/or domestic water heating. This characterization is limited to estimating the impacts associated with space heating loads only and does not apply to scenarios where a gas-fired heat pump is used to meeting cooling and/or DHW loads. A custom analysis should be used in such a case.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency source is a natural gas non-condensing boiler used for space heating, not process, meeting the federal equipment standards. The current Federal Standard minimum AFUE rating is 84% for boilers <300,000 Btu/hr capacity,[408] 80% E_T for boilers ≥300,000 Btu/h and ≤2,500,000 Btu/h, and 82% E_C for boilers >2,500,000 Btu/h.[409]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[410]

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is:[411]

$$\$0.115 * Capacity_{out}$$

Where:

$Capacity_{out}$ = Nominal heating output capacity (Btu/hr) of gas-fired heat pump

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

LOADSHAPE

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

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

[408] 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.
[409] Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.
[410] Consistent with assumption for a conventional space heat boiler.
[411] Based on an first cost estimates from GTI, which lists gas heat pumps as $100-$180/MBH output and conventional boilers as $15-35/MBH. The difference of the range averages ($140 - $25) is used to establish the incremental costs based on MBH output.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Gas-fired heat pumps consume electricity during their operation and therefore result in increased site electric load.

$$\Delta kWh = \frac{-Power * EFLH}{1000}$$

Where:

Power = Nominal maximum electrical power requirement for the gas-fired heat pump, W

= Actual. If unknown, assume 0.0052 W per Btu/hr heating input capacity[412]

EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

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

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

Capacity = Nominal Heating Input Capacity (Btu/hr) gas-fired heat pump

= Actual

EfficiencyRating(base) =Baseline equipment efficiency rating, depending on boiler input capacity.

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE[413]
≥300,000 Btu/h and ≤2,500,000 Btu/h	80% E_T[414]
>2,500,000 Btu/h	82% E_C[415]

EfficiencyRating(EE) = Efficent equipment efficiency rating

= Actual. If unknown, assume 130%[416]

100,000 = Conversion of Btu to Therms

412 Based on average of power requirements for Robur K18 (0.004341794 W/Btu/hr) and GAHP-A (0.005960768 W/Btu/hr)
413 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.
414 Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.
415 Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87
416 Based on findings presented Brio and GTI's Gas Heat Pump Roadmap Industry White Paper, November 2019.

For example, for a 150,000 Btu/hr gas-fired heat pump with AFUE 130% in at an existing large office building in unknown location:

ΔkWh =-0.0052 * 150,000 * 1549 / 1000

= -1,208.22 kWh

ΔTherms = 1549 * 150,000 * ((1.3/0.84)-1) / 100,000

= 1272.4 Therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[417]	Model Source
Convenience	0.01631	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014240	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011745	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[418]	0.014623	N/A

For example, for a 150,000 Btu/hr gas-fired heat pumpwith AFUE 130% at an existing large office building in unknown location:

ΔPeak Therms = 1272.4* 0.013082

= 16.6455 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

417 Calculated as the percentage of total savings in the maximum saving day, from models.
418 For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-GFHP-V01-220101

SUNSET DATE: 1/1/2025

3.3.26 Variable Refrigerant Flow (VRF) Systems

DESCRIPTION

This measure applies to the installation of a variable refrigerant flow (VRF) system in lieu of a traditional heat pump system. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

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

Variable Refrigerant Flow (VRF) systems are typically all-electric systems that use heat pumps to provide space heating and cooling to building spaces. They can serve multiple zones in a building, each with different heating and cooling requirements. VRF systems modulate the amount of refrigerant sent to each zone in accordance with conditioning requirements. In contrast, conventional HVAC systems deliver air or water and operate on a full-on or full-off schedule. Compared with air-to-air heat pumps, VRF offers energy savings due to better part-load efficiencies, heat recovery, smaller zones, and reduced duct losses

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be, at minimum, code compliant VRF equipment.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a code-compliant heat pump system, with components meeting the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[419]

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost should be determined on a site-specific basis, due to the variable nature of design requirements and the fact that the baseline to improved case system design may not be a simple component for component replacement. If not possible to determine, an incremental cost of $4.5/SQFT of building area should be used as a best estimate on incremental cost to install a VRF system[420].

LOADSHAPE

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

Loadshape NREV01:16 – Nonresidential Ventilation (by Building Type)

Algorithm

CALCULATION OF SAVINGS

Whole building modeling was performed using OpenStudio to determine savings estimates for the following building

[419] Consistent with measure lifetime assumptions for measure 3.3.4 Heat Pump Systems.

[420] ACEEE 2016 Summer Study Paper: Utility Program Cost Effectiveness of Variable Refrigerant Flow Systems. Incremental cost estimates from then Washington State University Extension Energy Program are listed as $12-$15 per square foot for a code-minimum system and $18 per square foot for a VRF system. $18 - $13.5 (average of $12 and $15) = $4.5 per square foot referenced in the TRM.

types: hotel, primary school, secondary school, midrise apartment, and office. Other building types should not use this characterization for savings estimates but should be noted so that the characterization can be expanded to include them in the future.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \text{SQFT} * (\text{Cool} + \text{Heat} + \text{Fan})$$

Where:

SQFT = Building square footage

= Actual

Cool, Heat, Fan = Savings factors for cooling, heating and fan energy, respectively. As indicated in the following table and specific to building classification. Established using OpenStudio modeling. Units are kWh/SQFT

Weather Zone	Building Type	Heat (kWh/SQFT)	Cool (kWh/SQFT)	Fan (kWh/SQFT)
Zone 5 (Burlington)	Hotel - Large	-0.33346	0.552849	2.016529
Zone 5 (Burlington)	Hotel - Small	-0.77062	0.461791	1.269607
Zone 5 (Burlington)	Primary School	-0.36603	0.419165	0.276555
Zone 5 (Burlington)	Secondary School	-0.33236	0.537251	0.384101
Zone 5 (Burlington)	Midrise Apartment	0.013104	0.226305	0.494401
Zone 5 (Burlington)	Office - Large	-0.07755	0.110837	1.794719
Zone 5 (Burlington)	Office - Medium	-0.30054	0.307518	0.379756
Zone 5 (Burlington)	Office - Small	-0.39407	0.123924	0.099816
Zone 6 (Mason City)	Hotel - Large	-0.41508	0.094191	2.067151
Zone 6 (Mason City)	Hotel - Small	-1.03922	0.311281	1.284555
Zone 6 (Mason City)	Primary School	-0.46795	0.256572	0.266787
Zone 6 (Mason City)	Secondary School	-0.0534	0.226952	0.268517
Zone 6 (Mason City)	Midrise Apartment	0.059517	0.22218	0.485346
Zone 6 (Mason City)	Office - Large	-0.12351	-0.21143	1.662037
Zone 6 (Mason City)	Office - Medium	-0.36804	0.197064	0.389187
Zone 6 (Mason City)	Office - Small	-0.59192	0.150707	0.350445
Average/unknown	Hotel - Large	-0.33207	0.402723	2.035629
Average/unknown	Hotel - Small	-0.85803	0.400139	1.29791
Average/unknown	Primary School	-0.72377	0.348614	0.275022
Average/unknown	Secondary School	-0.40465	0.387509	0.332844
Average/unknown	Midrise Apartment	0.041651	0.206514	0.515703
Average/unknown	Office - Large	-0.07378	-0.05851	1.766358
Average/unknown	Office - Medium	-0.28178	0.26853	0.398483
Average/unknown	Office - Small	-0.41448	0.116795	0.109849

For example, a 50,000 SQFT medium office in Zone 6 installing a VRF system instead of traditional heat pumps saves:

ΔkWh = 50000 * (-0.36804 + 0.197064 + 0.389187)

= 10,910.6 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \left[\frac{SQFT * Cool}{LH_{cooling}}\right] * CF$$

Where:

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

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

Building Type	CF[421]	Model Source
Education	96.7%	OpenStudio
Lodging (use for Hotel)	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio

For example a 50,000 SQFT medium office in Zone 6 installing a VRF system instead of traditional heat pumps saves (note: using Cooling Load Hours for Large Office):

ΔkW = ((50000 * 0.197064) / 4457) * 0.988

= 2.1842 kW

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-HVC-VRFS-V01-220101

Sunset Date: 1/1/2025

[421] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

3.4. Lighting

The nonresidential lighting measures use a standard set of variables for hours of use, waste heat factors, coincidence factors, and HVAC interaction effects. This table has been developed based on OpenStudio and eQuest modeling performed by VEIC, unless otherwise noted. The models, prototype building descriptions, methodology documentation, and final results can be found on the Iowa TRM SharePoint Site (TRM Reference Documents; Non Residential; Modeling). For ease of review, the table is included here and referenced in each measure.

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

Building Type	HOU	WHFe[422]	WHFd[423]	CF[424]	WHFh[425]	IFTherms Eff = 80%	IFkWh (resistance) COP = 1	IFkWh (heat pump) COP = 2.3	Model Source
General Agricultural Animal Housing and Warehousing	2920	1.0	1.0	61.8%	0.000	0.000	0.000	0.000	eQuest
Agriculture – Chicken Broilers[426]	3,251	1.0	1.0	76.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Chicken Breeders	4,606	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Chicken Layers	4,914	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Hens	2,231	1.0	1.0	76.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Toms	5,351	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a

422 Determined as the total building electrical savings divided by the lighting electrical savings. Note that effects of heat pump, electric heat or dehumidification were removed to isolate only the cooling waste heat impacts.
423 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.
424 This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
425 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.
426 Agriculture lighting loadshapes, operational hours, and HVAC interactive factors are sourced from the 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 9.0, September 2020. These values were developed based on field experience and research material for the general agriculture, indoor agriculture, poultry and dairy commodities. Due to livestock housing having little to no mechanical cooling systems, waste heat cooling and associated demand factors were assumed to be 1.00.

Building Type	HOU	WHFe[422]	WHFd[423]	CF[424]	WHFh[425]	IFTherms Eff = 80%	IFkWh (resistance) COP = 1	IFkWh (heat pump) COP = 2.3	Model Source
Agriculture – Turkey Breeder Toms	4,396	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Breeder Hens	5,446	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Dairy Long Day Lighting	6,205	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Convenience	4630	1.14	1.31	100.0%	0.36	0.015	0.36	0.16	eQuest
Education	1877	1.07	1.48	65.27%	0.45	0.019	0.45	0.20	OpenStudio
Exterior Lighting	4676	1.0	1.0	0%	0.000	0.000	0.000	0.000	OpenStudio
Grocery	4663	1.02	1.20	82.11%	0.30	0.013	0.30	0.13	OpenStudio
Health	3806	1.09	1.69	67.00%	0.35	0.015	0.35	0.15	OpenStudio
Hospital	6520	1.16	1.26	55.95%	0.18	0.008	0.18	0.08	OpenStudio
Industrial	2850	1.02	1.02	91.80%	0.37	0.016	0.37	0.16	eQuest
Lodging	3061	1.23	1.47	61.07%	0.19	0.008	0.19	0.08	OpenStudio
Multifamily	3061	1.13	1.15	71.17%	0.44	0.019	0.44	0.19	OpenStudio
Office - Large	2920	1.17	1.04	60.20%	0.29	0.013	0.29	0.13	OpenStudio
Office - Small	2920	1.10	1.28	51.79%	0.33	0.014	0.33	0.15	OpenStudio
Religious	2412	1.12	1.32	66.00%	0.46	0.020	0.46	0.20	eQuest
Restaurant	5443	1.00	1.47	100.00%	0.00	0.000	0.00	0.00	OpenStudio
Retail - Large	4065	1.00	1.28	100.0%	0.00	0.000	0.00	0.00	eQuest/Open Studio
Retail - Small	3694	1.09	1.20	100.00%	0.36	0.015	0.36	0.16	OpenStudio
Warehouse	2920	1.00	1.19	61.8%	0.00	0.000	0.00	0.00	eQuest/Open Studio
Nonresidential Average[427]	3065	1.06	1.28	69.07%	0.24	0.010	0.24	0.10	N/A
Unconditioned building	As above	1.0	1.0	As above	0.000	0.000	0.000	0.000	N/A
Refrigerated Cases[428]	As above	1.29	1.29	As above	0.000	0.000	0.000	0.000	N/A
Freezer Cases[429]	As above	1.50	1.50	As above	0.000	0.000	0.000	0.000	N/A

[427] For weighting factors, see HVAC variable table in section 3.3.
[428] 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.
[429] WHFe and WHFd for freezer case lighting is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP freezer system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.

3.4.1. Compact Fluorescent Lamp – Standard (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

3.4.2. Compact Fluorescent Lamp – Specialty (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

3.4.3. LED Lamp Standard

Description

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to baseline EISA incandescent, halogen, or compact fluorescent lamps. In addition, LED's inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. These factors make LEDs a highly efficient alternative to standard interior and exterior lighting options.

This specific characterization provides savings assumptions for LED lamps that replace standard screw-in connections (e.g., A-Type lamp) such as interior/exterior omnidirectional lamp options.

This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential vs. Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard. Furthermore, the Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that the more stringent standards (45 lumen per watt) prescribed in the 2007 EISA regulation to become effective in 2020 (known as the 'Backstop' provision) were not economically justified. However, natural growth of LED market share has and will continue to grow over the lifetime of the measure, and since baseline halogens would need to be replaced multiple times within the life of the measure, a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new LED screw-based lamps must be ENERGY STAR qualified based upon the v2.1 ENERGY STAR specification for lamps (https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2 qualified. Specifications are as follows:

Efficiency Level	Lumens / watt	
	CRI<90	CRI≥90
ENERGY STAR v2.1	80	70
CEE Tier 2[430]	95	80

Qualification could also be based or on the Design Light Consortium's qualified product list.[431]

[430] Also required to have rated life of 25,000 hours and dimming capability.
[431] https://www.designlights.org/QPL

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 38% EISA qualified halogen or incandescent and 1% CFL and 61%LED.[432] The baseline is forecast to continue to shift towards LEDs and therefore a mid-life 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 20,230.[433]

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:[434]

Lamp Type	CRI	Product Type	Cost	Incremental Cost
Standard A-lamp	<90	Baseline	$2.47	n/a
		ESTAR LED	$3.16	$0.69
		CEE T2 LED	$3.29	$0.82
	>=90	Baseline	$2.78	n/a
		ESTAR LED	$3.67	$0.89
		CEE T2 LED	$3.75	$0.96

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/ halogen,[435] CFL, and LED by weightings provided in table below.[436] 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 exisitng system.

[432] Based on review of CREED LightTracker data and DOE, 2019 'Energy Savings Forecast of Solid-State Lighting in General Illumination Applications'. See 'Lighting Forecast Workbook.xls'.

[433] Average rated life of omnidirectional bulbs on the ENERGY STAR qualified products list as of April, 2020.

[434] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. The baseline cost reflects the baseline mix. See "2021 LED Measure Cost and O&M Calc.xls" for more information.

[435] Incandescent/Halogen wattage is based upon the post first phase of EISA.

[436] Weightings based upon review of CREED LightTracker data for Illinois and DOE, 2019 'Energy Savings Forecast of Solid-State Lighting in General Illumination Applications'. See 'Lighting Forecast Workbook.xls'.

$Watts_{EE}$ = Actual wattage of LED purchased/installed. If unknown, use default provided below:[437]

Lower Lumen Range	Upper Lumen Range	Inc/ Halogen	CFL[438]	LED[439]	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
		38%	1%	61%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
250	309	25	4.7	3.7	11.9	3.5	4.0	2.9	3.5	8.4	7.9	9.0	8.4
310	749	29	8.8	7.1	15.5	6.6	7.6	5.6	6.6	8.9	7.9	9.9	8.9
750	1049	43	15.0	12.0	23.9	11.2	12.9	9.5	11.2	12.7	11.1	14.4	12.7
1050	1489	53	21.2	16.9	30.8	15.9	18.1	13.4	15.9	14.9	12.7	17.4	14.9
1490	2600	72	34.1	27.3	44.5	25.6	29.2	21.5	25.6	18.9	15.3	23.0	18.9
2601	3300	150	49.2	39.3	81.9	36.9	42.2	31.1	36.9	45.0	39.7	50.8	45.0
3301	3999	200	60.8	48.7	106.8	45.6	52.1	38.4	45.6	61.2	54.7	68.4	61.2
4000	6000	300	83.3	66.7	156.3	62.5	71.4	52.6	62.5	93.8	84.9	103.7	93.8
Weighted Average, if unknown[440]					25.6	12.4				13.2			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 3.4. If hours or building type are unknown, use the Nonresidential Average value.

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

ISR = In Service Rate or the percentage of units rebated that get installed

=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume the following:

Program	Discounted In Service Rate (ISR)[441]
Retail (Time of Sale)[442]	89%
Direct Install[443] and Retrofit	97%

Mid-Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be

437 $Watts_{EE}$ are calculated using the midpoint of the lumen range and an efficacy of 80 lumens/watt for ESTAR CRI <90,70 lumens/watt for ESTAR CRI>90, 95 lumens/watt for CEE Tier 2 CRI <90,80 lumens/watt for CEE Tier 2 CRI>90,

438 Baseline CFL watts are calculated using the midpoint of the lumen range and an assumed efficacy of 60 lumens/watt.

439 Baseline LED watts are calculated using the midpoint of the lumen range and an assumed efficacy of 75 lumens/watt.

440 Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

441 All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%). The second and third year installations rates are from NREL, "Chapter 6: Residential Lighting Evaluation Protocol of the Uniform Methods Project," October 2017. See "Non-Res Lighting ISR calculation_2019.xlsx" for more information.

442 The 1st year in service rate for Retail LEDs is a weighted average based on PY7 and PY9 evaluations from ComEd's, Illinois commercial lighting program (BILD) and PY9 data from Ameren Illinois Instant Incentives program.

443 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

replaced multiple times. In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that the more stringent standards (45 lumen per watt) prescribed in the 2007 EISA regulation to become effective in 2020 (known as the 'Backstop' provision) were not economically justified. However, natural growth of LED market share has and will continue to grow over the lifetime of the measure, and so a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. See 'Lighting Forecast Workbook_2021.xls' for details.

The calculated mid-life adjustments for 2022 are provided below for each fixture type:

Lamp Category	Year on adjustment is applied	Adjustment
ENERGY STAR	5	45%
CEE Tier 2	5	52%

Heating Penalty:

If electrically heated building:[444]

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

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent 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):[445]

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

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.

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

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

If unknown, use the Nonresidential Average value.

Peak Gas Savings

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

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 197[446]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

In order to account for the shift in baseline due to the natural growth of LED over the lifetime of the measure, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below:[447]

CRI	Product Type	Cost
<90	Inc/Hal	$1.40
	CFL	$1.68
	LED	$3.16
>=90	Inc/Hal	$1.40
	CFL	$1.95
	LED	$3.67

The present value of replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.20% are presented below:[448]

CRI	Location	PV of replacement costs for period 2021 Installs	Levelized annual replacement cost savings 2021 Installs
<90	Non Residential Average	$6.70	$0.96
>=90	Non Residential Average	$6.77	$0.97

Measure Code: NR-LTG-LEDA-V06-220101

Sunset Date: 1/1/2023

446 Number of days where HDD 55 >0.

447 Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017 and equivalent baseline bulbs.

448 See "2021 LED Measure Cost and O&M Calc.xlsx" for more information. The values assume the non-residential average hours assumption of 3065.

3.4.4. LED Lamp Specialty

DESCRIPTION

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to incandescent, halogen or compact fluorescent lamps. In addition, LED's inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. These factors make LEDs a highly efficient alternative to standard interior and exterior lighting options.

This specific characterization provides savings assumptions for LED Directional, Decorative, and Globe lamps.

This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

The Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A DOE Final Rule released on 1/19/2017 updated the definition of General Service Lamps (GSL) as provided in the 2009 Energy Independence and Security Act (EISA) such that the lamp types characterized in this measure would become subject to the backstop provision in EISA, which requires that after January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt.

On 9/5/2019 DOE repealed the 2017 Final rule, preventing this expansion of the definition of General Service Lamp to include these lamps. However, natural growth of LED market share has and will continue to grow over the lifetime of the measure, and since baseline halogens would need to be replaced multiple times within the life of the measure, a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new LED lamps must be ENERGY STAR qualified based upon the v2.1 ENERGY STAR specification for lamps (https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2 qualified. Specifications are as follows:

Efficiency Level	Lamp Type	Lumens / watt	
		CRI<90	CRI≥90
ENERGY STAR v2.1	Directional	70	61
	Decorative / Globe	65	65
CEE Tier 2[449]	Directional	85	70
	Decorative / Globe	95	80

Qualification could also be based on the Design Light Consortium's qualified product list.[450]

DEFINITION OF BASELINE EQUIPMENT

[449] Also required to have dimming capability.

[450] https://www.designlights.org/QPL

The baseline condition for this measure is assumed to be a blend of 42% EISA qualified halogen or incandescent and 58% baseline LED for decorative and globe lamps, and 14% EISA qualified halogen or incandescent and 86% baseline LED for decorative and globe lamps.[451] Lamp types include those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (≤40W equivalent(We)), candelabra base (≤60We), vibration service bulb, decorative candle with medium or intermediate base (≤40We), shatter resistant, and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5" diameter and >40We), candle (shapes B, BA, CA >40We), candelabra base lamps (>60We), and intermediate base lamps (>40We). Note however that all lamps are subject a baseline shift to account for the natural growth in LEDs over the lifetime of the measure.

Deemed Lifetime of Efficient Equipment

The rated life for directional bulbs is assumed to be 25,042 hours and for decorative bulbs is 17,129 hours.[452]

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:[453]

Bulb Type	CRI	Product Type	Cost	Incremental Cost
Directional	<90	Baseline	$7.42	n/a
		ESTAR LED	$7.80	$0.38
		CEE T2 LED	$18.96	$11.55
	>=90	Baseline	$7.27	n/a
		ESTAR LED	$7.63	$0.36
		CEE T2 LED	$18.54	$11.28
Decorative	<90	Baseline	$5.62	n/a
		ESTAR LED	$7.50	$1.88
		CEE T2 LED	$7.83	$2.21
	>=90	Baseline	$6.31	n/a
		ESTAR LED	$8.69	$2.38
		CEE T2 LED	$9.08	$2.76

Loadshape

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

[451] Based on review of CREED LightTracker data for Illinois and DOE, 2019 'Energy Savings Forecast of Solid-State Lighting in General Illumination Applications'. See 'Lighting Forecast Workbook.xls'.
[452] Average rated life of directional and decorative bulbs on the ENERGY STAR qualified products list as of April, 2020.
[453] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. The baseline cost reflects the baseline mix. See "2021 LED Measure Cost and O&M Calc.xls" for more information.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * Hours * WHFe * ISR$$

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed and includes blend of incandescent/halogen,[454] CFL and LED by weightings provided in table below.[455] Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

$Watts_{EE}$ = Actual wattage of LED purchased/installed. If unknown, use default provided below.[456]

[454] 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.

[455] Weightings based on review of CREED LightTracker data and DOE, 2019 'Energy Savings Forecast of Solid-State Lighting in General Illumination Applications'. See 'Lighting Forecast Workbook.xls'.

[456] $Watts_{EE}$ defaults are based upon the ENERGY STAR minimum luminous efficacy for the mid-point of the lumen range. See calculations in file "2017 Lighting Updates and Baseline Estimates".

EISA exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Hal	$Watts_{EE}$	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				42%	58%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
EISA Exempt	3-Way[457]	250	449	25	5.0	13.4	4.4	5.0	3.7	4.4	9.0	8.4	9.7	9.0
		450	799	40	8.9	21.9	7.8	8.9	6.6	7.8	14.1	13.0	15.3	14.1
		800	1,099	60	13.6	33.0	11.9	13.6	10.0	11.9	21.1	19.4	23.0	21.1
		1,100	1,599	75	19.3	42.6	16.9	19.3	14.2	16.9	25.7	23.3	28.4	25.7
		1,600	1,999	100	25.7	56.7	22.5	25.7	18.9	22.5	34.3	31.0	37.8	34.3
		2,000	2,549	125	32.5	71.1	28.4	32.5	23.9	28.4	42.7	38.7	47.2	42.7
		2,550	2,999	150	39.6	85.7	34.7	39.6	29.2	34.7	51.1	46.1	56.5	51.1
	Globe (medium and intermediate base < 750 lumens)	90	179	10	2.4	5.6	2.1	2.1	1.4	1.7	3.5	3.5	4.2	3.9
		180	249	15	3.9	8.5	3.3	3.3	2.3	2.7	5.2	5.2	6.3	5.9
		250	349	25	5.4	13.6	4.6	4.6	3.2	3.7	9.0	9.0	10.5	9.9
		350	749	40	10.0	22.5	8.5	8.5	5.8	6.9	14.1	14.1	16.7	15.7
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.4	5.0	1.2	1.2	0.8	1.0	3.8	3.8	4.2	4.0
		90	149	15	2.2	7.5	1.8	1.8	1.3	1.5	5.7	5.7	6.3	6.0
		150	299	25	4.1	12.8	3.5	3.5	2.4	2.8	9.4	9.4	10.5	10.0
		300	749	40	9.5	22.3	8.1	8.1	5.5	6.6	14.2	14.2	16.7	15.7
	Globe (candelabra bases less than 1050 lumens)	90	179	10	2.4	5.6	2.1	2.1	1.4	1.7	3.5	3.5	4.2	3.9
		180	249	15	3.9	8.5	3.3	3.3	2.3	2.7	5.2	5.2	6.3	5.9
		250	349	25	5.4	13.6	4.6	4.6	3.2	3.7	9.0	9.0	10.5	9.9
		350	499	40	7.7	21.2	6.5	6.5	4.5	5.3	14.7	14.7	16.7	15.9
		500	1,049	60	14.1	33.3	11.9	11.9	8.2	9.7	21.4	21.4	25.1	23.6
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than -1050 lumens)	70	89	10	1.4	5.0	1.2	1.2	0.8	1.0	3.8	3.8	4.2	4.0
		90	149	15	2.2	7.5	1.8	1.8	1.3	1.5	5.7	5.7	6.3	6.0
		150	299	25	4.1	12.8	3.5	3.5	2.4	2.8	9.4	9.4	10.5	10.0
		300	499	40	7.3	20.9	6.1	6.1	4.2	5.0	14.8	14.8	16.7	15.9
		500	1,049	60	14.1	33.3	11.9	11.9	8.2	9.7	21.4	21.4	25.1	23.6
	Weighted Average, if unknown[458]					26.3	9.4				16.9			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

[457] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

[458] Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

Directional Lamps - For Directional R, BR, and ER lamp types:[459]

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	$Watts_{EE}$ LED	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				14%	86%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	7.4	11.9	6.4	7.3	5.2	6.4	5.5	4.6	6.6	5.5
		473	524	45	8.3	13.3	7.1	8.2	5.9	7.1	6.2	5.1	7.5	6.2
		525	714	50	10.3	15.7	8.9	10.2	7.3	8.9	6.9	5.6	8.5	6.9
		715	937	65	13.8	20.8	11.8	13.5	9.7	11.8	9.0	7.2	11.0	9.0
		938	1,259	75	18.3	26.0	15.7	18.0	12.9	15.7	10.4	8.0	13.1	10.4
		1,260	1,399	90	22.2	31.4	19.0	21.8	15.6	19.0	12.4	9.6	15.8	12.4
		1,400	1,739	100	26.2	36.2	22.4	25.7	18.5	22.4	13.8	10.5	17.8	13.8
		1,740	2,174	120	32.6	44.5	28.0	32.1	23.0	28.0	16.6	12.5	21.5	16.6
		2,175	2,624	150	40.0	55.0	34.3	39.3	28.2	34.3	20.7	15.7	26.8	20.7
		2,625	2,999	175	46.9	64.4	40.2	46.1	33.1	40.2	24.2	18.3	31.3	24.2
		3,000	4,500	200	62.5	81.3	53.6	61.5	44.1	53.6	27.7	19.8	37.1	27.7
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	7.1	11.6	6.1	7.0	5.0	6.1	5.5	4.6	6.6	5.5
		450	499	45	7.9	13.0	6.8	7.8	5.6	6.8	6.2	5.2	7.4	6.2
		500	649	50	9.6	15.1	8.2	9.4	6.8	8.2	6.9	5.7	8.3	6.9
		650	1,199	65	15.4	22.2	13.2	15.2	10.9	13.2	9.0	7.0	11.3	9.0
	*ER30, BR30, BR40, or ER40	400	449	40	7.1	11.6	6.1	7.0	5.0	6.1	5.5	4.6	6.6	5.5
		450	499	45	7.9	13.0	6.8	7.8	5.6	6.8	6.2	5.2	7.4	6.2
		500	649	50	9.6	15.1	8.2	9.4	6.8	8.2	6.9	5.7	8.3	6.9
	*BR30, BR40, or ER40	650	1,419	65	17.2	23.8	14.8	17.0	12.2	14.8	9.0	6.8	11.6	9.0
	*R20	400	449	40	7.1	11.6	6.1	7.0	5.0	6.1	5.5	4.6	6.6	5.5
		450	719	45	9.7	14.6	8.4	9.6	6.9	8.4	6.2	5.0	7.7	6.2
	*All reflector lamps below lumen ranges specified above	200	299	20	4.2	6.3	3.6	4.1	2.9	3.6	2.8	2.2	3.4	2.8
		300	399	30	5.8	9.1	5.0	5.7	4.1	5.0	4.1	3.4	5.0	4.1
Weighted Average, if unknown[460]						20.6	12.2				8.5			

[459] From pg. 13 of the Energy Star Specification for lamps v2.1.

[460] Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90. Directional lamps are exempt from first phase of EISA regulations.

EISA non-exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/ Hal	$Watts_{EE}$ LED	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				42%	58%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
EISA Non-Exempt	Dimmable Twist, Globe (<5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	250	309	25	5.1	13.4	3.5	4.0	2.9	3.5	9.9	9.4	10.5	9.9
		310	749	29	9.6	17.7	6.6	7.6	5.6	6.6	11.1	10.2	12.1	11.1
		750	1049	43	16.4	27.5	11.2	12.9	9.5	11.2	16.2	14.6	18.0	16.2
		1050	1489	53	23.1	35.6	15.9	18.1	13.4	15.9	19.7	17.4	22.2	19.7
		1490	2600	72	37.2	51.7	25.6	29.2	21.5	25.6	26.2	22.5	30.2	26.2
Weighted Average, if unknown[461]						29.5	12.4				17.1			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

[461] Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 3.4. If hours or building type are unknown, use the Nonresidential Average value.

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

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume the following:

Program	Discounted In Service Rate (ISR)[462]
Retail (Time of Sale)[463]	89%
Direct Install[464] and Retrofit	97%

Heating Penalty:

If electrically heated building:[465]

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

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

Mid-Life Baseline Adjustment

During the lifetime of an LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. The market share of LED will continue to grow over the lifetime of the measure, and since baseline halogens would need to be replaced multiple times within the life of the measure, a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. See 'Lighting Forecast Workbook_2021.xls' for details.

The calculated mid-life adjustments for 2022 are provided below for each fixture type:

Lamp Category	Efficiency Level	Year on adjustment is applied	Adjustment
Decorative and Globe lamps	ENERGY STAR	5	62%
	CEE Tier 2	5	68%
Directional lamps	ENERGY STAR	5	68%
	CEE Tier 2	5	75%

462 All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%). The second and third year installations rates are from NREL, "Chapter 6: Residential Lighting Evaluation Protocol of the Uniform Methods Project," October 2017. See "Non-Res Lighting ISR calculation_2018.xlsx" for more information.

463 The 1st year in service rate for Retail LEDs is a weighted average based on PY7 and PY9 evaluations from ComEd's, Illinois commercial lighting program (BILD) and PY9 data from Ameren Illinois Instant Incentives program.

464 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

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

Summer Coincident Peak Demand Savings

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

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

CF = Summer Peak Coincidence Factor for measure is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

Natural Gas Energy Savings

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):[466]

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

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

= 197[467]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

In order to account for the shift in baseline due to the natural growth of LED over the lifetime of the measure, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below.[468]

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[466] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.
[467] Number of days where HDD 55 >0.
[468] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017 and equivalent baseline bulbs.

Lamp Type	CRI	Product Type	Cost
Directional	<90	Inc/Hal	$5.00
		LED	$7.80
	>=90	Inc/Hal	$5.00
		LED	$7.63
Decorative	<90	Inc/Hal	$3.00
		LED	$7.50
	>=90	Inc/Hal	$3.00
		LED	$8.69

The present value of replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.20% are presented below:[469]

			PV of replacement costs for period	Levelized annual replacement cost savings
Lamp Type	CRI	Location	2022 Installs	2022 Installs
Directional	<90	Nonresidential average	$12.88	$1.85
	>=90	Nonresidential average	$12.87	$1.85
Decorative	<90	Nonresidential average	$16.08	$2.31
	>=90	Nonresidential average	$16.20	$2.33

MEASURE CODE: NR-LTG-LEDS-V06-220101

SUNSET DATE: 1/1/2023

[469] See "2021 LED Measure Cost and O&M Calc.xlsx" for more information. The values assume the non-residential average hours assumption of 3065.

3.4.5. LED Fixtures

DESCRIPTION

The installation of Light-Emitting Diode (LED) lighting systems have comparable luminosity to incandescent bulbs and equivalent fluorescent lamps at significantly less wattage, lower heat, and with significantly longer lifetimes.

This measure provides savings assumptions for a variety of efficient lighting fixtures including internal and external LED fixtures, recess (troffer), canopy, and pole fixtures, as well as refrigerator and display case lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, all LED fixtures must fall within the lumen ranges listed in the tables and be ENERGY STAR labeled or on the Design Light Consortium qualifying product list.[470] All LED fixtures that fall outside the lumen ranges listed in the tables would have to be processed custom. Delamping projects, i.e., those achieving an overall decrease in luminosity, **MUST NOT** use default, tabulated baseline power assumptions, since default values assume luminosity is maintained. For such projects, actual baseline power must be used in savings calculations.

DEFINITION OF BASELINE EQUIPMENT

For TOS and RF installations, the baselines efficiency case is project specific and is determined using actual fixture types and counts from the existing space. The existing fluorescent fixture end connectors and ballasts must be completely removed to qualify.

Where the installation technology is not known, the assumed baselines condition for an outdoor pole/arm, wall-mounted, garage/canopy fixture and high-bay luminaire with a high intensity discharge light source is a metal halide fixture. Deemed fixture wattages are provided in reference tables at the end of this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated measure life of LED Fixtures is 13 years.[471]

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:

[470] DesignLights Consortium Qualified Products List http://www.designlights.org/qpl

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

$Watts_{Base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values when baseline is unknown.

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed. If unknown, use default provided in "LED New and Baseline Assumptions".

Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 3.4. by building type. If hours or building type are unknown, use the Nonresidential Average value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate is assumed to be 95% for Time of Sale and 100% for Retrofit.[472]

Heating Penalty:

If electrically heated building:

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

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts;[473] this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

Mid-life Adjustment:

A mid-life savings adjustment should be applied to any measure with a blended Standard T8 : T12 baseline. The adjustment should occur in 2022 to account for the baseline lamp replacement assumption changing from a blended 82/18 Standard T8/T12[474] to 100% Standard T8 by 2022.[475] The savings adjustment is calculated as follows, and is provided in the Reference Table section:

$$\%\ Adjustment = \left(\frac{Watts_{\text{T8base}} - Watts_{\text{EE}}}{Watts_{\text{Blended T8/T12 Base}} - Watts_{\text{EE}}}\right)$$

Where:

WattsT8Base = Input wattage of the existing system based on 100% T8 fixture; see reference table below.

WattsBlendedT8/T12 = Input wattage of the existing system based on 82% T8 / 18% T12; see reference table below.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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472 Negotiated value during Iowa TRM Technical Advisory Committee call, 08/25/2015.
473 Negative value because this is an increase in heating consumption due to the efficient lighting.
474 Blend of T8 to T12 is based upon Dunsky and Opinion Dynamics Baseline Study results, 2017.
475 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, although the timing of such updates is unknown. 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 2024 all replacement lamps are Standard T8s. Therefore while the more likely scenario would be a gradual shift of the 82/18 weighted baseline to T8s over the timeframe, to simplify this assumption, a single mid-life adjustment in 2022 is assumed.

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

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Lighting Reference Table in Section 3.4. for each building type. If the building is not cooled, WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Lighting Reference Table in Section 3.4. for each building type. If the building type is unknown, use the Nonresidential Average value.

Natural Gas Energy Savings

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

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts;[476] 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

= 197[477]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

See Reference Tables below for default assumptions.

Reference Tables[478]

[476] Negative value because this is an increase in heating consumption due to the efficient lighting.
[477] Number of days where HDD 55 >0.
[478] Watt, lumen, and costs data assumptions for efficient measures are based upon Design Light Consortium Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting

LED Category	EE Measure		Baseline			Incremental Cost	Mid-life Savings Adjustment (2022)
	Description	$Watts_{EE}$	Description	$Watts_{BASE}$	Base Cost		
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	40% CFL 26W Pin Based & 60% PAR30/38	54.3	$15	$27	N/A
LED Interior Directional	LED Track Lighting	12.2	10% CMH PAR38 & 90% Halogen PAR38	60.4	$25	$59	N/A
	LED Wall-Wash Fixtures	8.3	40% CFL 42W Pin Base & 60% Halogen PAR38	17.7	$25	$59	N/A
LED Display Case	LED Display Case Light Fixture	7.1 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	$10/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	$10/ft	$11/ft	N/A
	LED Refrigerated Case Light, Horizontal or Vertical	7.6 / ft	5'T8	15.2 / ft	$10/ft	$11/ft	N/A
	LED Freezer Case Light, Horizontal or Vertical	7.7 / ft	6'T12HO	18.7 / ft	$10/ft	$11/ft	N/A
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	8.9	F17T8 Standard Lamp - 2 foot	15.0	$5.00	$12.75	N/A
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	15.8	F32T8 Standard Lamp - 4 foot	28.2	$3.00	$15	N/A
	T8 LED Replacement Lamp (TLED), 2401-4000 lumens	22.9	F32T8/HO Standard Lamp - 4 foot	42	$11.00	$13.25	N/A
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	25.4	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$50	$53	97%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	36.7	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$55	$69	92%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	33.3	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$50	$55	96%
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	44.8	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$55	$76	90%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	57.2	18:82;4-Lamp 34w T12 (BF < 0.88): 4-Lamp 32w T8 (BF < 0.88)	118.3	$60	$104	91%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	21.8	18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91)	29.5	$50	$22	96%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	33.7	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$55	$75	96%
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	43.3	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF <	88.7	$60	$83	91%

suppliers, past Efficiency Vermont projects, and professional judgment. See "LED Lighting Systems TRM Reference Tables 2017 Iowa.xlsx" for more information and specific product links.

LED Category	EE Measure		Baseline			Incremental Cost	Mid-life Savings Adjustment (2022)
	Description	$Watts_{EE}$	Description	$Watts_{BASE}$	Base Cost		
			0.88)				
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	19.5	18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91)	29.5	$50	$10	97%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	32.1	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$55	$52	96%
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	43.5	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$60	$78	91%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	56.3	T5HO 2L-F54T5HO - 4'	120.0	$65	$131	N/A
	LED Surface & Suspended Linear Fixture, >7500 lumens	82.8	T5HO 3L-F54T5HO - 4'	180.0	$70	$173	N/A
LED High & Low Bay Fixtures	LED Low-Bay or High-Bay Fixtures, ≤ 10,000 lumens	61.6	3-Lamp T8HO Low-Bay	157.0	$75	$44	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	99.5	4-Lamp T8HO High-Bay	196.0	$100	$137	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	140.2	6-Lamp T8HO High-Bay	294.0	$125	$202	N/A
	LED High-Bay Fixtures, > 20,000 lumens	193.8	8-Lamp T8HO High-Bay	392.0	$150	$264	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	12.9	25% 73 Watt EISA Inc, 75% 1L T8	42.0	$20	$18	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	29.7	25% 146 Watt EISA Inc, 75% 2L T8	81.0	$40	$48	N/A
	LED Ag Interior Fixtures, 4,001-6,000 lumens	45.1	25% 217 Watt EISA Inc, 75% 3L T8	121.0	$60	$57	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	59.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	$80	$88	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	84.9	200W Pulse Start Metal Halide	227.3	$120	$168	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	113.9	320W Pulse Start Metal Halide	363.6	$160	$151	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	143.7	350W Pulse Start Metal Halide	397.7	$200	$205	N/A
	LED Ag Interior Fixtures, > 20,000 lumens	193.8	(2) 320W Pulse Start Metal Halide	727.3	$240	$356	N/A
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	34.1	100W Metal Halide	113.6	$60	$80	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	67.2	175W Pulse Start Metal Halide	198.9	$90	$248	N/A
	LED Exterior Fixtures, 10,001-15,000 lumens	108.8	250W Pulse Start Metal Halide	284.1	$120	$566	N/A
	LED Exterior Fixtures, >15,000 lumens	183.9	400W Pulse Start Metal Halide	454.5	$150	$946	N/A

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	50,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Interior Directional	LED Track Lighting	50,000	$39.00	70,000	$47.50	2,500	$12.71	40,000	$11.00
	LED Wall-Wash Fixtures	50,000	$39.00	70,000	$47.50	2,500	$9.17	40,000	$27.00
LED Display Case	LED Display Case Light Fixture	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	50,000	$8.63/ft	70,000	$9.50/ft	15,000	$1.13	40,000	$8.00
	LED Freezer Case Light, Horizontal or Vertical	50,000	$7.88/ft	70,000	$7.92/ft	12,000	$0.94	40,000	$6.67
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	50,000	$8.57	70,000	$13.67	24,000	$6.17	40,000	$11.96
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	50,000	$8.57	70,000	$13.67	24,000	$6.17	40,000	$11.96
	T8 LED Replacement Lamp (TLED), 2401-4000 lumens	50,000	$5.76	70,000	$13.67	24,000	$6.17	40,000	$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$78.07	70,000	$40.00	24,000	$26.33	40,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$89.23	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$96.10	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$114.37	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$137.43	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$65.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$100.44	70,000	$40.00	24,000	$12.33	40,000	$35.00

		EE Measure				Baseline			
LED Category	EE Measure Description	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 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$108.28	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	50,000	$62.21	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$93.22	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$114.06	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$152.32	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, >7500 lumens	50,000	$183.78	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay or High-Bay Fixtures, ≤ 10,000 lumens	50,000	$112.13	70,000	$62.50	18,000	$64.50	40,000	$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$186.93	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	50,000	$243.06	70,000	$62.50	18,000	$129.00	40,000	$117.50
	LED High-Bay Fixtures, >20,000 lumens	50,000	$297.87	70,000	$62.50	18,000	$172.00	40,000	$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	50,000	$41.20	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$65.97	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$80.08	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$105.54	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$179.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$190.86	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$237.71	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$331.73	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	50,000	$73.80	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$124.89	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures,	50,000	$214.95	70,000	$62.50	15,000	$68.00	40,000	$122.50

		EE Measure				Baseline			
LED Category	EE Measure Description	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
	10,001-15,000 lumens								
	LED Exterior Fixtures, > 15,000 lumens	50,000	$321.06	70,000	$62.50	15,000	$73.00	40,000	$132.50

MEASURE CODE: NR-LTG-LDFX-V05-220101

SUNSET DATE: 1/1/2023

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.[479]

The main markets served by T5 HO fixtures and lamps include retrofit in the commercial and nonresidential sector, specifically industrial, warehouse, and grocery facilities with higher ceiling heights that require maximum light output.

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

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

Definition of Efficient Equipment

The definition of the efficient equipment is T5 HO high-bay (>15ft mounting height) fixtures with 3, 4, 6, or 8-lamp configurations.

Definition of Baseline Equipment

The definition of baseline equipment varies based on number of lamps in a fixture and is defined in the baseline reference table at the end of this characterization.

Deemed Lifetime of Efficient Equipment

The deemed lifetime of the efficient equipment fixture is 15 years.[480]

Deemed Measure Cost

The deemed measure cost is found in reference table at the end of this characterization.

Loadshape

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * Hours * WHFe * ISR$$

Where:

$Watts_{Base}$ = Input wattage of the baseline system is dependant on new fixture configuration and

[479] Lighting Research Center. T5 Fluorescent Systems. http://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/lat5/abstract.asp

[480] Focus on Energy Evaluation "Business Programs: Measure Life Study" Final Report, August 9, 2009 prepared by PA Consulting Group.

found in the 'T5HO Efficient and Baseline Wattage and Cost Assumptions' reference table below.

$Watts_{EE}$ = Input wattage depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the 'T5HO Efficient and Baseline Wattage and Cost Assumptions' reference table below.

Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 3.4 as annual operating hours, by building type. If hours or building type are unknown, use the Nonresidential Average value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume 98%.[481]

<u>Heating Penalty:</u>

If electrically heated building:[482]

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

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building is not cooled, WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

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

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the

[481] Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD)

[482] Negative value because this is an increase in heating consumption due to the efficient lighting.

increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4.[483] 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

= 197[484]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

See reference tables for different cost assumptions for lamps and ballasts. When available, actual costs and hours of use should be used.

Reference Tables

T5HO Efficient and Baseline Wattage And Cost Assumptions[485]

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 Lifetimes[486]

	EE Measure				Baseline			
EE Measure Description	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-V02-200101

[483] Negative value because this is an increase in heating consumption due to the efficient lighting.
[484] Number of days where HDD 55 >0.
[485] 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.
[486] Costs include labor cost – see "Updated-T5HO-adjusted deemed costs.baselines-7-30-15.xlsx" for more information.

SUNSET DATE: 1/1/2024

3.4.7. High Performance and Reduced Wattage T8 Fixtures and Lamps (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

3.4.8. Metal Halide (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

3.4.9. Commercial LED Exit Sign

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent/compact fluorescent (CFL) exit sign in a Commercial building. LED exit signs use a lower wattage of power (≤ 5 Watts) and have a significantly longer life compared to standard signs that can use up to 40 watts.[487] This in addition to reduced maintenance needs, and characteristic low-temperature light quality makes LED exit signs a superior option compared to other exit sign technologies available today.

This measure was developed to be applicable to the following program types: Retrofit (RF), and Direct Install (DI).

Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs with an input power demand of 5 watts or less per face.[488]

Definition of Baseline Equipment

The baseline is the existing fluorescent/compact fluorescent (CFL) exit sign.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 13 years.[489]

Deemed Measure Cost

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of at $32.50.[490]

Loadshape

Loadshape E01 – Flat

Algorithm

Calculation of Savings

Electric Energy Savings [491]

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * Hours * WHFe$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

[487] ENERGY STAR "*Save Energy, Money and Prevent Pollution with LED Exit Signs*"

[488] 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.

[489] GDA Associates Inc. "Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures", June 2007.

[490] Price includes new exit sign/fixture and installation. LED exit cost cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming IA labor cost of 15 minutes @ $40/hr.

[491] There is no ISR calculation. Exit signs and emergency lighting are required by federal regulations to be installed and functional in all public buildings as outlined by the U.S. Occupational Safety and Health Standards (USOSHA 1993).

Program Type	Baseline Type	$Watts_{Base}$
Retrofit/Direct Install[492]	CFL (dual sided)	14W[493]
	CFL (single sided)	7W

$Watts_{EE}$ = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W[494]

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.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

ΔkWh = ((14 – 4) /1000) * 8,766 * 1.13

= 99.1 kWh

Heating Penalty

If electrically heated building:[495]

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

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

ΔkWhheatingpenalty = ((14 – 4) /1000) * 8,766 * (-0.43)

= -37.7 kWh

Summer Coincident Peak Demand Savings

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

Where:

[492] Federal Standards effectively ended the manufacturing of incandescent exit signs in 2006 and therefore in unknow instances it should be assumed existing exit signs use CFL lamps since the lifetime of any remaining incandescent exit signs would to have expired per the 13 year measure assigned to this measure.

[493] 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

[494] 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

[494] 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

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

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

CF = Summer Peak Coincidence Factor for this measure

= 1.0[496]

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

ΔkW = ((14 – 4) /1000) * 1.42 * 1.0

= 0.0142 kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated buiding (or if heating is unknown):[497]

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

ΔTherms = ((14 – 4) /1000) * 8,766 * (-0.018)

= -1.5779 therms

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 197[498]

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

ΔPeakTherms = -1.5779/197

= -0.0080 therms

[496] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
[497] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.
[498] Number of days where HDD 55 >0.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

Program Type	Component	Baseline Measure	
		Cost	Life (yrs)
Retrofit/Direct Install	CFL lamp	$13.00[499]	0.57 years[500]

MEASURE CODE: NR-LTG-EXIT-V04-200101

SUNSET DATE: 1/1/2024

[499] Consistent with assumption as listed by the U.S. Department of Energy, ENERGY STARY Life Cycle Cost Exit-Sign Calculator available at https://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs for estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes). Replacement of a CFL bulb is assumed to be $3 as noted by regional IA program details (IPL Business Assessment).

[500] ENERGY STAR "*Save Energy, Money and Prevent Pollution with LED Exit Signs*" specifies that CFL bulbs for Exit Signs typically have an average rated life of 5000-6000 hours. Given 24/7 run time assume Exit Light replacement requirements as 5,500/8760.

3.4.10. LED Street Lighting

This measure characterizes the savings associated with LED street lighting conversions where a Light Emitting Diode (LED) fixture replaces a Metal Halide, High Pressure Sodium or Mercury Vapor outdoor lighting system. LED street lights provide considerable benefits compared to HID lights including:

- Improved nighttime visibility and safety through better color rendering, more uniform light distribution and elimination of dark areas between poles.
- Reduced direct and reflected uplight which are the primary causes of urban sky glow.
- 40-80% energy savings (dependent on incumbent lighting source).
- 50-75% street lighting maintenance savings.[501]

This measure includes LED fixture housings including cobrahead and post-top and is applicable only where utility tariffs support LED street lighting conversions.

This measure was developed to be applicable for a one-to-one Retrofit (RF) opportunity only.[502]

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 characteristics[503] and all local, state, and federal codes.

Definition of Baseline Equipment

The baseline equipment is the existing system – a Metal Halide, High Pressure Sodium or Mercury Vapor outdoor lamp, ballast and fixture.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 20 years.[504]

Deemed Measure Cost [505]

Actual measure installation cost should be used (including material and labor).[506] Use actual costs of LED unit when know. If unknown use the default values/luminaire provided below:

---

[501] 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

[502] 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.

[503] 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

[504] 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

[505] 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).

[506] 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 SAVINGS [507]

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following nominal wattage based on technology.

Metal Halide = 250W[508]

Mercury Vapor = 175W[509]

High Pressure Sodium = 170W[510]

SUMMER COINCIDENT PEAK DEMAND SAVINGS[511]

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

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

[507] There is no ISR calculation. Savings are per unit.

[508] 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)

[509] Based on averaging Mercury Vapor information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (175W)

[510] Based on averaging High Pressure Sodium information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (50, 70, 100, 150250, 400).

[511] On-peak savings for street lighting occur mostly in the winter. Only off-peak demand savings occur during the summer months.

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M costs are estimated at $50/LED luminaire annually.[512]

MEASURE CODE: NR-LTG-STLT-V01-190101

SUNSET DATE: 1/1/2024

[512] Based upon NEEPs report and quantitative analysis of LED street light conversions in the Northeast and Mid-Atlantic region. municipal luminaires evaluated by "LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic", January 2015.

3.4.11. LED Traffic and Pedestrian Signals (Removed 2021)

This measure was archived since the federal code has required LEDs for all traffic and pedestrian modules manufactured since January 2006. No utility is continuing to offering this measure as a retrofit. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 5.0 Volume 3: Nonresidential Measures; Final: July 15, 2020; Effective January 1, 2021 in which the measure was last active.

3.4.12. Lighting Controls

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels by turning lights on or off in response to the presence (or absence) of people in a defined area. Associated energy savings depends on the building type, location area covered, type of lighting and activity, and occupancy pattern.

Daylight sensor lighting controls are devices that reduce lumen output levels in response to the amount of daylight available in an area. Such systems save energy by either shutting off lights completely or dimming when there is adequate natural light available.

This measure relates to the installation of interior occupancy sensors, daylighting or integrated controls on an existing lighting system (not replacement). Lighting control types covered by this measure include switch-mounted, remote-mounted, and fixture-mounted. Daylight sensors covered by this measure include "on or off", stepped dimming systems, such as dual ballast (high/low HID[513] or inboard/outboard), and continuous dimming systems based on light levels from available daylight. 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 lighting controls that regulate a minimum average wattage greater than 45W per control for switch, fixture and remote mounted occupancy sensors, and 20W for integrated sensors. If applicable, it must be accompanied by a daylight harvesting ballast system that meets current CEE specifications at full light output.[514] This measure includes both hard-wired and wireless controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with neither occupancy controls nor daylight control sensor. Also, lighting is operated at normal powers levels and controlled with a manual switch.

Note that in new construction or in areas receiving major rehab (additions, alterations renovations, or repairs), occupancy sensors are required by IECC 2012 (section C405.2.2.2) to be installed in the following locations; classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 ft^2 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 years.[515]

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

---

[513] Uniformed Methods Project: *Methods for Determining Energy Efficiency Savings for Specific Measures*: *Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol*, NREL, April 2013. Such HID fixtures typically have only one lamp that can be operated at two different output levels by a two stage ballast; this differs from stepped dimming systems that dim by controlling lamps powered by a single ballast.

[514] Visit http://library.cee1.org/content/commercial-lighting-qualifying-products-lists

[515] See file "DEER2014-EUL-table-update_2014-02-05.xlsx" or http://www.deeresources.com/

Lighting Control Type	Cost[516]
Switch-Mounted (Wall) Occupancy Sensor	$54
Fixture-Mounted Occupancy Sensor	$67
Remote-Mounted (Ceiling) Occupancy Sensor	$105
Fixture-Mounted Daylight Sensor	$50
Remote-Mounted Daylight Sensor	$65
Integrated Occupancy Sensor	$40
Integrated Dual Occupancy & Daylight Sensor	$50
Fixture-Mounted Dual Occupancy & Daylight Sensor	$100
Remote-Mounted Dual Occupancy & Daylight Sensor	$125

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [517]

$$\Delta kWh = kW_{Controlled} * Hours * ESF * WHFe$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. The total connected load per control should be collected from the customer, or use the default values presented below. Savings is an average per control or fixture.

Lighting Control Type	Default kW controlled[518]
Switch (Wall) Mounted Occupancy Sensor	0.254
Fixture-Mounted Occupancy Sensor	0.264
Remote (Ceiling) Mounted Occupancy Sensor	0.413
Fixture-Mounted Daylight Sensor	0.095
Remote-Mounted Daylight Sensor	0.239
Integrated Occupancy Sensor for LED Interior Fixtures < *10,000 Lumens*	0.031
Integrated Occupancy Sensor for LED Interior Fixtures ≥ *10,000 Lumens*	0.118
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < *10,000 Lumens*	0.031
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ *10,000 Lumens*	0.118
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < *10,000 Lumens*	0.031
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ *10,000 Lumens*	0.118
Remote-Mounted Dual Occupancy & Daylight Sensor	0.239

[516] Based on averaging typical prices quoted by online vendors. See 'Lighting Control Analysis_2020.xlxs'; "Cost" Sheet for more information.

[517] It is assumed an ISR of 100%

[518] Occupancy Sensor controlled kw is based on Alliant Data from program years 2018-2019. Removed 2 outlying data points as well as the Agricultural sector. See 'Lighting Control Analysis_2020.xlxs'; "Wattage_Alliant Data" sheet for details on calculations. For the raw data, please see file 'Alliant Data_Occ Sensors and Daylighting Controls 2018-2019.xlsx'. Integrated Dual and Daylight Sensors controlled kw is based on Efficiency Vermont data from program year 2017 for lighting controls. See 'Lighting Control Analysis_2020.xls'; " Wattage_EVT Data" sheet for details on calculations.

Hours = The total annual operating hours of lighting for each type of building before lighting controls. This number should be collected from the customer. If no data is available, the deemed average number of operating hours, by building type, should be used, as provided by Lighting Reference Table in Section 3.4. If buidling 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 a default energy saving factor of 28% for Daylighting Sensor Control Types and 24% for Occupancy Sensor controls. For Dual Sensors, assume 24% if the additional daylighting savings is not verified, and 38% when daylighting savings is verified.[519]

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.

<u>Heating Penalty:</u>

If electrically heated building:[520]

$$\Delta kWhheatpenalty = kW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table 3.4.

For example, for a Switch (Wall) Mounted Occupancy Sensor:

ΔkWh = 0.254 * 3,065 * 0.24 * 1.06

= 198.1 kWh

For a switch (wall) mounted occupancy sensor installed in a building with electric resistance heating, the electric heating penalty is:

ΔkWhheatingpenalty = 0.254 * 3,065 * 0.24 * (-0.24)

= -44.8 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kW_{Controlled} * WHFd * (CFbaseline - CF_{LC})$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4

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.

CF_{LC} = Summer Peak Coincidence Factor the lighting system with Lighting Controls installed is 0.15 regardless of building type.[521]

[519] *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Lawrence Berkeley National Laboratory, Page & Associates Inc. September 2011. Fig 7. Actual Installation values, pg 16.

[520] Negative value because this is an increase in heating consumption due to the efficient lighting.

[521] RLW Analytics, Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, Table i -13, pg X. Spring 2007. *Please note this study looks at Occupancy Sensors, however daylighting controls coincidence factor will be comparable.*

For example, for a Switch (Wall) Mounted Occupancy Sensor:

ΔkW = 0.254 * 1.28 * (0.6907 – 0.15)

= 0.1758 kW

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.

For example, for a Fixture-Mounted Daylight Sensor installed in a gas heated building:

ΔTherms = 0.095 * 3,065 * 0.28 * (-0.01)

= -0.82 Therms

Peak Gas Savings

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

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

Where:

ΔTherms = Therm impact calculated above

Heatdays = Heat season days per year

= 197[522]

For example, for a Switch (Wall) Mounted Occupancy Sensor installed in a gas heated building:

ΔPeakTherms = -1.87/197

= -0.0095 Therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-LTG-LICO-V01-210101

Sunset Date: 1/1/2023

[522] Number of days where HDD 55 >0.

3.4.13. Daylighting Control

Measure consolidated with 3.4.12 in version 5.0.

3.4.14. Multi-Level Lighting Switch

Description

Multi-level switching allows some of the electric lighting in a space to be switched off while maintaining a reasonably uniform distribution of light suitable for work. Multi-level switching typically use two or more separate light circuits each of which is controlled by a different switch. These circuits can be arranged in one of three ways:

1) Switching alternate lamps in each luminaire
2) Switching alternate luminaires
3) Switching alternate rows of luminaires

Multi-level switching is used in addition to the usual separation of lighting circuits into different functional areas and saves energy by allowing lamps to remain off when sufficient daylight is present, and by offering occupants the ability to have lower light levels for work. Additional energy can be saved by combining multi-level switching with occupancy sensors or photo-sensor controls.

Multi-level switching is required in the Commercial new construction building energy code (IECC 2012).[523] As such this measure can only relate to the installation of new multi-level lighting switches on an existing lighting system.

This measure was developed to be applicable to Retrofit (RF) opportunities only.

Definition of Efficient Equipment

In order for this characterization to apply, the efficient system is assumed to be a lighting system controlled by multi-level lighting controls.

Definition of Baseline Equipment

The baseline equipment is assumed to be an uncontrolled lighting system where all lights in a given area are on the same circuit or all circuits come on at the same time.

Deemed Lifetime of Efficient Equipment

The expected measure life for all lighting controls is assumed to be 10 years.[524]

Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the incremental capital cost for this measure is assumed to be $274.[525]

Loadshape

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

Calculation of Savings

Electric Energy Savings [526]

---

[523] ASHRAE 90.1-2010, IECC 2012 Lutron "Code Compliance, Commercial Application Guide".
[524] GDS Associates, Measure Life Report "Residential and Commercial/Industrial Lighting and HVAC Measures June, 2007
[525] 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.
[526] Assume ISR is 100%.

$$\Delta kWh = KWControlled * Hours * ESF * WHFe$$

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%.[527]

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 3.4.

Heating Penalty

If electrically heated building:[528]

$$\Delta kWhheatpenalty = KWControlled * Hours * ESF * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

For example, for multi-level lighting switches controlling a 0.200 kW connected load:

ΔkWh = 0.200 * 3,065 * 0.31 * 1.06

= 201.4 kWh

For multi-level lighting switches controlling a 0.200 kW connected load and installed in a building with electric resistance heating, the electric heating penalty is:

ΔkWhheatingpenalty = 0.200 * 3,065 * 0.31 * (-0.24)

= -45.6 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = KWcontrolled * ESF * WHFd * CF$$

Where:

[527] 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.

[528] Negative value because this is an increase in heating consumption due to the efficient lighting.

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table 3.4.

CF = Summer Peak Coincidence Factor for the Multi-Level Lighting Switch installed is assumed to be consistent with the lighting loadshapes.[529] See Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

> **For example**, for multi-level lighting switches controlling a 0.200 kW connected load:
>
> ΔkW = 0.200 * 0.31 * 1.28 * 0.6907
>
> = 0.0548 kW

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.

> **For example,** for multi-level lighting switches controlling a 0.200 kW connected load and installed in a gas heated building:
>
> ΔTherms = 0.200 * 3,065 * 0.31 * (-0.01)
>
> = -1.9 therms

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 197[530]

> **For example**, for multi-level lighting switches controlling a 0.200 kW connected load and installed in a gas heated building:
>
> ΔPeakTherms = -1.9/197
>
> = -0.0096 therms

[529] By applying the ESF and the same coincidence factor for general lighting savings we are in essence assuming that the savings from multi-level switching are as likely during peak periods as any other time. In the absence of better information this seems like a reasonable assumption and if anything may be on the conservative side since you might expect the peak periods to be generally sunnier and therefore more likely to have lower light levels. It is also consistent with the control type reducing the wattage lighting load, the same as the general lighting measures.

[530] Number of days where HDD 55 >0.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-MLLS-V03-200101

SUNSET DATE: 1/1/2021*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.5. Miscellaneous

3.5.1. Variable Frequency Drives for Process

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on fans and centrifugal pump motors in process applications. This characterization does not apply to positive displacement pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a motor 1-100 HP that does not have a VFD. The application must have a variable load, and installation is to include the necessary controls as determined by a qualified engineer. Savings are based on application of VFDs to a range of baseline load conditions including no control, inlet guide vanes, and outlet guide vanes.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. The retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.[531]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.[532]

DEEMED MEASURE COST

For retrofits, actual customer-provided costs will be used when available.

For time of sale, actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, default incremental VFD costs are listed below for 1-100 HP motors.[533]

HP	Cost
1-9 HP	$2,177
10-19 HP	$3,123
20-29 HP	$4,280
30-39 HP	$5,023

[531] 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".

[532] "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013."

[533] Incremental costs are sourced from the "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013" and adjusted to account for regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
40-49 HP	$5,766
50-59 HP	$6,591
60-69 HP	$7,550
70-79 HP	$8,173
80-89 HP	$8,796
90-100 HP	$9,576

LOADSHAPE

Custom Loadshape

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * Hours * ESF$$

Where:

HP = Nominal horsepower of controlled motor

= Actual

HOURS = Annual operating hours of motor

= Actual

ESF = Energy Savings Factor[534]

= 0.19 kWh/hp for process fans

= 0.26 kWh/hp for process centrifugal pumps

For example, a 50-horsepower VFD operating for 2386 hours annually driving a process fan would save:

ΔkWh = 50 * 2386 * 0.19

= 22,667 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS[535]

$$\Delta kW = HP * DSF$$

Where:

HP = Nominal horsepower of controlled motor

DSF = Summer Coincident Peak Demand Savings Factor[536]

= 0.16 kW/hp for process fans

[534] Energy savings factors derived from analysis of 16 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'.

[535] Coincident demand savings for variable frequency drives for process pumps and motors are based on claimed coincident peak demand savings from 14 MEC custom projects. If a process in which the installed VFD is known to occur off peak, coincident demand savings will be zero and should be accounted for that appropriately.

[536] Demand savings factors derived from analysis of 14 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'

= 0.26 kW/hp for process centrifugal pumps

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-VFDP-V03-200101

SUNSET DATE: 1/1/2023

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 2018.[537]

Efficiency Level		Top loading	Front Loading
Baseline	Federal Standard	≥1.35 MEF_{J2}, ≤8.8 IWF	≥2.00 MEF_{J2}, ≤4.1 IWF
Efficient	ENERGY STAR	≥2.2 MEF_{J2}, ≤4.0 IWF	

The Modified Energy Factor (MEF_{J2}) includes unit operation, water heating, and drying energy use, with the higher the value the more efficient the unit; *"The quotient of the capacity of the clothes container, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load."*

The Integrated Water Factor (IWF) indicates the total water consumption of the unit, with the lower the value the less water required; *"The quotient of the total weighted per-cycle water consumption for all wash cycles, divided by the capacity of the clothes washer."* [538]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years.[539]

DEEMED MEASURE COST

The incremental cost is assumed to be $190.[540]

LOADSHAPE

Loadshape RE14 - Residential Clothes Washer[541]

Loadshape G01 - Flat (gas)

[537] See Federal Standard 10 CFR 431.156.
[538] Definitions provided on the Energy star website.
[539] Appliance Magazine, January 2011 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.
[540] Based on Industry Data 2015 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.
[541] 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

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

Where:

Capacity = Clothes Washer capacity (cubic feet)

= Actual, if capacity is unknown, assume 3.3 cubic feet [542]

MEFbase = Modified Energy Factor of baseline unit

Efficiency Level	MEFbase		
	Top loading	Front Loading	Weighted Average[543]
Federal Standard	1.35	2.0	1.5

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

= 2190[544]

%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

542 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 04/27/2018).

543 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 04/27/2018) and ENERGY STAR weighting is based on eligible products as of 04/27/2018. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis_v2.xlsx":

Efficiency Level	Front	Top
Baseline	28%	72%
ENERGY STAR	100%	0%

544 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[545]		
	%CW	%DHW	%Dryer
Federal Standard	7.0%	28.1%	64.9%
ENERGY STAR	3.9%	15.5%	80.6%

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

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

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

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

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:[546]

	ΔkWH			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	1,421.9	610.9	1,013.8	202.8

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 hours[547]

CF = Summer Peak Coincidence Factor for measure

= 0.5[548]

545 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).

546 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.

547 Assuming an average load runs for an estimated 45 minutes.

548 In the absence of any commercial specific data, this is estimated at 50%.

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

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.325	0.139	0.231	0.046

NATURAL GAS SAVINGS

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

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

= 1.26[549]

$\%Gas_{Dryer}$ = 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	34.9	13.9	48.8

PEAK GAS SAVINGS

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

[549] 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.

to be:

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

Where:

ΔTherms = 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	ΔPeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.096	0.038	0.134

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where:

IWFbase = Water Factor of baseline clothes washer

Efficiency Level	IWFbase		
	Top loading	Front Loading	Weighted Average[550]
Federal Standard	8.8	4.1	7.5

IWFeff = Water Factor of efficient clothes washer

= Actual - If unknown assume average values provided below

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

Efficiency Level	IWF			ΔWater (gallons per year)
	Top Loaders	Front Loaders	Weighted Average	Weighted Average
Federal Standard	8.8	4.1	7.5	n/a
ENERGY STAR	4.0			21,393

DEEMED O&M COST ADJUSTMENT CALCULATION

[550] 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 04/27/2018) and ENERGY STAR weighting is based on eligible products as of 04/27/2018. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis_v2.xlsx":

Efficiency Level	Front	Top
Baseline	28%	72%
ENERGY STAR	100%	0%

N/A

MEASURE CODE: NR-MSC-CLWA-V02-190101

SUNSET DATE: 1/1/2022*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.5.3. Motors

Description

Electric motor systems consume large amounts of electrical energy and can provide an opportunity for significant energy savings. Energy consumption represents more than 97% of the total motor operating costs over the motors lifetime, and when replacing a working motor or a near-failure motor the energy efficiency of electrical motors can be improved by 20-30% on average, resulting in significant energy and cost savings.[551]

This measure applies to one-for-one replacement of old failed/near failure 1-350 horsepower[552] constant speed and uniformly loaded motors with new energy efficiency motors of the same rated horsepower that exceed NEMA Premium Efficiency levels.

This measure characterizes HVAC fan or pumping motors and was developed to be applicable to the following program types: Time of Sale (TOS)

Definition of Efficient Equipment

The new motor efficiency must meet program standards which exceed NEMA Premium Efficiency as listed and recognized by CEE to meet their criteria for energy efficiency and be compliant with DOE's amended energy conservation standards effective June 1, 2016.

Definition of Baseline Equipment

The baseline is a motor meeting Federal minimum efficiency requirements.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[553]

Deemed Measure Cost

Actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, incremental costs, regardless of motor type are based on nominal horsepower per the following relationship:[554]

For motors up to and equal to 300 horsepower: Cost = $20.12 * (HP rating) + $152.04

For motors larger than 300 horsepower: Cost = $23.82 * (HP rating) - $1,958.88

Loadshape

Loadshape NRE03 – Non-Residential Industrial Motor

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[551] Premium efficiency standards and sound motor management strategies as outlined by the Motor Decisions MatterSM (MDM) lead to reduced energy costs and increase productivity. See reference file "Motor Planning Kit."

552 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 NEMAL Premium specifications. See NEMA MG1-2011 Table 12-12 for more information http://www.nema.org.

[553] Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Measure Life Study, KEMA, August 25, 2009.

[554] Based on the dataset provided in DOCKET NO. E,G002/CIP-20-473 MINNESOTA ELECTRIC AND NATURAL GAS CONSERVATION IMPROVEMENT PROGRAM 2021-2023.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[555]

$$\Delta kWh = (kW_{Base} - kW_{EE}) * \ Hours$$

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}}\right)$$

$$kW_{EE} = \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}}\right)$$

Where:

0.746 = Conversion factor for HP to kWh

HP = Nominal horsepower of controlled motor

= Actual

LF = Load Factor; Motor Load at Fan/Pump Design CFM (Default = 75%)[556]

η_{Bmotor} = Federal baseline nominal/nameplate motor efficiency as shown in tables below for Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC), based on motor design type.

Nominal Full-Load Efficiencies of NEMA Design A, NEMA Design B and IEC Design N Motors (Excluding Fire Pump Electric Motors) at 60 Hz:

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1/.75	77	77	85.5	85.5	82.5	82.5	75.5	75.5
1.5/1.1	84	84	86.5	86.5	87.5	86.5	78.5	77
2/1.5	85.5	85.5	86.5	86.5	88.5	87.5	84	86.5
3/2.2	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5/3.7	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5/5.5	89.5	88.5	91.7	91	91	90.2	86.5	89.5
10/7.5	90.2	89.5	91.7	91.7	91	91.7	89.5	90.2
15/11	91	90.2	92.4	93	91.7	91.7	89.5	90.2
20/15	91	91	93	93	91.7	92.4	90.2	91
25/18.5	91.7	91.7	93.6	93.6	93	93	90.2	91
30/22	91.7	91.7	93.6	94.1	93	93.6	91.7	91.7
40/30	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50/37	93	93	94.5	94.5	94.1	94.1	92.4	92.4
60/45	93.6	93.6	95	95	94.5	94.5	92.4	93
75/55	93.6	93.6	95.4	95	94.5	94.5	93.6	94.1
100/75	94.1	93.6	95.4	95.4	95	95	93.6	94.1

[555] Prevailing energy Savings Methodology for motor measures as highlighted by SEEAction *Scoping Study to Evaluate Feasibility of national Databases for EM&V Documents and Measure Savings*, June 2011.

[556] Basic load measurements should be collected as motors do not run at the same load factor. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is therefore assumed to be 0.75. *Determining Electric Motor Load and Efficiency*, US DOE Motor Challenge, a program of the US Department of Energy, www1.eere.energy.gov/industry/bestpractices/pdfs/10097517.pdf.

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
125/90	95	94.1	95.4	95.4	95	95	94.1	94.1
150/110	95	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200/150	95.4	95	96.2	95.8	95.8	95.4	94.5	94.1
250/186	95.8	95	96.2	95.8	95.8	95.8	95	95
300/224	95.8	95.4	96.2	95.8	95.8	95.8		
350/261	95.8	95.4	96.2	95.8	95.8	95.8		
400/298	95.8	95.8	96.2	95.8				
450/336	95.8	96.2	96.2	96.2				
500/373	95.8	96.2	96.2	96.2				

Nominal Full-Load Efficiencies of NEMA Design C and IEC Design H Motors at 60 Hz:

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1/.75	85.5	85.5	82.5	82.5	75.5	75.5
1.5/1.1	86.5	86.5	87.5	86.5	78.5	77
2/1.5	86.5	86.5	88.5	87.5	84	86.5
3/2.2	89.5	89.5	89.5	88.5	85.5	87.5
5/3.7	89.5	89.5	89.5	89.5	86.5	88.5
7.5/5.5	91.7	91	91	90.2	86.5	89.5
10/7.5	91.7	91.7	91	91.7	89.5	90.2
15/11	92.4	93	91.7	91.7	89.5	90.2
20/15	93	93	91.7	92.4	90.2	91
25/18.5	93.6	93.6	93	93	90.2	91
30/22	93.6	94.1	93	93.6	91.7	91.7
40/30	94.1	94.1	94.1	94.1	91.7	91.7
50/37	94.5	94.5	94.1	94.1	92.4	92.4
60/45	95	95	94.5	94.5	92.4	93
75/55	95.4	95	94.5	94.5	93.6	94.1
100/75	95.4	95.4	95	95	93.6	94.1
125/90	95.4	95.4	95	95	94.1	94.1
150/110	95.8	95.8	95.8	95.4	94.1	94.1
200/150	96.2	95.8	95.8	95.4	94.5	94.1

$\eta_{EEmotor}$ =Efficient motor nominal/nameplate motor efficiency

= Actual

Hours = Hours for HVAC motors are found in table below:[557]

Building Type	Hot Water Pump m Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Convenience*	3628	2690	4630
Education	6367	2796	3544

[557] All values taken from IA VFD Fan and pump measure including building type to ensure consistency across IA TRM. Building types denoted with an asterisk indicate values were referenced from the ComEd TRM June 1, 2010 page 139. As we gather more information on prevalent types of participating motors, VEIC will add additional columns

Building Type	Hot Water Pump m Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Grocery	6499	2725	8743
Health	8720	4770	3478
Hospital	8289	8760	4570
Industrial*	3977	3080	2850
Lodging	5500	7909	3909
Multifamily	5382	5084	8760
Office - Large	5316	4596	2662
Office - Small	1952	2138	7667
Religious*	4763	2223	2412
Restaurant	3027	2719	7300
Retail – Large*	4218	2405	4065
Retail - Small	3029	2266	7410
Warehouse*	4100	1788	2920
Nonresidential (average)	3659	2182	4978

For all non HVAC applications, hour of use are found below:[558]

Unit HP Range	Mean Annual HOU
1-5	2,745
6-20	3,391
21-50	4,067
51-100	5,329
101-200	5,200
201-350	6,132

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

ΔkWh = 0.746 * 5 * (0.8/.895 – 0.8/0.905) * 8760

= 322.7 kWh

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%[559]

All other variables provided above.

[558] United States Industrial Electric Motor Systems Mark Opportunities Assessment (p. 66), December 2012: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

[559] Industrial Motor CF in IA_Electric Loadshapes – Working Draft.xls

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

ΔkW = 0.746 * 5 * (0.8/.895 – 0.8/0.905) * 0.793

= 0.029 kW

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure.[560]

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MCS-MOTR-V04-220101

SUNSET DATE: 1/1/2025

[560] Consider updating measure to include heating and cooling savings in future revisions.

3.5.4. Forklift Battery Charger

Description

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers have a greater system efficiency.

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

Definition of Efficient Equipment

High frequency battery charger systems with minimum Power Conversion Efficiency of 90% and a minimum 8-hour shift operation five days per week.

Definition of Baseline Equipment

SCR or ferroresonant battery charger systems with minimum 8-hour shift operation five days per week.

Deemed Lifetime of Efficient Equipment

15 years[561]

Deemed Measure Cost

The deemed incremental measure cost is $400.[562]

Loadshape

Loadshape NRE13 - Indust. 1-shift (8/5)

Loadshape NRE14 - Indust. 2-shift (16/5)

Loadshape NRE15 - Indust. 3-shift (24/5)

Loadshape NRE16 - Indust. 4-shift (24/7)

Algorithm

Electric Energy Savings

$$\Delta kWh = (CAP * DOD) * CHG * (CR_B / PC_B - CR_{EE} / PC_{EE}) * WHFe$$

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh.[563]

DOD = Depth of Discharge

= Use actual depth of discharge, otherwise use a default value of 80%.[564]

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561 Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 45

562 Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 42

563 Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley, "Economic Comparison of fuel cell powered forklifts to battery powered forklifts", International Journal of Hydrogen Energy Volume 37, Issue 17, (2012): 2.

564 Ryan Matley, "Measuring Energy Efficiency Improvements in Industrial Battery Chargers", (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.

CHG = Number of Charges per year

= Use actual number of annual charges, if unknown use values below based on the type of operations:[565]

Standard Operations	Number of Charges per year
1-shift (8 hrs/day – 5 days/week)	520
2-shift (16 hrs/day – 5 days/week)	1040
3-shift (24 hrs/day – 5 days/week)	1560
4-shift (24 hrs/day – 7 days/week)	2184

CR_B = Baseline Charge Return Factor

= 1.2485[566]

PC_B = Baseline Power Conversion Efficiency

= 0.84[567]

CR_{EE} = Efficient Charge Return Factor

= 1.107[568]

PC_{EE} = Efficient Power Conversion Efficiency

= 0.89[569]

WHFe = Waste heat factor for energy to account for cooling energy savings from reduced waste heat from the battery charger

= 1.09 for cooled warehouse, 1.0 for uncooled warehouse and 1.29 for refrigerated buildings.[570]

Default savings using defaults provided above are provided below:

Standard Operations	ΔkWh		
	Cooled warehouse	Uncooled warehouse	Refrigerated warehouse
1-shift (8 hrs/day – 5 days/week)	3,848.4	3,530.6	4,554.5
2-shift (16 hrs/day – 5 days/week)	7,696.8	7,061.3	9,109.1
3-shift (24 hrs/day – 5 days/week)	11,545.2	10,591.9	13,663.6
4-shift (24 hrs/day – 7 days/week)	16,163.3	14,828.7	19,129.0

Heating Penalty:

565 Number of charges is derived from the following reference and adjusted to the hours and days of the different types of shift operations. These values are based on an estimated 2-charge per 8-hour workday. See reference file: Ryan Matley, "Measuring Energy Efficiency Improvements in Industrial Battery Chargers", (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.

566 Ryan Matley, "Measuring Energy Efficiency Improvements in Industrial Battery Chargers", (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4 (average of SCR and Ferroresonant).

567 Ibid.

568 Ibid.

569 Ibid.

570 WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

If electrically heated building:[571]

$$\Delta kWhheatpenalty = (\text{CAP} * \text{DOD}) * \text{CHG} * (\text{CRB} / \text{PCB} - \text{CREE} / \text{PCEE}) * (-IFkWh)$$

Where:

IFkWh = Heating Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the battery charger

= 0.44 if resistence heat, 0.19 if heat pump, 0 if unheated.[572]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (PF_B/PC_B - PF_{EE}/PC_{EE}) * Volts_{DC} * Amps_{DC} / 1000 * WHFd * CF$

Where:

PF_B = Power factor of baseline charger

= 0.9095[573]

PF_{EE} = Power factor of high frequency charger

= 0.9370[574]

$Volts_{DC}$ = Actual DC rated voltage of charger (assumed baseline charger is replaced with same rated high frequency unit)

= Use actual battery DC voltage rating, otherwise use a default value of 48 volts.[575]

$Amps_{DC}$ = Actual DC rated amperage of charger (assumed baseline charger is replaced with same rated high frequency unit)

= Use actual battery DC ampere rating, otherwise use a default value of 81 amps.[576]

1,000 = watt to kilowatt conversion factor

WHFd = Waste heat factor for demand to account for cooling energy savings from reduced waste heat from the battery charger

= 1.43 for cooled warehouse, 1.0 for uncooled warehouse and 1.29 for refrigerated buildings.[577]

CF = Summer Coincident Peak Factor for this measure

= 0.0 (for 1- and 2-shift operation)[578]

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[571] Results in a negative value because this is an increase in heating consumption due to the less waste heat.

[572] WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

[573] Ibid.

[574] Ibid.

[575] Voltage rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, "Emerging Technologies Program Application Assessment Report #0808", Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

[576] Ampere rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, "Emerging Technologies Program Application Assessment Report #0808", Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

[577] WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

[578] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.

= 1.0 (for 3- and 4-shift operation)[579]

Other variables as provided above.

Default savings using defaults provided above are provided below:

Standard Operations	ΔkW		
	Cooled warehouse	Uncooled warehouse	Refrigerated warehouse
1-shift (8 hrs/day – 5 days/week)	0	0	0
2-shift (16 hrs/day – 5 days/week)	0	0	0
3-shift (24 hrs/day – 5 days/week)	0.1664	0.1165	0.1501
4-shift (24 hrs/day – 7 days/week)	0.1664	0.1165	0.1501

Natural Gas Savings

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):[580]

$$\Delta Therms = (\mathrm{CAP} * \mathrm{DOD}) * \mathrm{CHG} * (\mathrm{CRB} / \mathrm{PCB} - \mathrm{CREE} / \mathrm{PCEE}) * (-IFTherms)$$

Where:

IFTherms = Heating Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the battery charger

= 0.019 if gas heated, 0 if unheated[581]

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

= 197[582]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-MSC-BACH-V01-180101

[579] Ibid.

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

[581] WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

[582] Number of days where HDD 55 >0.

SUNSET DATE: 1/1/2022*

*This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.6. Food Service

3.6.1. Dishwasher

DESCRIPTION

This measure applies to ENERGY STAR high and low temperature under counter, stationary single tank door type, single tank conveyor, and multi tank conveyor dishwashers, as well as to high temperature pot, pan, and utensil dishwashers installed in a commercial kitchen. ENERGY STAR commercial dishwashers use approximately 40% less energy and water than standard models.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR certified dishwasher meeting idle energy rate (kW) and water consumption (gallons/rack) limits, as determined by both machine type and sanitation approach (chemical/low temperature versus high temperature).

ENERGY STAR Requirements (Version 3.0, Effective July 27, 2021)

Dishwasher Type	High Temp Efficiency Requirements			Low Temp Efficiency Requirements		
	Idle Energy Rate	Washing Energy	Water Consumption	Idle Energy Rate	Washing Energy	Water Consumption
Under Counter	≤ 0.30 kW	≤ 0.35 kWh/rack	≤ 0.86 GPR	≤ 0.25 kW	≤ 0.15 kWh/rack	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.55 kW	≤ 0.35 kWh/rack	≤ 0.89 GPR	≤ 0.30 kW	≤ 0.15 kWh/rack	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 0.90 kW	≤ 0.55 + 0.05 * SF_{rack}	≤ 0.58 GPSF	N/A		
Single Tank Conveyor	≤ 1.20 kW	≤ 0.36 kWh/rack	≤ 0.70 GPR	≤ 0.85 kW	≤ 0.16 kWh/rack	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 1.85 kW	≤ 0.36 kWh/rack	≤ 0.54 GPR	≤ 1.00 kW	≤ 0.22 kWh/rack	≤ 0.54 GPR

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new dishwasher that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be:[583]

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

[583] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, 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:[584]

	Dishwasher Type	Incremental Cost
Low Temp	Under Counter	$234
	Stationary Single Tank Door	$662
	Single Tank Conveyor	$0
	Multi Tank Conveyor	$970
High Temp	Under Counter	$2,025
	Stationary Single Tank Door	$995
	Single Tank Conveyor	$2050
	Multi Tank Conveyor	$970
	Pot, Pan, and Utensil	$1710

Loadshape

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

Algorithm

Calculation of Savings

ENERGY STAR dishwashers save energy in three categories: building water heating, booster water heating, and idle energy. Building water heating and booster water heating could be either electric or natural gas.

Electric Energy Savings

Custom calculation below, otherwise use deemed values found within the tables that follow.

$$\Delta kWh^{585} = \Delta BuildingEnergy + \Delta BoosterEnergy^{586} + \Delta IdleEnergy$$

Where:

ΔBuildingEnergy = Change in annual electric energy consumption of building water heater

= [($WaterUse_{Base}$ * RacksWashed * Days) * (ΔT_{in} *1.0 * 8.2 ÷ Eff_{Heater} ÷ 3,412)] - [($WaterUse_{ESTAR}$ * RacksWashed * Days) * (ΔT_{in} *1.0 * 8.2 ÷ Eff_{Heater} ÷ 3,412)]

ΔBoosterEnergy = Annual electric energy consumption of booster water heater

= [($WaterUse_{Base}$ * RacksWashed * Days) * (ΔT_{in} *1.0 * 8.2 ÷ Eff_{Heater} ÷ 3,412)] - [($WaterUse_{ESTAR}$ * RacksWashed * Days) * (ΔT_{in} *1.0 * 8.2 ÷ Eff_{Heater} ÷ 3,412)]

[584] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, which cites reference as "Difference between a similar ENERGY STAR and non-qualifying model EPA research using AutoQuotes, 2016 (for high/low temp undercounter/single door) and 2012 (all other types)".

[585] Algorithms and assumptions except for inlet water temperature increase for building water heaters derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

[586] Booster water heater energy only applies to high-temperature dishwashers.

ΔIdleEnergy = Annual idle electric energy consumption of dishwasher

= [$IdleDraw_{Base}$* (Hours *Days – Days * RacksWashed * WashTime ÷ 60)] – [$IdleDraw_{ESTAR}$* (Hours *Days – Days * RacksWashed * WashTime ÷ 60)]

Where:

$WaterUse_{Base}$ = Water use per rack (gal) of baseline dishwasher

= 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 83.5 °F for building water heaters[587] 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

[587] Inlet water temperature increase for building water heaters based on 140 °F building water heater set point and 56.5 °F inlet water temperature to the DHW system.

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

ΔkWh = ΔBuildingEnergy + ΔBoosterEnergy + ΔIdleEnergy

Where:

ΔBuildingEnergy = [(1.09 * 75 * 365.25) * (83.5 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)] - [(0.86 * 75 * 365.25) * (83.5 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)]

= 1,291.5 kWh

ΔBoosterEnergy = [(1.09 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98÷ 3,412)] - [(0.86 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98÷ 3,412)]

= 618.7 kWh

ΔIdleEnergy = [0.76 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)] – [0.30 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)]

= 2604 kWh

ΔkWh = 1,291.5 + 618.7 + 2,604

= 4,514 kWh

Default values for WaterUse, RacksWashed, kW_{Idle}, and WashTime are presented in the table below.

	RacksWashed	WashTime	WaterUse		IdleDraw	
Low Temperature	**All Dishwashers**	**All Dishwashers**	**Conventional**	**ENERGY STAR**	**Conventional**	**ENERGY STAR**
Under Counter	75	2.0	1.73	1.19	0.50	0.25
Stationary Single Tank Door	280	1.5	2.10	1.18	0.60	0.30
Single Tank Conveyor	400	0.3	1.31	0.79	1.60	0.85
Multi Tank Conveyor	600	0.3	1.04	0.54	2.00	1.00
High Temperature	**All Dishwashers**	**All Dishwashers**	**Conventional**	**ENERGY STAR**	**Conventional**	**ENERGY STAR**
Under Counter	75	2.0	1.09	0.86	0.76	0.30
Stationary Single Tank Door	280	1.0	1.29	0.89	0.87	0.55
Single Tank Conveyor	400	0.3	0.87	0.70	1.93	1.20
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	1.85
Pot, Pan, and Utensil	280	3.0	0.70	0.58	1.20	0.90

Savings for all water heating combinations are presented in the tables below.

<u>Electric building and electric booster water heating</u>

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	12,545.1	8,097.5	4,447.6
	Stationary Single Tank Door	46,434.3	25,942.4	20,491.9
	Single Tank Conveyor	48,582.3	28,626.3	19,956.0
	Multi Tank Conveyor	57,676.4	29,736.7	27,939.8
High Temp	Under Counter	13,355.3	8,840.9	4,514.4
	Stationary Single Tank Door	44,234.7	30,273.9	13,960.8
	Single Tank Conveyor	49,815.1	38,018.9	11,796.2
	Multi Tank Conveyor	79,584.3	46,689.9	32,894.4

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
	Pot, Pan, and Utensil	23,457.5	19,298.4	4,159.0

Electric building and natural gas booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	12,545.1	8,097.5	4,447.6
	Stationary Single Tank Door	46,434.3	25,942.4	20,491.9
	Single Tank Conveyor	48,582.3	28,626.3	19,956.0
	Multi Tank Conveyor	57,676.4	29,736.7	27,939.8
High Temp	Under Counter	10,423.3	6,527.5	3,895.7
	Stationary Single Tank Door	31,280.0	21,336.1	9,943.9
	Single Tank Conveyor	37,333.7	27,976.4	9,357.3
	Multi Tank Conveyor	58,710.4	35,069.3	23,641.0
	Pot, Pan, and Utensil	16,427.7	13,473.8	2,953.9

Natural gas building and electric booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	1,415.3	1,415.3
	Stationary Single Tank Door	2,410.7	1,205.3	1,205.3
	Single Tank Conveyor	9,350.4	4,967.4	4,383.0
	Multi Tank Conveyor	10,957.5	5,478.8	5,478.8
High Temp	Under Counter	7,234.7	4,011.8	3,222.9
	Stationary Single Tank Door	17,191.7	11,616.3	5,575.4
	Single Tank Conveyor	23,760.3	17,055.3	6,705.0
	Multi Tank Conveyor	36,009.9	22,432.0	13,578.0
	Pot, Pan, and Utensil	8,782.9	7,139.5	1,643.4

Natural gas building and natural gas booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	1,415.3	1,415.3
	Stationary Single Tank Door	2,410.7	1,205.3	1,205.3
	Single Tank Conveyor	9,350.4	4,967.4	4,383.0
	Multi Tank Conveyor	10,957.5	5,478.8	5,478.8
High Temp	Under Counter	4,302.6	1,698.4	2,604.2
	Stationary Single Tank Door	4,236.9	2,678.5	1,558.4
	Single Tank Conveyor	11,278.9	7,012.8	4,266.1
	Multi Tank Conveyor	15,136.0	10,811.4	4,324.6
	Pot, Pan, and Utensil	1,753.2	1,314.9	438.3

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh \,/\, (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.638

Other variables as defined above.

> **For example,** an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:
>
> ΔkW = 4514 / (18 * 365.25) *0.638
>
> = 0.4380 kW

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms^{588} = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

ΔBuildingEnergy = Change in annual natural gas consumption of building water heater

= [(WaterUse$_{Base}$ * RacksWashed * Days)*(ΔT$_{in}$ * 1.0 * 8.2 ÷ Eff$_{Heater}$ ÷ 100,000)] - [(WaterUse$_{ESTAR}$* RacksWashed * Days)*(ΔT$_{in}$ * 1.0*8.2 ÷ Eff$_{Heater}$ ÷ 100,000)]

ΔBoosterEnergy = Change in annual natural gas consumption of booster water heater

= [(WaterUse$_{Base}$ * RacksWashed * Days)*(ΔT$_{in}$ * 1.0 * 8.2 ÷ Eff$_{Heater}$ ÷ 100,000)] - [(WaterUse$_{ESTAR}$* RacksWashed * Days)*(ΔT$_{in}$ * 1.0*8.2 ÷ Eff$_{Heater}$ ÷ 100,000)]

Where:

Eff$_{Heater}$ = Efficiency of water heater

= Custom or 78% for gas building[589] and 80% for gas booster water heaters

100,000 = Therms to Btu conversion factor

Other variables as defined above.

> **For example**, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:
>
> ΔTherms = ΔBuildingEnergy + ΔBoosterEnergy
>
> Where:
>
> ΔBuildingEnergy = [(1.09 * 75 * 365.25)*(83.5 * 1.0 * 8.2 ÷ 0.78 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(83.5 * 1.0 * 8.2 ÷ 0.78 ÷ 100,000)]
>
> = 55.4 therms
>
> ΔBoosterEnergy = [(1.09 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)]
>
> = 25.9 therms
>
> ΔTherms = 55.4 + 25.9
>
> = 81.2 therms

[588] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, except for inlet water temperature increase for building water heaters and efficiency of gas building water heater
[589] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

Savings for all water heating combinations are presented in the tables below.

Electric building and natural gas booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	NA	NA	NA
	Stationary Single Tank Door	NA	NA	NA
	Single Tank Conveyor	NA	NA	NA
	Multi Tank Conveyor	NA	NA	NA
High Temp	Under Counter	122.6	96.7	25.9
	Stationary Single Tank Door	541.5	373.6	167.9
	Single Tank Conveyor	521.7	419.7	101.9
	Multi Tank Conveyor	872.5	485.7	386.8
	Pot, Pan, and Utensil	293.8	243.5	50.4

Natural gas building and natural gas booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	416.4	286.5	130.0
	Stationary Single Tank Door	1,887.2	1,060.4	826.8
	Single Tank Conveyor	1,681.8	1,014.2	667.6
	Multi Tank Conveyor	2,002.8	1,039.9	962.9
High Temp	Under Counter	384.9	303.7	81.2
	Stationary Single Tank Door	1,700.8	1,173.4	527.4
	Single Tank Conveyor	1,638.6	1,318.4	320.2
	Multi Tank Conveyor	2,740.4	1,525.6	1,214.8
	Pot, Pan, and Utensil	922.9	764.7	158.2

Natural gas building and electric booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	416.4	286.5	130.0
	Stationary Single Tank Door	1,887.2	1,060.4	826.8
	Single Tank Conveyor	1,681.8	1,014.2	667.6
	Multi Tank Conveyor	2,002.8	1,039.9	962.9
High Temp	Under Counter	262.4	207.0	55.4
	Stationary Single Tank Door	1,159.3	799.8	359.5
	Single Tank Conveyor	1,116.9	898.7	218.3
	Multi Tank Conveyor	1,868.0	1,039.9	828.1
	Pot, Pan, and Utensil	629.1	521.2	107.8

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms \;/\; Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔPeakTherms = 81.2 / 365.25

= 0.2223 therms/day

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 variales as defined above.

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔWater = ($WaterUse_{Base}$ * RacksWashed * Days) - ($WaterUse_{ESTAR}$ * RacksWashed * Days)

ΔWater = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)

= 14,792.6 gallons

Savings for all dishwasher types are presented in the table below.

	Annual Water Consumption (gallons)		
	Baseline	ENERGY STAR	Savings
Low Temperature			
Under Counter	47,391.2	32,598.6	14,792.6
Stationary Single Tank Door	214,767.0	120,678.6	94,088.4
Single Tank Conveyor	191,391.0	115,419.0	75,972.0
Multi Tank Conveyor	227,916.0	118,341.0	109,575.0
High Temperature			
Under Counter	29,859.2	23,558.6	6,300.6
Stationary Single Tank Door	131,928.3	91,020.3	40,908.0
Single Tank Conveyor	127,107.0	102,270.0	24,837.0
Multi Tank Conveyor	212,575.5	118,341.0	94,234.5
Pot, Pan, and Utensil	71,589.0	59,316.6	12,272.4

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-DISH-V03-220101

SUNSET DATE: 1/1/2024

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 4.0, Effective January 1, 2017)

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.022V+0.97	≤ 0.21V+0.90
15 ≤ V < 30	≤ 0.066V+0.31	≤ 0.12V+2.248
30 ≤ V < 50	≤ 0.04V+1.09	≤ 0.285V-2.703
V ≥ 50	≤ 0.024V+1.89	≤ 0.142V+4.445
Glass Door		
0 < V < 15	≤ 0.095V+0.445	≤ 0.232V+2.36
15 ≤ V < 30	≤ 0.05V+1.12	
30 ≤ V < 50	≤ 0.076V+0.34	
V ≥ 50	≤ 0.105V-1.111	
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.05V+0.28	≤ 0.057V+0.55

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.[590]

Deemed Measure Cost

[590]Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, which cites reference as "FSTC research on available models, 2009"
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

The incremental capital per cubic foot cost for this measure can be found below.[591]

Description and Volume (cu. ft.)	Refrigerator	Freezer
	Incremental Unit Cost per Foot	
Solid Door		
0 ≤ V < 15	$24.21	$30.41
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
Glass Door		
0 ≤ V < 15	$24.77	$33.01
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
Chest		
Solid/Glass	$57.11	$75.90

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.[592]

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

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}[593]
Solid Door Refrigerator	0.05V+1.36
Glass Door Refrigerator	0.1V+0.86
Solid Door Freezer	0.22V+1.38
Glass Door Freezer	0.29V+2.95
Solid Door Chest Refrigerator	0.05V+0.91
Glass Door Chest Refrigerator	0.06V+0.37

[591] Northwest Regional Technical Forum, ENERY STAR Version 4.0 Analysis. Refer to CostData&Analysis tab in ComRefrigeratorFreezer_v4_2.xlsm.
[592] Algorithms and assumptions from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016
[593] United States Department of Energy, 10 CFR Part 431, "Energy Conservation Standards for Commercial Refrigeration Equipment", March, 2017.

Equipment Type	kWh_{Base}[593]
Solid Door Chest Freezer	0.06V + 1.12
Glass Door Chest Freezer	0.08V+1.23

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR refrigerator or freezer

= Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V):[594]

Volume (ft3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.022V+0.97	≤ 0.21V+0.90
15 ≤ V < 30	≤ 0.066V+0.31	≤ 0.12V+2.248
30 ≤ V < 50	≤ 0.04V+1.09	≤ 0.285V-2.703
V ≥ 50	≤ 0.024V+1.89	≤ 0.142V+4.445
Glass Door		
0 < V < 15	≤ 0.095V+0.445	≤ 0.232V+2.36
15 ≤ V < 30	≤ 0.05V+1.12	
30 ≤ V < 50	≤ 0.076V+0.34	
V ≥ 50	≤ 0.105V-1.111	
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.05V+0.28	≤ 0.057V+0.55

V = Refrigerated volume (ft^3) 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

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft^3 would save:

ΔkWh = (kWh_{Base} – kWh_{ESTAR}) * Days

ΔkWh = [(0.05 * 35 + 1.36) – (0.04 * 35 + 1.09)] * 365.25

= 226.5kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh/HOURS) * CF$$

[594] ENERGY STAR, "ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers", v4.0, Effective January 1, 2017.

Where:

ΔkWh = Electric energy savings, calculated above

HOURS = Hours of refrigerator or freezer operation per year
= 8766[595]

CF = Summer peak coincidence factor
= 0.964

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft^3 would save:

ΔkW = (226.5/8766) * 0.964
= 0.0249kW

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-FSE-CSGD-V01-190101

Sunset Date: 1/1/2024

[595] Equipment is assumed to operate continuously, 24 hour per day, 365.25 days per year

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 that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment flow rate depends on program type. For TOS, the baseline equipment is a new pre-rinse spray valve with a maximum flow rate of 1.23 gpm or less.[596] For DI, the baseline equipment is an existing pre-rinse spray valve with a flow rate of 1.6 gpm or less.[597]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years.[598]

DEEMED MEASURE COST

For TOS programs, the incremental cost of this measure is assumed to be $0.[599] For DI programs, the total installed cost is assumed to be $54.[600]

LOADSHAPE

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

[596] Baseline for TOS programs is calculated using the maximum flow rate for each product class in 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment weighted by estimated 2018 shipments for each product class from Table 3.6.1: U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015.

[597] Code of Federal Regulations, Energy Conservation Standards 10 CFR § 431.266 (a) From January 1, 2006 through January 28, 2019 the code set the maximum flow rate of 1.6 gallons per minute.

[598] Measure life from U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015, page 8-13.

[599] Incremental measure cost based on U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015, page 8-1.

[600] Total installed cost is the manufacturer selling price ($35.40) from Table 8.2.1 multiplied by the retailer markup (1.52) from Table 8.2.2: U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015. It is assumed that programs typically install spray valves only when other kitchen equipment is also being installed, and therefore, there are no additional labor costs associated with spray valve installations.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Custom calculation below, otherwise use deemed value of 1,215.6 kWh for TOS and 3,014.8 kWh for DI.[601]

$$\Delta kWh = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 3{,}412 * \Delta WaterUse$$

Where:

HotPercentage = Percentage of hot water used for rinse

= Custom or If unknown, use 100%

T_{out} = Unmixed Outlet Water Temperature from the DHW system

= Actual, otherwise assume 140.[602]

T_{in} = Inlet Water Temperature to the DHW system

= Actual, otherwise assume 56.5.[603]

1.0 = Specific heat of water (Btu/lb/°F)

8.33 = Specific weight capacity of water (lb/gal)

Eff_{Heater} = Efficiency of water heater

= Custom or if unknown, use 98% for electric water heaters

3,412 = kWh to Btu conversion factor

∆WaterUse = Change in annual water consumption

= Custom calculation in Water Impact Descriptions and Calculation section of this measure, otherwise use 5,844.0 gal/yr for TOS and 14,493.1 gal/yr for DI

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above, would save:

ΔkWh = 1.00 * (140 – 56.5) * 1.0 * 8.33 / 0.98 / 3,412 * 5,844.0

= 1,215.6 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / ((Minutes/60) * Days) * CF$$

[601] Algorithms and assumptions except for water temperature values flow rates, and specific weight of water derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[602] 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.

[603] 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.

Where:

ΔkWh = Electric energy savings, calculated above

Minutes = Average daily minutes of spray valve operation

= Custom or if unknown, use 64 minutes per day.[604]

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 restaurant.[605]

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:

ΔkW = 1,215.6 / ((64/60) * 365.25) * 0.0250

= 0.07800 kW

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 52.1 therms/yr for TOS and 129.2 therms/yr for DI.[606]

$$\Delta Therms = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 100{,}000 * \Delta WaterUse$$

Where:

Eff_{Heater} = Efficiency of water heater

= Custom or if unknown, use 78%[607] for gas water heaters

100,000 = Btu to therms conversion factor

Other variables as defined above.

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

ΔTherms = 1.00 * (140 – 56.5) * 1.0 * 8.2 / 0.78 / 100,000 * 5,844.0

= 52.1 therms/yr

[604] ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

[605] 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.

[606] Algorithms and assumptions derived except for water temperature values, flow rates, specific weight of water, and gas water heater efficiency from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx

[607] 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%.

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms \ / \ Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

> **For example**, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:
>
> ΔPeakTherms = 52.1 / 365.25
>
> = 0.1437 therms/day

Water Impact Descriptions and Calculation

Custom calculation below, otherwise use deemed value of 5,844.0 gal/yr for TOS and 14,493.1 gal/yr for DI.[608]

$$\Delta WaterUse = (Flow_{Base} - Flow_{EE}) * Minutes * Days$$

Where:

$Flow_{Base}$ = Flow rate (gal/min) of baseline pre-rinse spray valve

= Custom or if unknown, use 1.23 gpm for TOS[609] and 1.6 gpm for DI[610]

$Flow_{EE}$ = Flow rate (gal/min) of efficient pre-rinse spray valve

= Custom or if unknown, use 0.98 gal/min[611]

Other variables as defined above.

> **For example**, an efficient pre-rinse spray valve, installed under the TOS program type, with defaults from the calculation above would save:
>
> ΔWaterUse = (1.23 – 0.98) * 64 * 365.25
>
> = 5,844.0 gal/yr

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-FSE-SPRY-V04-220101

Sunset Date: 1/1/2024

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608 Algorithms and assumptions, except for flow rates, derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx.

609 Baseline for TOS programs is calculated using the maximum flow rate for each product class in 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment weighted by estimated 2018 shipments for each product class from Table 3.6.1: U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015.

610 Code of Federal Regulations, Energy Conservation Standards 10 CFR § 431.266 (a) From January 1, 2006 through January 28, 2019 the code set the maximum flow rate of 1.6 gallons per minute.

611 A new pre-rinse spray valve is assumed to be 20% more efficient than the federal standard.

3.6.4. Infrared Upright Broiler

Description

This measure applies to new natural gas fired high efficiency upright broilers utilizing infrared burners and installed in a commercial kitchen. Upright broilers are heavy-duty, freestanding overfired broilers. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new natural gas upright broiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

Definition of Baseline Equipment

The baseline equipment is a new natural gas upright broiler without infrared burners.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[612]

Deemed Measure Cost

The incremental capital cost for this measure is $5,900.[613]

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:

$InputRate_{Base}$ = Rated energy input rate of baseline upright broiler (Btu/hr)

[612] Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

[613] Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

	= 95,000 Btu/hr[614]
$InputRate_{EE}$	= Rated energy input rate of infrared upright broiler (Btu/hr)
	= Custom or if unknown, use 82,333 Btu/hr[615]
Duty	= Duty cycle of upright broiler (%)
	= Custom or if unknown, use 70%[616]
Hours	= Typical operating hours of upright broiler
	= Custom or if unknown, use 2,496 hours[617]
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared upright broiler with default values from the algorithm above would save:

ΔTherms = [(95,000 – 82,333) *(0.70 * 2,496) / 100,000] / (82,333 / 1,000)

= 2.7 therms/ MBtu/hr input

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation
	= Custom or if unknown, use 312 days per year[618]

For example, an infrared upright broiler with default values from the calculation above would save:

ΔPeakTherms = 2.7 / 312

= 0.0087 therms/MBtu/hr input/day

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRUB-V01-170101

[614] Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

[615] 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%

[616] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

[617] 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

[618] Based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

SUNSET DATE: 1/1/2022*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.6.5. Infrared Salamander Broiler

Description

This measure applies to new natural gas fired high efficiency salamander broilers utilizing infrared burners installed in a commercial kitchen. Salamander broilers are medium-input overfired broilers that are typically mounted on the backshelf of a range. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new natural gas fired salamander broiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

Definition of Baseline Equipment

The baseline equipment is a new natural gas fired salamander broiler without infrared burners.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[619]

Deemed Measure Cost

The incremental capital cost for this measure is $1,000.[620]

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.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)/100{,}000}{InputRate_{EE}/1{,}000}$$

Where:

[619]Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

[620]Incremental 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 salamander broiler (Btu/hr)

= 38,500 Btu/hr[621]

$InputRate_{EE}$ = Rated energy input rate of infrared salamander broiler (Btu/hr)

= Custom or if unknown, use 24,750 Btu/hr[622]

Duty = Duty cycle of salamander broiler (%)

= Custom or if unknown, use 70%[623]

Hours = Typical operating hours of salamander broiler

= Custom or if unknown, use 2,496 hours[624]

100,000 = Btu to therms conversion factor

1,000 = Btu to Mbtu conversion factor

For example, an infrared salamander broiler with default values from the algorithm above would save:

ΔTherms = [(38,500 – 24,750) *(0.70 * 2,496) / 100,000] / (24,750 / 1,000)

= 9.7 therms/ MBtu/hr input

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms/Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[625]

For example, an infrared salamander broiler with default values from the calculation above would save:

ΔPeakTherms = 9.7 / 312

= 0.0311 therms/MBtu/hr input/day

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

[621] Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

[622] 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%

[623] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

[624] 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

[625] 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

N/A

MEASURE CODE: NR-FSE-IRBL-V01-170101

SUNSET DATE: 1/1/2022*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.6.6. 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.[626]

Deemed Measure Cost

The incremental capital cost for this measure is $2,200.[627]

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.[628]

$$\Delta Therms = [(\Delta PreheatEnergy + \Delta CookingEnergy) * Days/100{,}000]/(\frac{InputRate_{EE}}{1{,}000})$$

Where:

ΔPreheatEnergy = ($PreheatRate_{Base}$ * Preheats * PreheatTime / 60) - ($PreheatRate_{EE}$ * Preheats *

[626]Measure life from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-broilers/#calc

[627]Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562

[628] 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

PreheatTime / 60)

ΔCookingEnergy = ($InputRate_{Base}$ - $InputRate_{EE}$) * Hours

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[629]

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 preheat[630]

60 = Minutes to hours conversion factor

$InputRate_{Base}$ = Input energy rate of baseline charbroiler

= 128,000 Btu/hr

$InputRate_{EE}$ = Input energy rate of infrared charbroiler

= Custom or if unknown, use 96,000 Btu/hr

Hours = Average daily hours of operation

= Custom or if unknown, use 8 hours per day

For example, an infrared charbroiler with default values from the calculation above would save:

ΔTherms = [(ΔPreheatEnergy + ΔCookingEnergy) * Days /100,000] / ($InputRate_{EE}$/1,000)

Where:

ΔPreheatEnergy = (64,000 * 1 * 15 / 60) - (54,000 * 1 * 15 / 60)

= 2,500 Btu/day

ΔCookingEnergy = (128,000 – 96,000) * 8

= 256,000 Btu/day

ΔTherms = [(2,500 + 256,000) * 312 / 100,000] / (96,000/1,000)

= 8.4 therms/ MBtu/hr input

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

[629]Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3

[630]Typical preheat time from FSTC Broiler Technology Assessment

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an infrared charbroiler with default values from the calculation above would save:

ΔPeakTherms = 8.4 / 312

= 0.0269 therms/MBtu/hr input/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-FSE-IRCB-V01-170101

Sunset Date: 1/1/2022*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.6.7. Convection Oven

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR convection ovens installed in a commercial kitchen. Convection ovens are general purpose ovens that use fans to circulate hot, dry air over the food surface. ENERGY STAR certified convection ovens are approximately 20% more efficient than standard ovens.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified convection oven meeting idle energy rate (kW or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and oven capacity (full size versus half size).

ENERGY STAR Requirements (Version 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.[631]

DEEMED MEASURE COST

The incremental capital cost for this measure is $400.[632]

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 convection oven below, otherwise use deemed value of 1,938.5 kWh for full-size ovens and 192.1 kWh for half-size ovens.[633]

[631] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, which cites reference as "FSTC research on available models, 2009" https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

[632] Measure cost from 2014-2023 Iowa Statewide Assessment of Energy Efficiency Potential

[633] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy	= ($IdleRate_{Base}$* (Hours - FoodCooked/$Production_{Base}$)) - ($IdleRate_{ESTAR}$ * (Hours - FoodCooked/$Production_{ESTAR}$))
ΔCookingEnergy	= (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

For example, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:

ΔkWh = (ΔIdleEnergy + ΔCookingEnergy) * Days /1,000

Where:

ΔIdleEnergy	= (2,000 * (12 – 100 / 90)) - (1,600 * (12 – 100 / 90))
	= 4,356 Wh
ΔCookingEnergy	= (100 * 73.2/ 0.65) - (100 * 73.2/ 0.71)
	= 952 Wh
ΔkWh	= (4,356 + 952) * 365.25 / 1,000
	= 1,938.5 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh \,/\, (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.787

Other variables as defined above.

> **For example**, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:
>
> ΔkW = 1,938.5 / (12 * 365.25) * 0.787
>
> = 0.3481 kW

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 129.4 therms/yr.[634]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = ($IdleRate_{Base}$* (Hours - FoodCooked/$Production_{Base}$)) - ($IdleRate_{ESTAR}$ * (Hours - FoodCooked/$Production_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

100,000 = Btu to therms conversion factor

FoodCooked = Food cooked per day

= Custom or if unknown, use 100 pounds

$Production_{Base}$ = Production capacity of baseline gas convection oven

= 83 lb/hr

$Production_{ESTAR}$ = 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

[634] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

= 44%

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR gas convection oven

= Custom or if unknown, use 46%

Other variables as defined above.

For example, an ENERGY STAR gas convection oven with default values from the algorithm above would save:

ΔTherms = (ΔIdleEnergy + ΔCookingEnergy) * Days /100,000

Where:

ΔIdleEnergy = (15,100 * (12 - 100 / 83)) - (12,000 * (12 - 100 / 86))

= 32,960 Btu/day

ΔCookingEnergy = (100 * 250/ 0.44) - (100 * 250/ 0.46)

=2,470 Btu/day

ΔTherms = (32,960 + 2,470) * 365.25 / 100,000

= 129.4 therms/yr

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR gas convection with default values from the algorithm above would save:

ΔPeakTherms = 129.4 / 365.25

= 0.3543 therms/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-FSE-ESCV-V01-170101

Sunset Date: 1/1/2024

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.[635]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1800.[636]

LOADSHAPE

Loadshape NRGC01 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[635] Measure life from Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc . This calculator is supported by the Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014.

[636] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 633.9 therms/yr.[637]

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔPreheatEnergy = ($PreheatEnergy_{Base}$ * Preheats) - ($PreheatEnergy_{EE}$ * Preheats)

ΔIdleEnergy = $IdleRate_{Base}$* (Hours – (FoodCooked/$Production_{Base}$) – (Preheats * PreheatTime / 60)) - $IdleRate_{EE}$ * (Hours – (FoodCooked/$Production_{EE}$) – (Preheats * PreheatTime / 60))

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ Eff_{EE})

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[638]

100,000 = Btu to therms conversion factor

$PreheatEnergy_{Base}$ = Preheat energy of baseline oven

= 35,000 Btu

$PreheatEnergy_{EE}$ = Preheat energy of efficient oven

= Custom or if unknown, use 18,000 Btu

Preheats = Number of preheats per day

= Custom or if unknown, use 1 preheat per day

PreheatTime = Length of one preheat

= Custom or if unknown, use 15 minutes per preheat

60 = Minutes to hours conversion factor

$IdleRate_{Base}$ = Idle energy rate of baseline oven

= 70,000 Btu/hr

$IdleRate_{EE}$ = Idle energy rate of efficient oven

= Custom or if unknown, use 57,000 Btu/hr

Hours = Average daily hours of operation

= Custom or if unknown, use 10 hours per day[639]

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

---

[637] Unless otherwise noted, the assumptions are derived from the Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator, supported by the Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014, pg. 6.

[638] Assumptions are derived from the FSTC Oven Technology Assessment.

[639] Ibid.

$Production_{EE}$ = Production capacity of efficient oven

= Custom or if unknown, use 220 pizzas per hour

EFOOD = ASTM energy to food

= 190 Btu/pizza

Eff_{Base} = Cooking efficiency of baseline oven

= 20%

Eff_{EE} = Cooking efficiency of efficient oven

= Custom or if unknown, use 42%

For example, an efficient conveyor oven with default values from the algorithm above would save:

ΔTherms = (ΔPreheatEnergy + ΔIdleEnergy + ΔCookingEnergy) * Days /100,000

Where:

ΔPreheatEnergy = (35,000 * 1) - (18,000 * 1)

= 17,000 Btu/day

ΔIdleEnergy = 70,000* (10 - (250 / 150) - (1 * 15 / 60)) - 57,000 * (10 - (250 / 220) - (1 * 15 / 60))

= 74,856 Btu/day

ΔCookingEnergy = (250 * 190/ 0.20) - (250 * 190/ 0.42)

= 124,405 Btu/day

ΔTherms = (17,000 + 74,856 +124,405) * 312 / 100,000

= 674.7 therms/yr

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms \ / \ Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Days = Annual days of operation

= Custom or if unknown, use 312 days per year

For example, an efficient conveyor oven with default values from the algorithm above would save:

ΔPeakTherms = 674.7 / 312

= 2.163 therms/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-FSE-CVOV-V05-220101

SUNSET DATE: 1/1/2025

3.6.9. Infrared Rotisserie Oven

Description

This measure applies to new natural gas fired high efficiency rotisserie ovens utilizing infrared burners and installed in a commercial kitchen. Rotisserie ovens are designed for batch cooking, with individual spits arranged on a rotating wheel or drum within an enclosed cooking cavity. Infrared ovens move heat faster and carry a higher heat intensity than non-infrared ovens.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new natural gas rotisserie oven with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

Definition of Baseline Equipment

The baseline equipment is a new natural gas rotisserie oven without infrared burners.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[640]

Deemed Measure Cost

The incremental capital cost for this measure is $2,700.[641]

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.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)/100{,}000}{InputRate_{EE}/1{,}000}$$

Where:

[640] Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

[641] Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

$InputRate_{Base}$ = Energy input rate of baseline rotisserie oven (Btu/hr)

= 50,000 Btu/hr[642]

$InputRate_{EE}$ = Energy input rate of infrared rotisserie oven (Btu/hr)

= Custom of if unknown, use 40,323 Btu/hr[643]

Duty = Duty cycle of rotisserie oven (%)

= Custom or if unknown, use 60%[644]

Hours = Typical operating hours of rotisserie oven

= Custom or if unknown, use 2,496 hours[645]

100,000 = Btu to therms conversion factor

1,000 = Btu to Mbtu conversion factor

For example, an infrared rotisserie oven with default values from the algorithm above would save:

ΔTherms = [(50,000 – 40,323) *(0.60 * 2,496) / 100,000] / (40,323 / 1,000)

= 3.6 therms/ MBtu/hr input

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms/Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[646]

For example, an infrared rotisserie oven with default values from the calculation above would save:

ΔPeakTherms = 3.6 / 312

= 0.0115 therms/MBtu/hr input/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

[642] Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7-2 .
[643] 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%
[644] Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7-2.
[645] 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.
[646] Based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7-2.

N/A

MEASURE CODE: NR-FSE-IROV-V02-220101

SUNSET DATE: 1/1/2025

3.6.10. Commercial Steam Cooker

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR steam cookers installed in a commercial kitchen. Commercial steam cookers contain compartments where steam energy is transferred to food by direct contact. ENERGY STAR certified steam cookers have shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficiency steam delivery.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified steam cooker meeting idle energy rate (kW or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and pan capacity.

ENERGY STAR Requirements (Version 1.2, Effective August 1, 2003)

<table>
<tr><th rowspan="2">Pan Capacity</th><th colspan="2">Electric Efficiency Requirements</th><th colspan="2">Natural Gas Efficiency Requirements</th></tr>
<tr><th>Idle Energy Rate</th><th>Cooking Efficiency</th><th>Idle Energy Rate</th><th>Cooking Efficiency</th></tr>
<tr><td>3-pan</td><td>≤ 400 W</td><td rowspan="4">≥ 50%</td><td>≤ 6,250 Btu/hr</td><td rowspan="4">≥ 38%
N/A</td></tr>
<tr><td>4-pan</td><td>≤ 530 W</td><td>≤ 8,350 Btu/hr</td></tr>
<tr><td>5-pan</td><td>≤ 670 W</td><td>≤ 10,400 Btu/hr</td></tr>
<tr><td>6-pan and larger</td><td>≤ 800 W</td><td>≤ 12,500 Btu/hr</td></tr>
</table>

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.[647]

DEEMED MEASURE COST

The incremental capital cost for this measure is $3,400 for electric steam cookers and $2,270 for gas steam cookers.[648]

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGC01 - Nonresidential Gas Cooking – Restaurant

[647] Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016 http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[648] Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. Calculator cites EPA research using AutoQuotes, July 2016.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below, otherwise use deemed value from the table that follows.[649]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy = [((1 – SteamMode) *$IdleRate_{Base}$ + SteamMode * $Production_{Base}$ * Pans *EFOOD/Eff_{Base})* (Hours – FoodCooked/($Production_{Base}$ * Pans))] - [((1 – SteamMode) *$IdleRate_{ESTAR}$ + SteamMode * $Production_{ESTAR}$ * Pans *EFOOD/Eff_{ESTAR})* (Hours – FoodCooked/($Production_{ESTAR}$ * Pans))]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ 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 capacity[650]

$IdleRate_{ESTAR}$ = 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

[649] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

[650] 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 cooker[651]

= 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

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

ΔkWh = (ΔIdleEnergy + ΔCookingEnergy) * Days / 1,000

Where:

ΔIdleEnergy = [((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 Wh

ΔCookingEnergy = (100 * 30.8/ 0.28) - (100 * 30.8/ 0.50)

= 4,840 Wh

ΔkWh = (44,418 + 4,840) * 365.25 /1,000

= 17,991.6 kWh

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:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.787

651 Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

Other variables as defined above

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

ΔkW = 17,991.6 / (12 * 365.25) * 0.787

= 3.2305 kW

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas steam cooker below, otherwise use deemed value from the table that follows.[652]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = [((1 – SteamMode) *$IdleRate_{Base}$ + SteamMode * $Production_{Base}$ * Pans *EFOOD/Eff_{Base})* (Hours – FoodCooked/($Production_{Base}$ * Pans))] - [((1 – SteamMode) *$IdleRate_{ESTAR}$ + SteamMode * $Production_{ESTAR}$ * Pans *EFOOD/Eff_{ESTAR})* (Hours – FoodCooked/($Production_{ESTAR}$ * Pans))]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ 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 capacity[653]

$IdleRate_{ESTAR}$ = 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

EFOOD = ASTM energy to food

[652] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

[653] Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR for steam generator and boiler-based cookers

= 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker[654]

= 16.5%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR gas steam cooker

= Custom or if unknown, use 38%

Other variables as defined above.

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

ΔTherms = (ΔIdleEnergy + ΔCookingEnergy) * Days / 100,000

Where:

ΔIdleEnergy = [((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 Btu

ΔCookingEnergy = (100 * 105/ 0.17) - (100 * 105/ 0.38)

= 36,005 Btu

ΔTherms = (281,434 + 36,005) * 365.25 /100,000

= 1,159.4 therms

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

$$\Delta PeakTherms = \Delta Therms/Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

ΔPeakTherms = 1,159.4 / 365.25

= 3.1743 therms/day

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 134,412.0 gallons per year.[655] Savings are the same for

[654] Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

[655] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

electric and gas steam cookers.

$$\Delta Water = (\Delta WaterUse_{Base} - \Delta WaterUse_{ESTAR}) * Hours * Days$$

Where:

$WaterUse_{Base}$ = Water use (gal/hr) of baseline steam cooker

= 40 gal/hr

$WaterUse_{ESTAR}$ = Water use (gal/hr) of ENERGY STAR steam cooker[656]

= Custom or if unknown, use 9.3 gal/hr

Other variables as defined above

For example, a steam cooker with defaults from the calculation above would save

ΔWaterUse = (40 – 9.3) * 12 * 365.25

= 134,412.0 gal/year

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-STMC-V03-220101

SUNSET DATE: 1/1/2025

[656] 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 3.0, Effective October 1, 2016)

Fryer Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
Standard Open Deep-Fat Fryer	≤ 800 W	≥ 83%	≤ 9,000 Btu/hr	≥ 50%
Large Vat Open Deep-Fat Fryer	≤ 1,100 W	≥ 80%	≤ 12,000 Btu/hr	

Definition of Baseline Equipment

The baseline equipment is a new electric or natural gas fryer that is not ENERGY STAR certified.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[657]

Deemed Measure Cost

The incremental capital cost for this measure is $276 for standard electric, $1,150 for large vat electric, $1,860 for standard gas, and $1,850 for large vat gas fryers.[658]

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 fryer below, otherwise use deemed value of 3,128.2 kWh for standard fryers and

[657] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016 ,which cites reference as "FSTC research on available models, 2009" https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

[658] Measure costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, which cites reference as "EPA research on available models using AutoQuotes, July 2016".

2,537.9 kWh for large vat fryers.[659]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy = ($IdleRate_{Base}$* (Hours – FoodCooked/$Production_{Base}$))- ($IdleRate_{ESTAR}$ * (Hours – FoodCooked/$Production_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

Hours = Average daily hours of operation

= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

FoodCooked = Food cooked per day

= Custom or if unknown, use 150 pounds

$Production_{Base}$ = Production capacity of baseline electric fryer

= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$Production_{ESTAR}$ = Production capacity of ENERGY STAR electric fryer

= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers

$IdleRate_{Base}$ = Idle energy rate of baseline electric fryer

= 1,200 W for standard fryers and 1,350 W for large vat fryers

$IdleRate_{ESTAR}$ = Idle energy rate of ENERGY STAR electric fryer

= Custom or if unknown, use 800 W for standard fryers and 1,100 for large vat fryers

EFOOD = ASTM energy to food

= 167 Wh/lb

Eff_{Base} = Cooking efficiency of baseline electric fryer

= 75% for standard fryers and 70% for large vat fryers

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric fryer

= Custom or if unknown, use 83% for standard fryers and 80% for large vat fryers

[659] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

> **For example**, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:
>
> ΔkWh = (ΔIdleEnergy + ΔCookingEnergy) * Days /1,000
>
> Where:
>
> ΔIdleEnergy = (1200 * (16 – 150 / 65)) - (800 * (16 – 150 / 70))
> = 5,345 Wh
>
> ΔCookingEnergy = (150 * 167/ 0.75) - (150 * 167/ 0.83)
> = 3,219 Wh
>
> ΔkWh = (5,345 + 3,219) * 365.25 / 1,000
> = 3,128.2 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.787

Other variables as defined above.

> **For example**, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:
>
> ΔkW = 3,128.2 / (16 * 365.25) * 0.787
> = 0.4213 kW

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.[660]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = ($IdleRate_{Base}$* (Hours – FoodCooked/$Production_{Base}$))- ($IdleRate_{ESTAR}$ * (Hours – FoodCooked/$Production_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

100,000 = Btu to therms conversion factor

$Production_{Base}$ = Production capacity of baseline gas fryer

= 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$Production_{ESTAR}$ = Production capacity of ENERGY STAR gas fryer

[660] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

= 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.

For example, an ENERGY STAR standard-sized gas fryer, using default values from above, would save:

ΔTherms = (ΔIdleEnergy + ΔCookingEnergy) * Days /100,000

Where:

ΔIdleEnergy = (14,000 * (16 – 150 / 60)) - (9,000 * (16 – 150 / 65))

= 65,769 Btu/day

ΔCookingEnergy = (150 * 570/ 0.35) - (150 * 570/ 0.50)

=73,286 Btu/day

ΔTherms = (65,769 + 73,286) * 365 / 100,000

= 507.9 therms/yr

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms \ / \ Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR standard-sized gas fryer, using default values from above, would save:

ΔPeakTherms = 507.9 / 365.25

= 1.3906 therms/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

MEASURE CODE: NR-FSE-ESFR-V03-220101

SUNSET DATE: 1/1/2025

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
≤ 320 W/ft^2 ≤ 1.00 kW	Reported	≤ 2,650 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.[661]

Deemed Measure Cost

The incremental capital cost for this measure is $0 for an electric griddle and $360 for a gas griddle.[662]

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.[663]

[661] Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016, which cites reference as "FSTC research on available models, 2009" http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[662] 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

[663] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy = [(IdleRate$_{Base}$* Width * Length) * (Hours – FoodCooked/Production$_{Base}$)] – [(IdleRate$_{ESTAR}$ * Width * Length) * (Hours – FoodCooked/Production$_{ESTAR}$))

ΔCookingEnergy = (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/ft^2

IdleRate$_{ESTAR}$ = Idle energy rate of ENERGY STAR electric griddle

= Custom or if unknown, use 320 W/ft^2

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%

For example, an ENERGY STAR electric griddle with defaults from the calculation above would save:

ΔkWh = (ΔIdleEnergy + ΔCookingEnergy) * Days / 1,000

Where:

ΔIdleEnergy =[400 * (3 * 2) * (12 – 100 / 35)] – [320 * (3 * 2) * (12 – 100 / 40)] = 3,703 Wh

ΔCookingEnergy = (100 * 139/ 0.65) - (100 * 139/ 0.70)

= 1,528 Wh

ΔkWh = (3,703 + 1,528) * 365.25 /1,000

= 1,910.4 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW \quad = \Delta kWh \;/\; (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.787

Other variables as defined above.

For example, an ENERGY STAR electric griddle with defaults from the calculation above would save:

ΔkW = 1,910.4 / (12 * 365.25) * 0.787

= 0.3430 kW

Natural Gas Energy Savings

Custom calculation for a natural gas griddle below, otherwise use deemed value of 131.4 therms.[664]

$$\Delta Therms = (\Delta IdleEnergy + \ \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = [IdleRate$_{Base}$* (Width * Length) * (Hours – FoodCooked/Production$_{Base}$)] – [IdleRate$_{ESTAR}$ * (Width * Length) * (Hours – FoodCooked/Production$_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff$_{Base}$) - (FoodCooked * EFOOD/ Eff$_{ESTAR}$)

Where:

100,000 = Btu to therms conversion factor

Production$_{Base}$ = Production capacity of baseline gas griddle

= 25 lb/hr

Production$_{ESTAR}$ = Production capacity of ENERGY STAR gas griddle

= Custom or if unknown, use 45 lb/hr

IdleRate$_{Base}$ = Idle energy rate of baseline gas griddle

[664] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

= 3,500 Btu/hr/ft^2

$IdleRate_{ESTAR}$ = Idle energy rate of ENERGY STAR gas griddle

= Custom or if unknown, use 2,650 Btu/hr/ft^2

EFOOD = 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.

For example, an ENERGY STAR gas griddle with defaults from the calculation above would save:

ΔTherms = (ΔIdleEnergy + ΔCookingEnergy) * Days /100,000

Where:

ΔIdleEnergy = [3,500 * (3 * 2) * (12 – 100 / 25)] – [2,650 * (3 * 2) * (12 – 100 / 45)]

= 12,533 Btu/day

ΔCookingEnergy = (100 * 475/ 0.32) - (100 * 475/ 0.38)

= 23,438 Btu/day

ΔTherms = (12,533 + 23,438) * 365.25 /100,000

= 131.4 therms/yr

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms \ / \ Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR gas griddle with defaults from the calculation above would save:

ΔPeakTherms = 131.4 / 365.25

= 0.3598 therms/day

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-FSE-ESGR-V02-220101

Sunset Date: 1/1/2025

3.7. Shell Measures

Many of the Nonresidential Shell measures use load hours (LH) to calculate heating and cooling savings. The table with these values is included in this section and referenced in each measure. The benefit of improved shell performance is realized during any period of time air conditioning equipment (both heating and cooling) is in operation, and therefore it follows that system loading hours (as opposed to *effective* full load hours) may more appropriately quantify measure impacts that relate to a building's shell.

Calculation of LH uses the same approach and base files as EFLH, as described in Section 3.3. To calculate the LH by building type and climate zone provided below, VEIC created OpenStudio and/or eQuest models for each building type. The LH calculation is based on hourly building loads (total heating/cooling output). The calculation allows for a more generally applicable LH determination that is tied to the load profiles of various building prototypes and not affected by modeling irregularities that can be equipment specific. The load profiles are related to system characteristics such as constant vs. variable air volume and single- vs. multi-zone configurations, but not sensitive to how the energy model treats equipment operation at very low loads or performs sizing estimates. The calculation sums the annual total (heating or cooling) load hours.

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

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

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average/unknown		Weighting Factors for Nonresidential Average[665]	Model Source
	Heating LH	Cooling LH	Heating LH	Cooling LH	Heating LH	Cooling LH		
Convenience	3024	3005	2129	4054	2690	3628	0%	eQuest
Education	6213	3354	6633	2771	6430	2996	9%	OpenStudio
Grocery	6217	2871	6819	2425	6499	2725	0%	OpenStudio
Health	8729	5240	8732	4405	8720	4770	0%	OpenStudio
Hospital	8286	8760	8272	8760	8289	8760	0%	OpenStudio
Industrial	3396	3537	2233	4526	3080	3977	0%	eQuest
Lodging	5218	8019	6234	7309	5500	7909	0%	OpenStudio
Multifamily	5145	5424	5998	4575	5382	5084	0%	OpenStudio
Office - Large	5037	4844	5787	4457	5316	4596	0%	OpenStudio
Office - Small	4641	3941	5329	3265	5087	3678	26%	OpenStudio
Religious	2485	4347	1667	5267	2223	4763	16%	eQuest
Restaurant	2954	3019	3619	2217	3321	2798	7%	OpenStudio
Retail - Large	2699	3621	1807	4623	2405	4218	5%	eQuest
Retail - Small	4222	2636	4935	1839	4596	2445	11%	OpenStudio
Warehouse	2025	3617	1390	4553	1788	4100	26%	eQuest
Nonresidential Average	3480	3643	3473	3723	3561	3734	N/A	N/A

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

3.7.1. Infiltration Control

Description

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured with the assistance of a blower-door by qualified/certified inspectors.[666] Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

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

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

Note: separate callouts are applicable for Multifamily or mixed use retail plus Multifamily building types. Savings impacts for such building types were modeled using OpenStudio.

Definition of Efficient Equipment

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

Definition of Baseline Equipment

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air-sealing.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[667]

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)

E01 – Flat

Algorithm

Calculation of Savings

[666] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[667] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

For Multifamily, or mixed use retail plus Multifamily building types[668]:

$$\Delta kWh = \Delta CFM_{50} * (Cool + Fan + Pump + \frac{Heat*10{,}000}{(\eta_{heating} * 3{,}412)})$$

For purposes of loadshape application, components should be separated. Cool savings should use Cooling loadshape. Fan savings should use Flat loadshape for exclusively Multifamily buildings, or an appropriate electric heat loadshape in instances of mixed use. Pump savings should use an appropriate electric heat loadshape. Heat savings should use the appropriate heating loadshape.

Where:

ΔCFM_{50} = Change in infiltration rate between pre and post conditions, as measured by blower door testing at 50 Pascals.

Note: if blower door testing was completed at a pressure of 75 Pa, use the following conversion factor: $CFM_{50} = CFM_{75}/1.3$

Savings Source Multipliers as noted below, based on climate zone and use type. If building heating is **NOT** electric, Heat = 0 and refer to Natural Gas Savings section:

Climate Zone (City based upon)	Use Type	Cool (kWh/CFM_{50})	Fan (kWh/CFM_{50})	Pump (kWh/CFM_{50})	Heat ($therms/CFM_{50}$)
Zone 5 (Burlington)	Multifamily Only	0.03577	0.15331	0.01085	0.11825
Zone 5 (Burlington)	Multifamily / mixed use retail	0.10523	0.17936	0.00967	0.11107
Zone 6 (Mason City)	Multifamily Only	0.03403	0.55017	0.01948	0.21499
Zone 6 (Mason City)	Multifamily / mixed use retail	0.08849	0.31821	0.02013	0.22555
Average/unknown	Multifamily Only	0.03941	0.24876	0.01180	0.14810
Average/unknown	Multifamily / mixed use retail	0.10773	0.24375	0.01225	0.15097

$\eta_{heating}$ = Efficiency of heating system, expressed as COP

= Actual. For equipment with HSPF ratings, use the following conversion to COP:

COP = HSPF/3.413

10,000 = Conversion from therms to Btu

3,142 = Conversion from Btu to kWh.

For all other building types:

668 Based on OpenStudio modeling results. See measure reference documents for supporting information and assumptions.

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

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to air sealing

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * LH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Infiltration at natural conditions as estimated by blower door testing before air sealing

= Actual[669]

CFM_{Post} = Infiltration at natural conditions as estimated by blower door testing after air sealing

= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^oF] during cooling season between outdoor air temperature and assumed 75^oF indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][670]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

0.018 = Specific Heat Capacity of Air (Btu/ft^3*°F)

LM = Latent multiplier to account for latent cooling demand

= dependent on location: [671]

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	4.1
Zone 6 (Mason City)	4.2
Average/ unknown	4.2

1000 = Converts Btu to kBtu

$\eta_{cooling}$ = Energy efficiency ratio (EER) of cooling system (kBtu/kWh)

669 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.

670 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.

671 The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

= Actual. If not directly specified, EER may be calculated from other commonly listed efficiency ratings (kW/ton or COP):

EER = 12 / 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

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * LH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 3{,}412)}$$

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^oF] during heating season between outdoor air temperature and assumed 55^{o}F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][672]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/ unknown	35.9	19.1

3,142 = 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 SqFt) in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

ΔkWh = $\Delta kWh_{cooling} + \Delta kWh_{heating}$

= [((340 – 225) * 60 * 2,445 * 3.6 * 0.018 * 4.2) / (1000 * 10.5)] +

[((340 – 225) * 60 * 4,596 * 19.1 * 0.018) / (1.92 * 3,412)]

= 437 + 1664

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[673]

[672] 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.

[673] The values in the table represent estimates of savings from a 10-15% improvement in air leakage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

End Use	HVAC System	SavingsPerUnit (kWh/ft^2)
Cooling Chillers	Chiller	0.027
Cooling DX	Air Conditioning	0.041
Space Heat	Electric Resistance/Furnace	0.2915
Heat Pump - Cooling	Heat Pump	0.041
Heat Pump - Heating	Heat Pump	0.1885

SqFt = Building square footage

= Actual

<u>Additional Fan savings</u>

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[674]

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:

ΔkWh = 81 * 0.0314 * 29.3

= 75 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWhcooling}{LHcooling} * CF$$

Note: for Multifamily, or mixed use retail plus Multifamily building types,

$$\Delta \text{kWhcooling} = \Delta \text{CFM}_{50} * \text{Cool}$$

Where:

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use. Any building type that contains a portion of multifamily housing should use Multifamily assumptions.

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type). Any building type that contains a portion of multifamily housing should use Multifamily assumptions.

Building Type	CF[675]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio

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

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

Building Type	CF[675]	Model Source
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[676]	92.3%	N/A

For example, a small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

ΔkW = 437 / 2,445 * 1.00

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

For Multifamily, or mixed use retail plus Multifamily building types:

$$\Delta Therms = \Delta \mathrm{CFM}_{50} * \frac{Heat}{\eta_{heating}}$$

For all other building types:

$$\Delta Therms = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * LH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 100{,}000)}$$

Where:

100,000 = Conversion from BTUs to Therms

Other factors as defined above

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

ΔTherms = ((340 – 225) * 60 * 2,954 * 15.4 * 0.018) / (0.70 * 100,000)

= 81 therms

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

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

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[677]

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:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[678]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[679]	0.014658	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

ΔPeakTherms = 81 * 0.015262

= 1.221 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[677] 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.

[678] Calculated as the percentage of total savings in the maximum saving day, from models.

[679] For weighting factors, see HVAC variable table in section 3.3.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-AIRS-V05-220101

SUNSET DATE: 1/1/2027

3.7.2. Foundation Wall Insulation

Description

Energy and demand 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 assembly R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

For retrofit projects, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly. If existing condition is unknown, assume IECC 2006.

For new construction projects, baseline is building code, IECC 2012.

Deemed Lifetime of Efficient Equipment

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

Deemed Measure Cost

For retrofit projects, full installation costs should be used.

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

$$\Delta \text{kWh}_{\text{cooling}} = \frac{\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}}\right) * Area_{AG} * LH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

$R_{existingAG}$ = Above grade wall heat loss coefficient, with existing insulation, for the complete structural assembly [(hr-^{o}F-ft^{2})/Btu][680]

R_{newAG} = Above grade wall heat loss coefficient, with new insulation, for the complete structural assembly [(hr-^{o}F-ft^{2})/Btu]

$Area_{AG}$ = Area of the above grade wall surface in square feet

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75^{o}F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][681]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kBtu

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

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta \text{kWh}_{\text{heating}} = \frac{\left(\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}}\right) * Area_{AG}\right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}}\right) * Area_{BG}\right)\right) * LH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$R_{existingBG}$ = Below grade wall assembly heat loss coefficient with existing insulation, for the complete structural assembly [(hr-^{o}F-ft^{2})/Btu]

= 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

680 In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A "Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations" to outline an approach using convenient lookup tables.

681 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.

selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft^2-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69

R_{newBG} = Below grade wall assembly heat loss coefficient with new insulation, for the complete structural assembly [(hr-^{o}F-ft^2)/Btu]

$Area_{BG}$ = Area of the below grade wall surface in square feet.

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{o}F] during heating season between outdoor air temperature and assumed 55^{o}F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][682]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = 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.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[683]

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh_{cooling} / LH_{cooling}) * CF$$

Where:

682 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.

683 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.

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use

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

Building Type	CF[684]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[685]	92.3%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta Therms = \frac{\left(\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}}\right) * Area_{AG}\right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}}\right) * Area_{BG}\right)\right) * LH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other terms as defined above.

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[686]	Model Source
Convenience	0.016482	eQuest

684 This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
685 For weighting factors, see HVAC variable table in section 3.3.
686 Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF[686]	Model Source
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[687]	0.014658	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-FINS-V04-210101

SUNSET DATE: 1/1/2024

[687] For weighting factors, see HVAC variable table in section 3.3.

3.7.3. Roof Insulation

Description

Energy and demand savings are realized through reductions in the building cooling and heating loads.

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

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

Definition of Efficient Equipment

The efficient condition is insulation levels that exceed code requirements and should be determined by the program. IECC 2012 requirements are shown in the following tables:

	ASHRAE/IECC Climate Zone 5 (A, B, C)	
	Assembly Maximum	Insulation Min. R-Value
Insulation entirely above deck	U-0.039	R-25 ci
Metal building (with R-5 thermal blocks)	U-0.035	R-19 + R-11 LS
Attic and other	All other: U-0.027 Group R: U-0.021	All other: R-38 Group R: R-49

	ASHRAE/IECC Climate Zone 6 (A, B, C)	
	Assembly Maximum	Insulation Min. R-Value
Insulation entirely above deck	U-0.032	R-30 ci
Metal building (with R-5 thermal blocks)	U-0.031	R-25 + R-11 LS
Attic and other	U-0.021	R-49

Note: ci = continuous insulation, LS = Liner System

Definition of Baseline Equipment

The retrofit baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire roof assembly. If existing condition is unknown, assume IECC 2006.

The new construction baseline is code requirement, IECC 2012.

Deemed Lifetime of Efficient Equipment

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

Deemed Measure Cost

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

Loadshape

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

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

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

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

Where:

$R_{existing}$ = CompleteComplete roof assembly heat loss coefficient with existing insulation [(hr-^{o}F-ft^2)/Btu][688]

R_{new} = Complete roof assembly heat loss coefficient with new insulation [(hr-^{o}F-ft^2)/Btu]

Area = Area of the insulated roof surface in square feet, as measured from within the conditioned space (area of overhangs or eaves should be excluded, for example).

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{o}F] during cooling season between outdoor air temperature and assumed 75^{o}F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][689]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kBtu

[688] In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A “Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations” to outline an approach using convenient lookup tables.

[689] 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.

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

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^oF] during heating season between outdoor air temperature and assumed 55^oF heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][690]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = 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, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft^2 of R-20 roof insulated to R-35, 10.5 SEER central AC, and 1.92 COP heat pump system:

ΔkWh = $\Delta kWh_{cooling} + \Delta kWh_{heating}$

= ((1/20 – 1/35) * 1,500 * 1.0 * 1,839 * 0.2 / (1,000 * 10.5)) + ((1/20 – 1/35) * 1,500 * 1.0 * 4,935 * 24.9/ (3,412 * 1.92))

= 1.1 + 602.9

= 604 kWh

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$\Delta kWh_{heating}$ = ΔTherms * Fe * 29.3

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[691]

[690] 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.

[691] 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)

29.3 = Conversion from therms to kWh

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft^2 of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

ΔkWh = 56.5 * 0.0314 *29.3

= 52.0 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWhcooling}{LHcooling} * CF$$

Where:

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use

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

Building Type	CF[692]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[693]	92.3%	N/A

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft^2 of R-20 roof insulated to R-35, and 10.5 SEER central AC:

ΔkW = 1.1/1,839 * 1.00

= 0.0006 kW

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.

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

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

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Complete roof heat loss coefficient with existing insulation [(hr-^{o}F-ft^2)/Btu]

R_{new} = Complete roof heat loss coefficient with new insulation [(hr-^{o}F-ft^2)/Btu]

Area = Area of the insulated roof surface in square feet. Assume 1000 sq ft for planning.

$LH_{heating}$ =Load Hours for Heating are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{o}F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft^2 of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

ΔTherms = ((1/20 – 1/35) * 1,500 * 1.0 * 4,4584,935 * 24.9/ (100,000 * 0.70))

= 56.5 therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[694]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio

[694] Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF[694]	Model Source
Warehouse	0.015677	eQuest
Nonresidential Average[695]	0.014658	N/A

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft^2 of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

ΔPeakTherms = 56.5 * 0.014055

= 0.794 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-XINS-V05-210101

SUNSET DATE: 1/1/2024

[695] 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:

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

Where:

$R_{existing}$ = Complete wall assembly heat loss coefficient with existing insulation [(hr-^{o}F-ft^{2})/Btu][696]

R_{new} = Complete wall assembly heat loss coefficient with new insulation [(hr-^{o}F-ft^{2})/Btu]

Area = Area of the wall surface in square feet.

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{o}F] during cooling season between outdoor air temperature and assumed 75^{o}F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][697]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

[696] In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A "Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations" to outline an approach using convenient lookup tables.

[697] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

1,000 = Conversion from Btu to kBtu

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

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][698]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = 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.

$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[699]

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWhcooling}{LHcooling} * CF$$

Where:

[698] 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.

[699] 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.

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use

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

Building Type	CF[700]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[701]	92.3%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Complete wall heat loss coefficient with existing insulation [(hr-°F-ft^2)/Btu]

R_{new} = Complete wall heat loss coefficient with new insulation [(hr-°F-ft^2)/Btu]

Area = Area of the wall surface in square feet. Assume 1000 sq ft for planning.

$LH_{heating}$ = Load Hours for Heating are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

PEAK GAS SAVINGS

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

Where:

[700] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
[701] For weighting factors, see HVAC variable table in section 3.3.

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[702]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[703]	0.014658	N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-SHL-WINS-V03-210101

Sunset Date: 1/1/2024

[702] Calculated as the percentage of total savings in the maximum saving day, from models.
[703] 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.[704]

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $1.50 per square foot of window area.[705]

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

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

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

Algorithm

CALCULATION OF SAVINGS

The following calculations apply to a single window assembly. Note that the effects of a lower SHGC are not considered in this characterization. A lower SHGC does not necessarily equate to net savings due to the possible opposite effects it can have on heating and cooling loads. For optimum design and estimation of impacts from solar gain, a custom analysis should be performed that takes into account building site and orientation considerations.

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

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

[704] Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.

[705] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta \text{kWh}_{\text{cooling}} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft^2.°F.h)

= Dependent on climate zone and window type. If unknown, assume the most conservative value, 0.36. See table below for IECC2012 requirements:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft^2.°F.h)

= Actual.

A_{window} = Area of insulated window (including visible frame and glass) (ft^2)

$LH_{cooling}$ Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][706]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = 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:

$$\Delta \text{kWh}_{\text{heating}} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

[706] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^oF] during heating season between outdoor air temperature and assumed 55^oF heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][707]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = 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

= if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system and a 1.92 COP Heat Pump system:

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

= (((0.43 – 0.25) * 8 * 2,217 * 0.2) / (1000 * 12.0)) + (((0.43 – 0.25) *8 * 3,619 * 24.9) / (3,412 * 1.92)) * 15

= (0.053 + 19.8) * 15

= 397.8 kWh

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.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[708]

29.3 = Conversion from therms to kWh

[707] 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.

[708] 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.

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

ΔkWh = 73.0 * 0.0314 * 29.3

= 67.2 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWhcooling}{LHcooling} * CF$$

Where:

$LH_{cooling}$ =Load hours of air conditioning are provided in Section 3.7, Shell end use

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

Building Type	CF[709]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[710]	92.3%	N/A

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system:

ΔkW = (0.053 * 15) / 2,217 * 0.996

= 0.0004 kW

Natural Gas Savings

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft^2.°F.h)

[709] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.
[710] For weighting factors, see HVAC variable table in section 3.3.

= Dependent on climate zone and window type. See table below:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft^2.°F.h)

= Actual.

A_{window} = Net area of insulated window (ft^2)

$LH_{heating}$ = Load Hours for Heating are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^oF] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

= if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

For example, a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2’ x 4’ openable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

ΔTherms = (((0.43 – 0.25) * 21 * 3,6194,767 * 24.9) / (100,000 * 0.70)) * 15

= 73.0

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[711]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio

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

Building Type	GCF[711]	Model Source
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[712]	0.014658	N/A

For example, a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

ΔPeakTherms = 73.0 * 0.015262

= 1.11

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WIND-V05-210101

SUNSET DATE: 1/1/2024

[712] 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 an **exterior door** with insulation levels that exceed code requirements and should be determined by the program.

Definition of Baseline Equipment

The retrofit baseline condition is the existing condition of the **exterior door** and requires assessment of the existing insulation. It should be based on the entire door assembly. If existing condition is unknown, assume IECC 2006.

Deemed Lifetime of Efficient Equipment

The measure expected useful life (EUL) is assumed to be 25 years.[713]

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

$$\Delta \text{kWh}_{\text{cooling}} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 \; * \; \eta_{cooling})}$$

Where:

713 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-^oF-ft^2)/Btu]. If unknown, assume 2.7 for swinging door, 4.75 for nonswinging door.[714]

R_{new} = New door heat loss coefficient [(hr-^oF-ft^2)/Btu]

Area = Area of the door surface in square feet.

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^oF] during cooling season between outdoor air temperature and assumed 75^oF indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][715]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kBtu

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

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^oF] during heating season between outdoor air temperature and assumed 55^oF heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][716]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = Conversion from Btu to kWh.

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

[714] IECC 2012 and 2015 code requirement

[715] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

[716] 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%*

For example, for a restaurant in Mason City installing a new 21 ft^2, insulated, swinging door with an R-value of 11, savings with a 10.5 SEER central AC system and a 1.92 COP Heat Pump system:

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

= (((1/2.7 – 1/11) * 21 * 2,217 * 0.2) / (1000 * 10.5)) + (((1/2.7 – 1/11) *21 * 3,619 * 24.9) / (3,412 * 1.92))

= 0.2 kWh + 80.7 kWh

= 80.9 kWh

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[717]

29.3 = Conversion from therms to kWh

For example, for a restaurant in Mason City installing a new 21 ft^2, insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

ΔkWh = 7.55 * 0.0314 * 29.3

= 6.94 kWh

Summer Coincident Peak Demand Savings

$\Delta kW = (\Delta kWh_{cooling} / LH_{cooling}) * CF$

Where:

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use

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

Building Type	CF[718]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio

[717] 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.

[718] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF[718]	Model Source
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[719]	92.3%	N/A

For example, for a restaurant in Mason City installing a new 21 ft^2, insulated, swinging door with an R-value of 11, savings with a 10.5 SEER central AC system:

ΔkW = 0.2 / 2,2172,176 * 0.996

= 0.00009 kW

Natural Gas Savings

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Existing door heat loss [(hr-°F-ft^2)/Btu]

R_{new} = New door heat loss coefficient [(hr-°F-ft^2)/Btu]

Area = Area of the door surface in square feet.

$LH_{heating}$ = Load Hours for Heating are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

For example, for a restaurant in Mason City installing a new 21 ft^2, insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

ΔTherms = (((1/2.7 – 1/11) * 21 * 3,619 * 24.9) / (100,000 * 0.70))

= 7.55

Peak Gas Savings

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

[719] For weighting factors, see HVAC variable table in section 3.3.

Building Type	GCF[720]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average[721]	0.014658	N/A

For example, for a restaurant in Mason City installing a new 21 ft^2, insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

ΔPeakTherms = 9.95 * 0.0152620

= 0.152 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-DOOR-V05-210101

SUNSET DATE: 1/1/2024

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

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

3.8. Refrigeration

3.8.1. LED Refrigerator Case Light Occupancy Sensor

Description

Occupancy sensors are devices that reduce lighting levels and/or turn lights on or off in response to the presence (or absence) of people in a defined area. This measure applies to the installation of occupancy sensors on linear LED lights on commercial glass-door, reach-in coolers and freezers. Savings result from a reduction in electric energy use by case lighting and from a reduced cooling load due to less heat gain from the lighting.

This measure applies to the following program types: RF.

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be occupancy sensors meeting program requirements, installed on linear LED lights on commercial glass-door, reach-in coolers and freezers.

Definition of Baseline Equipment

The baseline equipment is linear LED lights without occupancy controls, installed on commercial glass-door, reach-in coolers and freezers.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years.[722]

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.[723]

Loadshape

Loadshape NREL01 – Nonresidential Lighting – Convenience

Loadshape NREL03 – Nonresidential Lighting – Grocery

Loadshape NREL13 – Nonresidential Lighting – Retail – Large

Loadshape NREL14 – Nonresidential Lighting – Retail – Small

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below, otherwise use 290.8 kWh per control for coolers and 331.4 kWh per control for freezers..

$$\Delta kWh = kW_{Controlled} * (Hours * \%Controlled) * (1 + (0.80/COP))$$

[722] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

[723] Measure cost from Efficiency Vermont No. 2015-90 TRM. Based on information provided by Green Mountain Electric Supply for a Wattstopper FS705 product.

Where:

$kW_{Controlled}$ = Total lighting load (kW) connected to the control.

= Actual, or if unknown, assume 0.090 kW[724]

Hours = Annual case lighting hours of use

= Actual or if unknown, assume 6,575 hours[725]

%Controlled = Percentage savings due to the occupancy sensor

= Actual or if unknown, assume 40%[726]

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 freezers[727]

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

ΔkWh = $kW_{Controlled}$ * (Hours * %Controlled) * (1 + (0.80 / COP))

ΔkWh = 0.090 * (6,575 * 0.40) * (1 + (0.80 / 3.5))

= 290.8 kWh per control

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 1.00 for all building types

Other variables as defined above

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

ΔkW = (290.8 / 6,575) * 1.00

= 0.044 kW

NATURAL GAS ENERGY SAVINGS

N/A

[724] Controlled lighting load from Efficiency Vermont No. 2018 TRM, based on LED Refrig Lighting ERCO_Talking_Pointsv3, PG&E
[725] Assumption for a business operating 18 hours per day
[726] Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls.
[727] 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.

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-V01-190101

SUNSET DATE: 1/1/2024

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.[728]

Deemed Measure Cost

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of $1,266 per heater control.[729]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = Doors * \left(kW_{Base} * Hours * ESF * \left(1 + \frac{R_H}{COP}\right)\right)$$

Where:

kW_{Base} = Per door electric energy consumption of door heater

[728] Commercial Refrigeration Anti-Sweat Heater Controls, California Technical Forum, Workpaper SWCR001-01, May 2019

[729] Measure cost from "Incremental Cost Study, Phase Four Final Report." Northeast Energy Efficiency Partnerships. June 15, 2015.

= Assume 0.066 kW for coolers and 0.230 kW for freezers[730]

Doors = Number of doors controlled by sensor

= Actual

Hours = Annual hours of cooler or freezer operation

= Assume 8,760 hours per year

%Off = Percentage of hours annually that the door heater element is powered off due to controls

= 45.1% for coolers and freezers[731]

R_H = Residual heat fraction: estimated percentage of heat produced by heaters that remains in the freezer or cooler case and must be removed by the refrigeration unit

= Actual or if unknown, use 0.65[732]

COP = Coeffiecint of performance of cooler or freezer

= Actual or if unknown, use 3.5 for coolers and 2.0 for freezers[733]

For example, a 3-door reach-in cooler with a door heater control would save:

ΔkWh = Doors * (kW_{Base} * Hours * ESF * (1 + R_H /COP))

ΔkWh = 3 * (0.066 * 8,760 * 0.451 * (1+0.65 /3.5))

928 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.964

Other variables as defined above.

[730] Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

[731] Difference in effective runtime of an uncontrolled heater and all control style heater controls. Anti-sweat door heater control reduced run time. The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 69, Section 4.1.4, Table 37.

[732] Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

[733] 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.

For example, a 3-door reach-in cooler with a door heater control would save:

$\Delta kW = (928/8760) * 0.964$

$= 0.1021$ 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-DHCT-V03-220101

SUNSET DATE: 1/1/2026

3.8.3 Efficient Motors for Walk-in and Display Case Coolers / Freezers

Description

This measure applies to the replacement of an existing permanent split capacitator (PSC) evaporator fan motor with an electrically commutated motor (ECM) or Q-Sync motor on commercial walk-in or display case coolers or freezers. Savings result from a reduction in electric energy use from a more efficient fan motor and from a reduced cooling load due to less heat gain from a more efficient fan motor in the air stream.

This measure applies to the following program types: RF.

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be an ECM or Q-Sync installed on a commercial walk-in or display case cooler or freezer.

Definition of Baseline Equipment

The baseline equipment is a standard-efficiency PSC fan motor installed on a commercial walk-in or display case cooler or freezer.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[734]

Deemed Measure Cost

Actual equipment and labor costs should be used if available. In actual costs are unknown, the full installed cost for a brushless DC fan motor is $245 ($185 for the motor, $60 for installation labor including travel time) and $170 ($110 for the motor, $60 for installation labor including travel time) for Q-Sync.[735]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below, otherwise use default savings values in table below.

$$\Delta kWh = \frac{W_{Output}\ /EFF_{Base} - W_{Output}\ /EFF_{EE}}{1{,}000} \times Hours \times DC \times LF \times \left(1 + \frac{1}{COP}\right)$$

Where:

W_{Output} = Output wattage of installed fan motor

[734] DEER 2014

[735] EC Motor cost is an average of costs from Natural Resource Management ($250) and direct from the manufacturer GE ($120), consistent with the costs reported in a Northeast Energy Efficiency Partnership (NEEP) incremental cost study, Q-SyncMotors.xlsx. Q-Sync cost also derived from the same study.

= Actual; or if unknown, use 14.95 W for display cases[736] or 42 W for walk-ins[737]

EFF_{Base} = Efficiency of baseline motor

= Actual or if unknown, use 29%[738]

EFF_{EE} = Efficiency of efficient motor

= Actual or if unknown, use 66% for ECM[739] or 73.1% for Q-Sync[740]

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[741]

DC = Duty cycle of fan motor

= Custom or if unknown, assume 100% for coolers and 94% for freezers[742]

COP = Coefficient of performance of cooler or freezer

= Actual or if unknown, use 3.5 for coolers and 2.0 for freezers[743]

For example, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$\Delta kWh = (W_{Output} / EFF_{Base} - W_{Output} / EFF_{EE})/1{,}000 \times Hours \times DC \times LF \times (1 + 1/COP)$

$\Delta kWh = (14.95/0.29 - 14.95/0.66)/1{,}000 * 8766 * 1.00 * 0.90 * (1 + 1/3.5)$

= 293.1 kWh

Savings for all efficient motor types are presented in the table below:

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
Cooler	Display Case	ECM	293.1
		Q-Sync	315.5

[736] 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

[737] The Cadmus Group, *Commercial Refrigeration Loadshape Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, October 2015. Walk-in motor wattage derived using motor type efficiencies and output ratings. Calculated power consumption comparable to NEEP loadshape reported values for walk-in motors.

[738] Chapter 5 of Technical Support Document in support of DOE Notice of Proposed Rulemaking for Commercial Refrigeration Equipment, 08/28/2013

[739] Chapter 5 of Technical Support Document in support of DOE Notice of Proposed Rulemaking for Commercial Refrigeration Equipment, 08/28/2013

[740] Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015. Reference file "PUB58600.pdf" Table 1, page 7.

[741] Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

[742] 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)."

[743] 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.

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
	Walk-in	ECM	823.6
		Q-Sync	886.3
Freezer	Display Case	ECM	321.5
		Q-Sync	346.0
	Walk-in	ECM	903.2
		Q-Sync	971.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.964

Other variables as defined above.

> **For example**, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:
>
> ΔkW = (293.1/8766) * 0.964
>
> = 0.0322 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-ECMF-V03-190101

SUNSET DATE: 1/1/2024

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.[744]

Deemed Measure Cost

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of $42 per linear foot of cover.[745]

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

SavingsRate = Electric demand savings (kW/ft) from installing a night cover

[744] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

[745] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

= Actual; or if unknown, use savings rate from table below depending on display case temperature:[746]

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 day[747]

Days = Number of days per year that night covers are in use

= Actual or if unknown, use 365.25 days per year

For example, a low-temperature display case with night covers installed on a 12-foot wide opening, using the defaults above, would save:

ΔkWh = CaseFt * SavingsRate * Hours * Days

ΔkWh = 12 * 0.03 * 6 * 365.25

= 788.9 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-V02-180101

Sunset Date: 1/1/2024

[746] "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.

[747] Assumed 18-hour of uncovered operation of display case, based on a typical operating scenario from "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case" Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division, August 8, 1997.

3.8.5. Refrigerated Beverage Vending Machine

Description

This measure applies to new ENERGY STAR Class A, Class B, Combination A, or Combination B refrigerated vending machines. A refrigerated beverage vending machine is a commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages (a beverage in a sealed container) on payment. ENERGY STAR vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR Class A, Class B, Combination A, or Combination B refrigerated vending machine meeting energy consumptions requirements as determined by equipment type.

Class A Machine: A refrigerated bottled and/or canned beverage vending machine that is not a combination vending machine and in which 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Class B Machine: Any refrigerated bottled and/or canned beverage vending machine not considered to be Class A, and is not a combination vending machine.

Combination Vending Machine: A bottled and/or canned beverage vending machine containing two or more compartments separated by a solid partition, that may or may not share a product delivery chute, in which at least one compartment is designed to be refrigerated, as demonstrated by the presence of temperature controls, and at least one compartment is not.

Combination A Machine: A combination vending machine where 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Combination B Machine: A combination vending machine that is not considered to be Combination A.

ENERGY STAR Requirements (Version 4.0, Effective April 29, 2020)

Equipment Type	Maximum Daily Energy Consumption (kWh/day)
Class A	≤ 0.04836V + 2.2599
Class B	≤ 0.04576V + 1.936
Combination A	≤ 0.07998V + 2.4738
Combination B	≤ 0.09768V + 1.7952

Definition of Baseline Equipment

The baseline equipment is a new or rebuilt, Class A, Class B, Combination A, or Combination B refrigerated vending machine that is not ENERGY STAR certified, but adheres to Federal Energy Conservation Standards.[748]

Deemed Lifetime of Efficient Equipment

[748] 10 CFR §431.296 (b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines. Effective for machines manufactured on or after January 8, 2019.

The expected measure life is assumed to be 10 years.[749]

Deemed Measure Cost

The incremental cost of this measure is $199.[750]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below.

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline vending machine

= Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{Base}[751]
Class A	0.052V + 2.43
Class B	0.052V + 2.20
Combination A	0.086V + 2.66
Combination B	0.111V + 2.04

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR vending machine

= Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{EE}[752]
Class A	≤ 0.04836V + 2.2599
Class B	≤ 0.04576V + 1.936
Combination A	≤ 0.07998V + 2.4738
Combination B	≤ 0.09768V + 1.7952

V = Refrigerated volume[753] (ft^3)

= Actual installed

[749] Measure life from Final Report: Volume 2, Assessment of Energy and Capacity Savings Potential in Iowa: Appendices. The Cadmus Group, February 28, 2012

[750] Incremental cost from Focus on Energy, Business Programs Incremental Cost Study, PA Consulting Group, October 28, 2009

[751] 10 CFR §431.296 (b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

[752] ENERGY STAR Version 4.0 requirements for maximum daily energy consumption

[753] V = the refrigerated volume (ft^3) of the refrigerated bottled or canned beverage vending machine, as specified in Appendix C of the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 32.1 - 2010, ''Methods of Testing for Rating Vending Machines for Bottled, Canned or Other Sealed Beverages." For combination vending machines, the refrigerated volume does not include any non-refrigerated compartments.

Days = Days of vending machine operation per year

= 365.25 days per year

For example, an ENERGY STAR, Class A vending machine with a volume of 30 ft^3 would save:

ΔkWh = (kWh_{Base} – kWh_{ESTAR}) * Days

ΔkWh = [(0.052 * 30 + 2.43) – (0.04836 * 30 + 2.2599)] * 365.25

= 102.0 kWh

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

= 8,766[754]

CF = Summer peak coincidence factor

= 0.964[755]

For example, an ENERGY STAR vending machine with a volume of 30 ft^3 would save:

ΔkW = (102.0/8,766) * 0.964

= 0.011 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-ESVE-V03-210101

Sunset Date: 1/1/2024

[754] Equipment is assumed to operate continuously, 24 hour per day, 365.25 days per year

[755] Based on modeling performed by VEIC of Grocery building type. This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

3.8.6. Refrigerator and Freezer Recycling

DESCRIPTION

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided in two ways. First, a regression equation is provided that requires the use of key inputs describing the retired unit (or population of units) and is based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study. The second methodology is a deemed approach based on applying program data from MidAmerican and Alliant from 2019 and 2020 to the regression equation. Note that since both methods are based on residential units, this program is limited to residential-sized units in commercial settings. Furthermore, it is assumed that these retired units are not "secondary" units, but that the program is encouraging the early removal of inefficient units that are ultimately replaced.

The savings are equivalent to the Unit Energy Consumption of the retired unit minus an assumed baseline replacement unit (any additional savings attributed to purchasing a new high efficiency unit would be claimed through the Time of Sale measure) and should be claimed for the assumed remaining useful life of that unit. The user should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary. This measure also includes a section accounting for the interactive effect of reduced waste heat on the heating and cooling loads.

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

DEFINITION OF EFFICIENT EQUIPMENT

The existing inefficient refrigerator is removed from service and replaced.

DEFINITION OF BASELINE EQUIPMENT

The existing inefficient unit must be operational.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated remaining useful life of the recycling units is 6.5 years.[756]

DEEMED MEASURE COST

Measure cost includes the cost of pickup and recycling of the refrigerator and should be based on actual costs of running the program. If unknown, assume $100 per unit.[757]

LOADSHAPE

Loadshape RE09 - Residential Refrigerator

Loadshape RE02 – Residential Freezer

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

[757] Based on program costs provided by Mid American and Alliant Energy in 2021.

Algorithm

Calculation of Savings

Energy Savings

Regression analysis: Refrigerators

Energy savings for refrigerators are based upon a linear regression model using the following coefficients:[758]

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

$$\Delta kWh_{Unit} = \Big[83.32 + (Age * 3.68) + (Pre - 1990 * 485.04) + (Size * 27.15) + (Side - by - side * 406.78) + (Primary\ Uage * 161.86) + \left(\frac{CDD}{365.25} * unconditioned * 15.37\right) + \left(\frac{HDD}{365.25} * unconditioned * -11.07\right)\Big] - UEC_{BaseRefrig}$$

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

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

CDD = Cooling Degree Days

= Dependent on location:[759]

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

[758] 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.

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

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

HDD = Heating Degree Days

= Dependent on location:[760]

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	5,052	13.83

$UEC_{BaseRefrig}$ = Assumed consumption of a new baseline residential-sized refrigerator

= 558.3 kWh[761]

Deemed approach: Refrigerators

$$\Delta kWh_{Unit} = UEC_{Retired} - UEC_{BaseRefrig}$$

Where:

$UEC_{Retired}$ = Unit Energy Consumption of retired unit based on Mid American and Alliant 2019 and 2020 program data[762]:

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

= Dependent on climate zone as provided in table below.

Deemed refrigerator savings are provided below:

Climate Zone (City based upon)	UEC	ΔkWh per unit
5 (Burlington)	954.0	395.7
6 (Mason City)	902.5	344.2
Average/unknown	939.8	381.5

[760] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.
[761] 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.
[762] See "IA Refrig Freezer Recycling.xls' for details.

Regression analysis: Freezers

Energy savings for freezers are based upon a linear regression model using the following coefficients:[763]

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

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

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

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

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

$UEC_{BaseFreezer}$ = Assumed consumption of a new baseline residential sized freezer

= 381.2 kWh[764]

Deemed approach: Freezers

$$\Delta kWh_{Unit} = UEC_{Retired} - UEC_{BaseFreezer}$$

Where:

$UEC_{Retired}$ = Unit Energy Consumption of retired unit based on Mid American and Alliant 2019 and 2020 program data[765]:

Independent Variable Description	2019/2020 Program Data
Age (years)	30.3
Pre-1990 (=1 if manufactured pre-1990)	0.49
Size (cubic feet)	15.7

[763] 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.

[764] 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.

[765] See "IA Refrig Freezer Recycling.xls' for details.

Independent Variable Description	2019/2020 Program Data
Chest Freezer Configuration (=1 if chest freezer)	0.50
Interaction: Located in Unconditioned Space x CDD/365.25	0.83

Deemed freezer savings are provided below:

Climate Zone (City based upon)	UEC	ΔkWh per unit
5 (Burlington)	962.4	581.2
6 (Mason City)	894.5	513.3
Average/unknown	943.2	562.0

Additional Waste Heat Impacts[766]

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

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

Where:

Conditioned = % of units in conditioned space

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

= If unknown assume unit is in conditioned space – 100%

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

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

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

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

= 54% for unit in heated space[767]

= 0% for unit in heated space

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

= Actual - If not available, use:[768]

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 on	8.2	2.40

[766] 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.

[767] Based on 197 days where HDD 55>0, divided by 365.25.

[768] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.38[769]

%ElecHeat = Percentage of businesses with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	30%[770]

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

= (CoolF / ηCool) * %Cool

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

= 34% for unit in cooled space[771]

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP[772]

%Cool = Percentage of businesses with cooling

AC use	%Cool
Cooling	100%
No Cooling	0%
Unknown	74%[773]

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta kWh_{WasteHeat}$
Refrigerator	5 (Burlington)	-10.9
	6 (Mason City)	-9.5
	Average/unknown	-10.5
Freezer	5 (Burlington)	-16.0

769 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.

770 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).

771 Based on 123 days where CDD 65>0, divided by 365.25.

772 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).

773 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.

Unit Type	Climate Zone (City based upon)	$\Delta kWh_{WasteHeat}$
	6 (Mason City)	-14.1
	Average/unknown	-15.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

HOURS = Equivalent Full Load Hours as calculated using eShapes loadprofile

Refrigerators = 5280

Freezers = 5895

WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat:[774]

Refrigerator Location	WHFdCool
Cooled space	1.29[775]
Uncooled	1.0

CF = Coincident factor as calculated using eShapes loadprofile

Refrigerators = 70.9%

Freezers = 95.3%

Deemed approach: Refrigerators

Climate Zone (City based upon)	ΔkW per unit
5 (Burlington)	0.0507
6 (Mason City)	0.0441
Average/unknown	0.0489

Deemed approach: Freezers

[774] 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.

[775] 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.

Climate Zone (City based upon)	ΔkW per unit
5 (Burlington)	0.0897
6 (Mason City)	0.0792
Average/unknown	0.0867

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).[776]

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

Where:

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

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

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

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

= 54% for unit in heated space[777]

= 0% for unit in unheated space

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

=Actual, if unknown assume74%[778]

%GasHeat = Percentage of businesses with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	70%[779]

0.03412 = Converts kWh to Therms

[776] 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.

[777] Based on 197 days where HDD 55>0, divided by 365.25.

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

[779] 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.

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta Therms_{WasteHeat}$
Refrigerator	5 (Burlington)	-3.0
	6 (Mason City)	-2.6
	Average/unknown	-2.8
Freezer	5 (Burlington)	-4.3
	6 (Mason City)	-3.8
	Average/unknown	-4.2

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:

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 197[780]

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta Therms_{WasteHeat}$
Refrigerator	5 (Burlington)	-0.0150
	6 (Mason City)	-0.0131
	Average/unknown	-0.0145
Freezer	5 (Burlington)	-0.0220
	6 (Mason City)	-0.0195
	Average/unknown	-0.0213

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-REF-RFRC-V03-220101

[780] Number of days where HDD 55 >0.

SUNSET DATE: 1/1/2026

3.8.7. Scroll Refrigeration Compressor

DESCRIPTION

This measure applies to scroll refrigerant compressors utilized in commercial refrigeration including supermarkets, foodservices and convenience store applications.[781] 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 continuously.[782] 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.[783]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be the existing reciprocating compressor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for scroll compressors is 12 years.[784]

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

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[781] 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.

[782] 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.

[783] Following the expansion of highly efficient motors rules effective March 2015, the US DOE Code of Federal Regulations also regulates and has appliance/code standards for the efficiency level of pumps, fans and compressors in order to improve overall system efficiency. The final ruling for compressors and walk-in coolers/freezers refrigeration systems was made effective in September 2017 with compliance required on July 10, 2020.

[784] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.5, "Effective/Remaining Useful Life Values", California Public Utilities Commission. See "DEER2014-EUL-table-update_2014-02-05.xlsx"

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \frac{\left((Avg\ Cap * FLH) * (\frac{1}{EER_{base}} - \frac{1}{EER_{ee}})\right)}{1000} * units$$

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 used.[785]

EER_{Base} = Cooling efficiency of existing compressor in Btu/watt-hour. See reference tables for values.

EER_{ee} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour. See reference tables for values

FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are as follows for the different refrigeration temperature applications.[786]

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

Units = Number of units

= Actual number of units installed

Summer Coincident Peak Demand Savings

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

Where:

kW = gross customer connected load kW savings for the measure (kW)

FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3910 hours for medium temperature applications and 4139 hours for low temperature applications.[787]

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

Natural Gas Energy Savings

N/A

[785] 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.

[786] 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

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

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES[788]

Baseline and Qualifying EER Values by Capacity, and Temperature Application[789]

Low Temperature Baseline and Qualifying EER Condensing temp 90°F, Evap Temp -25°F			
Capacity Bins in BTU/Hr	**HP equivalent**[790]	**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

788 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.

789 Supermarket refrigeration systems typically operate at two evaporator temperatures, medium temperature and low temperature. Medium temperature cases vary from 10˚F to 35˚F with a typical mean evaporating temperature of 20˚F. Medium temperature cases are typically used for meats, dairy, beverages and walk-in coolers. Low-temperature cases vary from -15˚F to - 25˚F and are used for frozen foods, ice cream, and walk-in freezers. A typical mean low temperature evaporating temperature is -25˚F.

790 At low temperatures the standard calculation for Compressor HP vs. Btu/Hr is 4226 Btu/hr per HP. Round numbers to 4200 for ease of binning.

Medium Temperature Baseline and Qualifying EER Condensing temp 90°F, Evap Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase	Average EERee
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

MEASURE CODE: MEASURE CODE: NR-RFG-SCR-V02-190101

SUNSET DATE: 1/1/2023

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.[791]

Deemed Measure Cost

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of $10.22 per square foot.[792]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below,[793] 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

= 561 Btu/hr for coolers and 898 Btu/hr for freezers

[791] DEER 2014 Effective Useful Life

[792] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008.

[793] Algorithms and assumptions from Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Strip Curtains v.1.4

	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 (ft^2) of cooler or freezer covered by strip curtains

= Custom or if unknown, assume 21 ft^2

For example, a cooler with strip curtains installed at a grocery store, using the defaults from above, would save:

ΔkWh = ((Q_{Base}/EER × 1000) - (Q_{EE}/EER × 1000)) × EFLH/A × A

ΔkWh = ((4,661/10.6 × 1000) - (559/10.6 × 1000)) × 7,693/21 × 21

= 2,977.0 kWh

Savings for grocery stores, restaurants, convenient stores, and unknown building types are presented in the table below.[794]

	Grocery Store		Restaurant		Convenience Store		Unknown Building Type	
	(kWh/ft^2)	(kWh/ Case)	(kWh/ft^2)	(kWh/ Case)	(kWh/ft^2)	(kWh/ Case)	(kWh/ft^2)	(kWh/ Case)
Cooler	142.3	2,988.1	31.4	659.9	26.3	553.2	59.5	1,249.7
Freezer	619.3	13,005.4	168.1	3,529.1	39.1	820.9	251.4	5,278.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh/EFLH) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.964

794 Savings for unknown building types represent the average of grocery store, restaurant, and convenience store savings.

Other variables as defined above.

For example, a cooler with strip curtains installed at a restaurant, using the defaults above, would save:

ΔkW = (2,977.0/7,693) * 0.964

= 0.3730 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-V03-190101

Sunset Date: 1/1/2021*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

3.8.9. Ice Maker

DESCRIPTION

This measure relates to the installation of a new ENERGY STAR certified commercial ice maker. The ENERGY STAR label applies to air-cooled, batch-type and continuous-type machines including ice-making head (IMH), remote-condensing units (RCU), and self-contained units (SCU). ENERGY STAR ice makers are approximately 15% more efficient than standard ice makers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the efficient equipment must be an ENERGY STAR certified commercial ice maker meeting energy consumption rate and potable water use limits, as determined by equipment type and for batch-type ice makers, ice harvest rate range.[795]

ENERGY STAR Requirements (Version 3.0, Effective January 28, 2018)

ENERGY STAR Requirements for Air-Cooled Batch-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)	Potable Water Use (gal/100 lbs ice)
IMH	H < 300	≤ 9.20 - 0.01134H	≤ 20.0
	300 ≤ H < 800	≤ 6.49 - 0.0023H	
	800 ≤ H < 1500	≤ 5.11 - 0.00058H	
	1500 ≤ H ≤ 4000	≤ 4.24	
RCU	H < 988	≤ 7.17 – 0.00308H	≤ 20.0
	988 ≤ H ≤ 4000	≤ 4.13	
SCU	H < 110	≤ 12.57 - 0.0399H	≤ 25.0
	110 ≤ H < 200	≤ 10.56 - 0.0215H	
	200 ≤ H ≤ 4000	≤ 6.25	
ENERGY STAR Requirements for Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)	Potable Water Use (gal/100 lbs ice)
IMH	H < 310	≤ 7.90 – 0.005409H	≤ 15.0
	310 ≤ H < 820	≤ 7.08 – 0.002752H	
	820 ≤ H ≤ 4000	≤ 4.82	
RCU	H < 800	≤ 7.76 – 0.00464H	≤ 15.0
	800 ≤ H ≤ 4000	≤ 4.05	
SCU	H < 200	≤ 12.37 – 0.0261H	≤ 15.0
	200 ≤ H < 700	≤ 8.24 – 0.005429H	
	700 ≤ H ≤ 4000	≤ 4.44	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new commercial ice maker that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

[795] https://www.energystar.gov/sites/default/files/Final%20V3.0%20ACIM%20Specification%205-17-17_1_0.pdf

The expected measure life is assumed to be 8 years.[796]

Deemed Measure Cost

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is $0 for Batch-Type and $222 for Continuous-Type ice makers.[797]

Loadshape

Loadshape NRE01 - Nonresidential Electric Refrigeration – Restaurant

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below, otherwise use deemed values from the table that follows.[798]

$$\Delta kWh = \left[\frac{(kWh_{Base} - kWh_{ESTAR})}{100}\right] * (Duty * H) * Days$$

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)

[796] Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016 http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[797] Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. Calculator cites EPA research using AutoQuotes, 2016.

[798] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh_{Base}	kWh_{ESTAR}
IMH	H < 300	10-0.01233H	≤ 9.20 - 0.01134H
	300 ≤ H < 800	7.05-0.0025H	≤ 6.49 - 0.0023H
	800 ≤ H < 1500	5.55-0.00063H	≤ 5.11 - 0.00058H
	1500 ≤ H ≤ 4000	4.61	≤ 4.24
RCU	H < 988	7.97-0.00342H	≤ 7.17 – 0.00308H
	988 ≤ H ≤ 4000	4.59	≤ 4.13
SCU	H < 110	14.79-0.0469H	≤ 12.57 - 0.0399H
	110 ≤ H < 200	12.42-0.02533H	≤ 10.56 - 0.0215H
	200 ≤ H ≤ 4000	7.35	≤ 6.25
Energy Consumption of Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh_{Base}	kWh_{ESTAR}
IMH	H < 310	9.19-0.00629H	≤ 7.90 – 0.005409H
	310 ≤ H < 820	8.23-0.0032H	≤ 7.08 – 0.002752H
	820 ≤ H ≤ 4000	5.61	≤ 4.82
RCU	H < 800	9.7-0.0058H	≤ 7.76 – 0.00464H
	800 ≤ H ≤ 4000	5.06	≤ 4.05
SCU	H < 200	14.22-0.03H	≤ 12.37 – 0.0261H
	200 ≤ H < 700	9.47-0.00624H	≤ 8.24 – 0.005429H
	700 ≤ H ≤ 4000	5.1	≤ 4.44

100 = Factor to convert kWh_{Base} and kWh_{ESTAR} into energy consumption per pound of ice

Duty = Duty cycle (%) of ice maker

= Custom or if unknown, use 0.75

H = Ice harvest rate (pounds of ice/day)

= Custom or if unknown, use value from table below as determined by equipment type

Ice Harvest Rate (H) of Air-Cooled Batch-Type Ice Makers		
IMH	RCU	SCU
650	1,150	170
Ice Harvest Rate (H) of Air-Cooled Continuous-Type Ice Makers		
IMH	RCU	SCU
680	1,170	240

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

ΔkWh = [((7.05 – 0.0025*650) – (6.49 – 0.0023 * 650)) / 100] * (0.75 * 650) * 365.25

= [((5.425) – (4.995)) / 100] * (0.75 * 650) * 365.25

= 765.7 kWh

Savings for all ice maker types are presented in the table below.

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	kWh_{Base}	kWh_{ESTAR}	Savings (kWh)
IMH	9,659.7	8,894.1	765.7
RCU	14,459.8	13,010.7	1,449.1
SCU	3,778.6	3,215.6	563.0
Energy Consumption of Air Cooled Continuous-Type Ice Makers			
Ice Maker Type	kWh_{Base}	kWh_{ESTAR}	**Savings (kWh)**
IMH	11,277.2	9,702.5	1,574.7
RCU	16,217.6	12,980.5	3,237.1
SCU	5,241.5	4,560.8	680.7

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, calculated above

Hours = Average daily hours of operation

= Custom or if unknown, use 12 hours per day

CF = Summer peak coincidence factor

= 0.964

Other variables as defined above.

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

ΔkW = 765.7 / (12 * 365.25) * 0.964

= 0.1684kW

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain “maximum potable water use per 100 pounds of ice made” requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory indicates that all of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement.[799] Therefore, there are no assumed water impacts for this measure.

[799] AHRI Certification Directory, Accessed on 3/21/2018

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ESIM-V02-190101

SUNSET DATE: 1/1/2024

3.8.10. Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

Description

This measure is for the installation of controls for efficient motors – defined as electrically commutated motors (ECM) or Q-Sync motors, per measure 3.8.3 – in existing walk-in and display case coolers or freezers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow.

This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 3.8.3 Efficient Motor for Walk-in and Display Case Coolers / Freezers.

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

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

Definition of Efficient Equipment

The measure must control a minimum of 16 Watts where fans operate continuously at full speed. This measure is limited to motors that are rated equal to or less than 3/4 HP output capacity. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

- The compressor runs more than 4380 hours annually
- The evaporator fan does not run at full speed all the time
- The evaporator fan motor runs on poly-phase power
- Evaporator does not use off-cycle or time-off defrost.

Definition of Baseline Equipment

In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by electrically commutated motors (ECM) or Q-Sync motors.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[800]

Deemed Measure Cost

The measure cost is assumed to be $291.[801]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Savings are estimated using a trend fit based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association[802] and supported by a PGE workpaper. Note that climate differences across all

[800] Source: DEER
[801] Source: DEER
[802] See ‘Evap Fan Control.xlsx’.

California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Iowa. Savings found in the aforementioned source are presented in combination with savings from an ECM upgrade, however for the purposes of this measure only those associated with the controller are considered.

Electric Energy Savings

$$\Delta kWh = \left(\left(5988.5 * kW_{Output}\right) + 63.875\right) * \#Motors$$

Where:

kW_{Output} = Output wattage of installed fan motor, in kW

= Actual or if unknown, use 0.01495 kW[803]

#Motors = number of fan motors controlled

For example, a cooler with ECM motor controls for three 0.15 kW evaportor fans would save:

ΔkWh = ((5988.5 * kW_{Output}) + 63.875) * #Motors

ΔkWh = ((5988.5 * 0.15) + 63.875) * 3

= 2886.5 kWh

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, calculated above

Hours = Annual hours of cooler or freezer operation

= Assume 8,766 hours

CF = Summer peak coincidence factor

= 0.964[804]

For example, a cooler with ECM motor controls for three 0.15 kW evaportor fans would save:

ΔkW = $(\Delta kWh/Hours) * CF$

ΔkW = ((2886.5/8766) * 0.964

= 0.32 kW

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

803 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.

804 Based on modeling performed by VEIC of Grocery building type. This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECMC-V01-190101

SUNSET DATE: 1/1/2024

3.8.11. Adding Doors to Open Refrigeration Display Cases

Description

Open display cases are typically found in grocery and convenience stores and have been a preference of store owners because they allow customers a clear view and easy access to refrigerated products. This measure is retrofitting existing, open, refrigerated display cases by adding and installing doors. The baseline equipment is an open vertical or horizontal display case with no doors or covering. The efficient equipment is the installation of solid doors on the existing display case. Replacement of open display cases with new display cases with doors is not covered under this measure characterization.

Energy savings are based on air infiltration reduction from the addition of doors to the open display cases. The air infiltration reductions assume a reduced heat gain and subsequent reduced load on the refrigeration compressors. Both radiant and conduction heat losses were factored into the analysis as well. Energy savings are based on a per linear foot of display case.

Interactive HVAC energy savings were also included in the measure savings analysis. The HVAC interactive effects calculation assesses the measure's impact on the heating and cooling equipment. With adding a door to an open refrigerated display case, excess cold air leaking into the conditioned space no longer has to be treated by the heating system, resulting in additive savings. Similarly, the reduction in cold air from the open refrigerated display case no longer supplements the efforts of the space cooling equipment, which results in an overall increase in its consumption.

High, medium, and low temperature cases are eligible for this measure; however, the measure assumptions detailed in this characterization are based on medium temperature display cases, with the installation of zero energy doors, as it was deemed the most likely candidate for participation in this measure.

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

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

Definition of Efficient Equipment

The efficient condition is retrofitting an existing open, refrigerated, display case by adding doors.

Definition of Baseline Equipment

The baseline condition is an open, refrigerated, display case without any covering.

Deemed Lifetime of Efficient Equipment

The expected measure life is 12 years.[805]

Deemed Measure Cost

The incremental cost, which includes both material and labor, is $522 per linear foot.[806]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

[805] The measure life is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

[806] The incremental cost is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

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

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = ((\Delta HG \, * \, CL) / \, (EER \, * \, 1000) \, * \, 8760) \, + \, (MMBtu_{HVAC\,Cool} \, * \, CL \, * \, (1 \, / \, SEER) \, * \, 1000)$$

Where:

ΔkWh = gross customer annual kWh savings

ΔHG = Heat Gain, the decreased load or the reduced heat gain on the open refrigerated display case with the installation of a door (Btu/hr-linear foot)

= 1,148 Btu/h-ft[807]

CL = Case Length, refrigerated case length in feet

= Actual

EER = Energy Efficiency Ratio; display case compressor efficiency (Btu/hr-watt)

= Actual. If unknown, use 11.36[808]

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

8760 = Annual operating hours of the refrigerated display case[809]

$MMBtu_{HVAC\,Cool}$ = Total cooling load increase on the HVAC equipment per linear foot of display case

= -2.789 MMBtu/ft[810]

SEER = Seasonal Energy Efficiency Ratio; HVAC equipment operating efficiency (Btu/hr-watt)

807 The change in heat gain is sourced as the typical value for a medium temperature display case adding doors from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116", April 2014. The workpaper assumes a net reduction in heat gain with the installation of doors on open refrigerated display cases. The primary benefits account for the decrease in excess heat entering the display case from air infiltration. Radiation and conduction heat gains were also included in the derivation of this value. Additionally, the net heat gain has built in assumptions on how often the refrigerated case doors will be used and the display case accessed by customers and site associates, reducing some of the air infiltration benefits of the new door.

808 Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications. The efficiency analysis and product review is sourced from the Efficiency Vermont TRM, which utilizes data from Emerson Climate Technology software. Medium temperature cases have an EER value of 11.36.

809 The measure assumes the baseline equipment is not employing night covers or any other covering but is in fact left open for the duration of its operation.

810 The MMBtu increase on the HVAC cooling equipment is based on an outdoor air temperature bin analysis, the total hours of operation of the cooling system, and the building's overall loss of additional cooling as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain amount of conditioned air has to be treated to replace the air previously cooled by the display case. Furthermore, the analysis assumes an increased load on the cooling system, at outdoor temperatures above 62.5°F. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load increase on the HVAC cooling equipment per linear foot of display case, please see the 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

= Actual. If unknown, use 13.00[811]

For example, a grocery store installed doors on four open refrigerated cases, which amounted to 12 linear feet of retrofitted display cases, savings the site:

ΔkWh = ((1148 x 12) / (11.36 x 1000) x 8760) + (-2.789 x 12 x (1 / 13) x 1000)

= 8,049 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((\Delta HG * CL)/(EER * 1000) * CF_{Refrigeration}) + ((MMBtu_{HVAC\ Cool} / Hours_{Cool} * CL * (1 / SEER) * 1000) * CF_{Cool})$$

Where:

$Hours_{Cool}$ = Total combined hours the site is providing cooling

= 3,329 hours[812]

$CF_{Refrigeration}$ = Summer peak coincidence factor for the refrigerated display case

= 0.964

CF_{Cool} = Summer peak coincidence factor for the HVAC cooling system (dependent on building type)

Building Type	CF_{Cool}[813]	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average[814]	92.3%	N/A

NATURAL GAS SAVINGS

[811] In light of limited existing market data for the efficiency of commercial air condition equipment in Iowa grocery and convenience stores, SEER assumptions are conservatively sourced from IECC 2012

[812] The total combined hours in which the site is providing cooling is based on an outdoor air temperature bin analysis, where the site is conditioning cold air at outdoor temperatures of 62.5°F and above. Weather data was sourced from TMY3 data for Des Moines, IA. For more information on the derivation of these hours, please see 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

[813] This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

[814] For weighting factors, see HVAC variable table in section 3.3.

$$\Delta Therms = MMBtu_{HVAC\ Heat} * CL * (1 / AFUE) * 10$$

Where:

ΔTherms = gross customer annual therms savings

$MMBtu_{HVAC\ Heat}$ = Total heating load decrease on the HVAC equipment per linear foot of display case

= 4.754 MMBtu/ft[815]

CL = Case Length, refrigerated case length in feet

= Actual

AFUE = 80%[816]

10 = Conversion from MMBtu to therms

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF[817]	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest

[815] The MMBtu decrease on the HVAC heating equipment is based on an outdoor air temperature bin analysis, the total hours of operation in which the site is providing heat, and the building's overall reduced heating load as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain reduction of conditioned air that had to be treated to make up for the air previously cooled by the display case. The reduced heat gain on the refrigerated display case equals the reduced heat loss by the site and a heating load that no longer has to be provided by the HVAC system. Furthermore, the analysis assumes a decrease load on the heating system, at outdoor temperatures below 62.5°F. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load decrease on the HVAC heating equipment per linear foot of display case, please see the 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

[816] Typical heating system efficiency of 80%, consistent with current heating efficiency assumptions for lighting HVAC interactive effects for commercial fossil fuel-fired systems.

[817] Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF[817]	Model Source
Nonresidential Average[818]	0.014658	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFR-DOOR-V01-210101

SUNSET DATE: 1/1/2026

[818] For weighting factors, see HVAC variable table in section 3.3.

3.8.12 Refrigeration Economizers

Description

This measure applies to commercial walk in refrigeration systems and may include outside air economizers as well as evaporator fan controllers. Economizers save energy by bringing in outside air when weather conditions allow, rather than operating the compressor to satisfy a cooling load. Typically, walk-in refrigeration systems evaporator fans run not only during times the compressor is operating, but also when there is no cooling load to provide air circulation. Evaporator fans can be an inefficient method of providing air circulation since they can be oversized for the sole function of circulation. Therefore, installing an auxiliary circulator fan and using it instead to meet circulation needs can offer additional energy savings. Energy is not only saved from a lower circulation power requirement, but also from the fact that there is less waste heat from the motors that the system would have to subsequently remove. This measure allows for economizer systems with evaporator fan controls plus a circulation fan or without the option of a circulation fan.

This measure was designed to best characterize walk in refrigeration systems with compressors that are less than 8 horsepower in size individually and operate at a temperature setpoint within the range of 15-55 degrees Fahrenheit. Systems not meeting these specifications should be considered on a custom basis.

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

If applied to other program types, the measure savings should be verified. IECC code requires economizers in certain instances and therefore projects relying on code baseline definitions must verify eligibility.

Definition of Efficient Equipment

A commissioned economizer system installed on a walk-in refrigeration system.

Definition of Baseline Equipment

The baseline condition is a walk-in refrigeration system without an economizer**.**

Deemed Lifetime of Efficient Equipment

The estimated life of this measure is 15 years.[819]

Deemed Measure Cost

Installation costs can vary considerably depending on system size (larger systems may require multiple economizer units), physical site layouts (locating economizer intakes and ductwork), and controls elected. Therefore, actual site-specific costs should be used as a custom cost input.

Loadshape

Loadshape NRE17 – Refrigeration Economizer

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Electric energy savings is dependent on whether the economizer system is installed with an auxiliary circulator fan

[819] Estimated life from Efficiency Vermont TRM

and controls necessary to turn off evaporator fans when the compressor is not operating.

With Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] + [((kWEvap * nFans * DCComp * BF) - kWCirc - (kWEcon * DCEcon)) * Hours]$$

Without Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] - [kWEcon * DCEcon * Hours]$$

Where:

HP = Horsepower of Compressor

= actual installed

kWhCond = Condensing unit savings, per hp. Based on climate zone and compressor type (value from savings table):[820]

Climate Zone (City based upon)	Hermetic / Semi-Hermetic	Scroll	Discus
Zone 5 (Burlington)	758	665	629
Zone 6 (Mason City)	1149	1009	995
Average/unknown	815	716	667

Hours = Number of annual hours that economizer operates:[821].

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	1,877
Zone 6 (Mason City)	2,848
Average/unknown	2,020

DCComp = Duty cycle of the compressor

= 50% [822]

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW[823]

kWCirc = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW[824]

nFans = Number of evaporator fans

[820] See Iowa Economizer Calc.xls for derivation and details. 5HP compressor size used to develop kWh/Hp value. Assumes no floating head pressure controls and compressor is located outdoors.

[821] Based on TMY3 data for respective cities. Assumes a cooler setpoint of 38 degrees and economizer deadband setting of 5 degrees (economizer won't begin operation until temperature is 33 degrees or lower).

[822] A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor.

[823] Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

[824] Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present

= actual number of evaporator fans

DCEcon = Duty cycle of the economizer fan on days that are cool enough for the economizer to be working

= If known, actual installed. Otherwise assume 63%[825]

BF = Bonus factor for reduced cooling load attributed to removing waste heat from evaporator fans. Dedicated high-efficiency circulator fans require less power and use high efficiency motors, resulting in less waste heat.

= 1.3[826]

kWEcon = Connected load kW of the economizer fan(s)

= If known, actual installed. Otherwise assume 0.227 kW.[827]

For example, adding an outdoor air economizer with an efficient circulator fan and controls in climate zone 5 to a 5 hp walk in refrigeration unit with 3 evaporator fans and a scroll compressor would annually save (assuming other default assumptions):

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans * DCComp * BF) – kWCirc – (kWEcon * DCEcon)) * Hours]

= [5 * 665] + [((0.123 * 3 * .5 * 1.3) – 0.035 – (0.227 * 0.63)) * 1877]

= 3208.9 kWh

Summer Coincident Peak Demand Savings

No savings are expected since all savings occur during the winter months.

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-RFG-ECON-V01-210101

Sunset Date: 1/1/2024

825 Average of two manufacturer estimates of 50% and 75%.

826 Bonus factor (1+ 1/3.5) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F

827 The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).

3.8.13 Auto-Closers for Walk-In Doors

Description

This measure is for installing an auto-closer to the main insulated opaque door(s) of a walk-in cooler or freezer. The auto-closer must firmly close the door when it is within 1 inch of full closure.

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

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

Definition of Efficient Equipment

This measure consists of the installation of an automatic, hydraulic-type door closer on main walk-in cooler or freezer doors. These closers save energy by reducing the infiltration of warm outside air into the refrigeration itself.

Definition of Baseline Equipment

The baseline condition is assumed to be a walk-in cooler or freezer without an automatic closure.

Deemed Lifetime of Efficient Equipment

The deemed measure life is 8 years.[828]

Deemed Measure Cost

The deemed measure cost is $157.19 for a walk-in cooler or freezer.[829] This is consistent with the value found in the NW RTF Measure data.

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

Calculation of Savings

Electric Energy Savings

Savings calculations are based on values from NW Regional Technical Form developed measure "Grocery Store Door Auto Closer".[830]

Annual Savings	Refrigerated Space Temperature	kWh
Walk in Cooler	Medium	215
Walk in Freezer	Low	2,730

[828] DEER 2014 Effective Useful Life

[829] Southern California Edison "Refrigerated Storage Auto Closer: Work Paper SCE17RN024 Revision 0", pg 10. November 4, 2016.

[830] Based on NW RTF measure (v.2 from 2014) savings, which were based on the consumptions found in lab tests by Emerson Gasket Test Lab, conducted in September 2008. For specific set points & values, please see NW RTF_ComGroceryAutoCloser_v1_2.xlsm.

Summer Coincident Peak Demand Savings

The measure has deemed kW savings[831] therefore a coincidence factor does not apply.

Annual Savings	Refrigerated Space Temperature	kW
Walk in Cooler	Medium	0.054
Walk in Freezer	Low	0.680

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: NR-RFG-ACWD-V01-220101

Sunset Date: 1/1/2027

[831] Based on NW RTF measure (v.2 from 2014) savings, which were based on the consumptions found in lab tests by Emerson Gasket Test Lab, conducted in September 2008. For specific set points & values, please see NW RTF_ComGroceryAutoCloser_v1_2.xlsm

3.8.14 Refrigeration Tune-Up – Remote Condensing Unit

Description

Refrigeration tune-up (maintenance) includes the professional cleaning of refrigeration system condenser and evaporator tubes, oil level and pressure, compressor and pump checks, pressure control checks, filter inspections, defrost, etc. Follow check list of items for proper operation. This tune-up measure is specific to non-self-contained refrigeration equipment, such as split and rack systems.

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

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

Definition of Efficient Equipment

The efficient condition is remote condensing unit refrigeration equipment associated with a commercial enterprise that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The certified technician must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks:

- Clean and inspect condenser and evaporator coils;
- Clean drain pan;
- Inspect/clean fans, screens, grills, filters, and drier cores;
- Check operation and optimize of sub-cooling and superheat temperatures, heat reclaimers, and defrost heaters
- Tighten all line voltage connections;
- Inspect/replace relays and capacitors as needed; and
- Add/remove refrigerant charge as needed.

Definition of Baseline Equipment

The baseline condition is a commercial remote condensing refrigeration system that has not been inspected or tuned up in more than 12 months.

Deemed Lifetime of Efficient Equipment

The expected measure life is 3 years.[832]

Deemed Measure Cost

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used.

Loadshape

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{\left(Capacity * FLH * (\frac{1}{EER_{base}})\right)}{1000} * SF$$

Where:

Capacity = Refrigeration system capacity in Btu/h. See reference table for values based on system compressors. For prescriptive measures the average capacity for each range of size is used.[833]

EER_{Base} = Efficiency of existing refrigeration system in Btu/watt-hour. Use actual if known. If unknown, default to reference tables for compressor values.

FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are as follows for the different refrigeration temperature applications.[834]

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

SF = Refrigeration savings factor from tune-up

= 6%[835]

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.[836]

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

[833] 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.

[834] 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

[835] The 6% savings factor represents a mid-point estimate based on the following sources; 7% savings is indicated from Wisconsin's FOE program. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0 and 5% savings is indicated for combined maintenance/energy service tune-ups from online sources like supermarket green news, chill match, and Verisae.

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

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES[837]

Baseline and Qualifying EER Values by Capacity, and Temperature Application[838]

Low Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp -25°F		
Capacity Bins in BTU/Hr	HP equivalent[839]	Average EERbase
0-4200	1	3.85
4200-8399	2	4.83
8400-12599	3	5.06
12600-16799	4	5.26
16800-20999	5	5.36
21000-25199	6	5.69
25200-29399	7	5.71
29400-33599	8	6.14
33600-37800	9	5.64
37800-42000	10	5.73

Medium Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp 20°F		
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase
0-7500	1	8.14
7500-14999	2	9.28
15000-22499	3	10.64
22500-29999	4	11.18
30000-37499	5	11.12

[837] 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.

[838] Supermarket refrigeration systems typically operate at two evaporator temperatures, medium temperature and low temperature. Medium temperature cases vary from 10˚F to 35˚F with a typical mean evaporating temperature of 20˚F. Medium temperature cases are typically used for meats, dairy, beverages and walk-in coolers. Low-temperature cases vary from -15˚F to - 25˚F and are used for frozen foods, ice cream, and walk-in freezers. A typical mean low temperature evaporating temperature is -25˚F.

[839] At low temperatures the standard calculation for Compressor HP vs. Btu/Hr is 4226 Btu/hr per HP. Round numbers to 4200 for ease of binning.

Medium Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp 20°F		
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase
37500-44999	6	11.74
45000-52499	7	11.68
52500-59999	8	12.54
60000-67499	9	12.46
67500-75000	10	11.44

MEASURE CODE: NR-RFG-TURU-V01-220101

SUNSET DATE: 1/1/2027

3.8.15 Refrigeration Tune-Up – Self-Contained Unit

Description

Refrigeration tune-up (maintenance) includes the professional cleaning of refrigeration system condenser and evaporator tubes, oil level and pressure, compressor and pump checks, pressure control checks, filter inspections, defrost, etc. Follow check list of items for proper operation. This tune-up measure is specific to self-contained refrigeration equipment.

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

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

Definition of Efficient Equipment

The efficient condition is self-contained condensing unit refrigeration equipment associated with a commercial enterprise that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The certified technician must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks:

- Clean and inspect condenser and evaporator coils;
- Clean drain pan;
- Inspect/clean fans, screens, grills, filters, and drier cores;
- Check operation and optimize of sub-cooling and superheat temperatures, heat reclaimers, and defrost heaters
- Tighten all line voltage connections;
- Inspect/replace relays and capacitors as needed; and
- Add/remove refrigerant charge as needed.

Definition of Baseline Equipment

The baseline condition is a commercial self-contained condensing refrigeration system that has not been inspected or tuned up in more than 12 months.

Deemed Lifetime of Efficient Equipment

The expected measure life is 3 years.[840]

Deemed Measure Cost

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used.

Loadshape

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

[840] The expected measure life is sourced from DEER2014 EUL Table for measures: "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils".

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{kW}{Hp} * Hours * DC * Hp * SF$$

Where:

$$\frac{kW}{Hp} = \frac{(V * A * PF)}{1000 * Hp}$$

V = Volts

= Actual, if known

A = Amps

= Actual, if known

PF = Power factor

= Actual, if known

Hp = Nominal horsepower of the unit

= Actual

If refrigeration system equipment metrics are unknown, default kW/hp can be sourced from the following tables:[841]

Average Refrigerator Compressor Demand and Consumption per Horsepower (kW/Hp)

Size Tier	kW/Hp	Weighting
¼ hp	1.6503	40%
½ hp	1.3832	40%
¾ hp	1.3800	10%
1 hp	1.4582	10%
Average	1.4972	100%

Average Freezer Compressor Demand and Consumption per Horsepower (kW/Hp)

Size Tier	kW/Hp	Weighting
¼ hp	1.3111	20%
½ hp	1.3984	10%
¾ hp	1.1776	40%
1 hp	1.2637	30%
Average	1.2522	100%

Hours = 8,760 hours

[841] Source: Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92. Weights not based on actual market share, but on the number of compressors for which data is available in each category

DC =Duty cycle of compressor[842]

= 62% for refrigerators

= 80% for freezers

SF = Refrigeration savings factor from tune-up

= 6%[843]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

kW = gross customer connected load kW savings for the measure (kW)

Hours = 8760 hours

DC =Duty cycle of compressor[844]

= 62% for refrigerators

= 80% for freezers

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

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-TUSC-V01-220101

SUNSET DATE: 1/1/2027

[842] System duty cycle is sourced from, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92,

[843] The 6% savings factor represents a mid-point estimate based on the following sources; 7% savings is indicated from Wisconsin's FOE program. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0 and 5% savings is indicated for combined maintenance/energy service tune-ups from online sources like supermarket green news, chill match, and Verisae.

[844] System duty cycle is sourced from, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92,

3.8.16 Vending Machine Controllers

Description

This measure relates to the installation of new controls on either a new or existing non-ENERGY STAR refrigerated beverage vending machines. A refrigerated beverage vending machine is a commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages (a beverage in a sealed container) on payment. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations.

This measure relates to the installation of a new control on a new or existing unit. This measure should **not** be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a standard non-ENERGY STAR refrigerated beverage vending machine, without a control system capable of powering down lighting and refrigeration systems during periods of inactivity. This includes new or rebuilt, Class A, Class B, Combination A, or Combination B refrigerated vending machines that are not ENERGY STAR certified, but adhere to Federal Energy Conservation Standards. [845]

Deemed Lifetime of Efficient Equipment

The measure expected useful life (EUL) is assumed to be 5 years. [846]

Deemed Measure Cost

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes:

Refrigerated Vending Machine: $215.50[847]

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

[845] 10 CFR §431.296 (a) &(b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines. (a) is effective for machines manufactured before January 8, 2019. (b) is effective for machines manufactured on or after January 8, 2019.

[846] The expected measure life is from DEER2014 EUL Table for "Vending Machine Controller", updated February 5, 2014. This is consistent with the Massachusetts Joint Utilities Measure Life Study, Energy & Resource Solutions, November 2005.

[847] San Diego Gas & Electric "Work Paper WPSDGENRCS0001 Vending Machine Controller" June 15, 2012. Measure cost + Labor cost.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \Delta kWhLighting + \Delta kWhRef\ BMC$$

$$\Delta kWhLighting = ((8760 - HOURS_{Occupied}) * WBulb)/1000$$

$$\Delta kWhRef\ BMC = MDEC * SleepHours / 24 * Days$$

Where:

$HOURS_{Occupied}$ = Assumed hours of occupancy [848]

Building Type	$HOURS_{Occupied}$
Education	1,877
Health	3,806
Hospital	6,520
Industrial	2,850
Lodging	3,061
Multifamily	3,061
Office - Large	2,920
Office - Small	2,920
Religious	2,412
Restaurant	5,443
Retail - Large	4,065
Retail - Small	3,694
Warehouse	2,920
Non-Residential Average	**3,065**

If Unknown, select the "Non-Residential Average".

W_{Bulb} = Wattage of bulb in Refrigerated Beverage Vending Machine.

= Actual, if unknown use 56.4 W[849] for fluorescent T8 bulbs[850] and 31.6 W[851] for TLEDs.

---

[848] Hours of Use per section 3.4 Lighting, weighted per section 3.3 HVAC. The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging.

[849] See IL TRM, Section 3.4.5 LED Fixtures for the F32T8 Standard Lamp - 4 foot x 2 bulbs.

[850] Per Houghton, D. 1996. "Refrigerated Vending Machines - Overlooked Devices Hold Opportunities for Efficiency, New Services." E Source Tech Update, TU-96-7, the typical backlit display for a refrigerated beverage vending machine consists of two five-foot linear fluorescent lamps." (PGE, SWAP011-01 Vending and Beverage Merchandise Controller measure, MeasureDataSpec file)

[851] See IL TRM, Section 3.4.5 LED Fixtures for the TLED Lamp x 2 bulbs.

MDEC = Maximum Daily Energy Consumption per Federal regulations[852].

Class	Vintage	EQN	MDEC (kWh/d)
A	post-2019	0.052 * V + 2.43	3.52
B		0.052 * V + 2.20	3.29
Combination A		0.086 * V + 2.66	4.47
Combination B		0.111 * V + 2.04	4.37
A	pre-2019	0.055 * V + 2.56	3.72
B		0.073 * V + 3.16	4.69

V = Refrigerated Volume.

= Actual, *if unknown use 21 cu. ft.* [853]

SleepHours = Maximum hours of sleep mode per day.

= 4 hrs [854]

Days = Operating Days/yr.

= 365

For example, adding controls to a Class B, post-2019 Vintage, Refrigerated Beverage Vending Machine, with 2 T8 bulbs, located in a Small Office:

$\Delta kWh = \Delta kWh_{ligthing} + \Delta kWh_{Ref\ BMC}$

$\Delta kWh_{ligthing} = ((8760 – HOURS_{Occupied}) * W_{Bulb})/1000$

$= ((8760 – 2920) * 56.4\ W)/1000$

= 329 kWh/yr

$\Delta kWh_{Ref\ BMC}$ = MDEC x Usage Reduction Rate x Days

= 3.29 * 4/24 * 365

= 200 kWh/yr

ΔkWh = 530 kWh/yr

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

N/A

Peak Gas Savings

N/A

[852] 10 CFR 431. Subpart Q §431.296 (a) & (b).

[853] U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program. (n.d.) “Purchasing Energy-Efficient Refrigerated Beverage Vending Machines.” Updated January 2020.

[854] Itron, Inc. 2005. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report. Prepared for the California Public Utilities Commission. Pg 3-22.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-RBMC-V01-220101

SUNSET DATE: 1/1/2027

3.8.17 Floating Head Pressure Controls

Description

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90 degrees. By installing a "floating head pressure control" condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that as the outdoor temperature drops, the compressor will not have to work as hard to reject heat from the cooler or freezer. This measure is for the application of floating head pressure controls for compressors ≤ 10HP and a condensing temperature set to 70ºF. This measure is strictly limited to single compressor systems.

As illustrated in the Algorithms section, impacts for this measure are influenced by compressor horsepower, temperature application (refrigerator or freezer) and whether the system is self-contained or relies on remote condensing. Self-contained units are assumed to reject heat to conditioned or semi-conditioned space, whereas remote condensing units are assumed to reject heat to the outdoor environment.

This measure applies to the following program types: RF.

Definition of Efficient Equipment

The efficient condition is a fully commissioned single-compressor refrigeration system that has been retrofitted with floating head pressure control.

Definition of Baseline Equipment

The baseline is an existing, single-compressor refrigeration system without floating head pressure control.

Deemed Lifetime of Efficient Equipment

The expected measure life is 15 years.[855]

Deemed Measure Cost

Actual equipment and labor costs should be used if available. If actual costs are unknown, the full installed costs, per HP of compressor capacity, can be assumed as:[856]

Unit Type	Temperature Range	
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Self-Contained Unit (SCU)	$404.95/HP	$442.23/HP
Remote Condensing Unit (RCU)	$404.95/HP	$442.23/HP

Loadshape

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

855 California DEER 2014 Effective Useful Life (EUL) table. See Reference file "DEER2014 EUL Table Update.xlsx".

856 Costs are based on number of additional valves per condenser motor for different HP ratings and includes installation labor costs. Costs are averaged and shown on a per HP basis. See reference document ComGroceryFHPCSingleCompressor_v2_1.xlsm, worksheet 'CostData&Analysis,' blue highlighted cells. Costs were inflated to 2021$ from 2012$ using the US BLS's CPI Inflation Calculator.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = HP * Savings\ Factor$$

Where:

HP = Actual compressor capacity, in horsepower

Savings Factor = kWh savings per horsepower of compressor rating, based on the following tables[857]:

Zone 5 (Burlington)	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	412	386

Zone 6 (Mason City)	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	491	460

Average/unknown	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	432	405

For example, a medium temperature, remote condensing system with 5 horsepower compressor in Zone 5, would save:

ΔkWh = HP * Savings Factor

ΔkWh = 5 * 386

= 1930 kWh

Summer Coincident Peak Demand Savings

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

Where:

[857] Derived from RTF saving estimates for the NW climate zone and extrapolated to Iowa climate zone by using heating degree-days. RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v2_1.xlsm, 2020. See supporting workbook "fhp savings extrapolation iowa.xlsx" for full extrapolation.

ΔkWh = Electric energy savings, calculated above

Hours = Operating hours below the assumed 70ºF setpoint, which represents hours where floating head pressure controls will produce savings:[858]

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	6387
Zone 6 (Mason City)	7344
Average/unknown	6661

CF = Summer peak coincidence factor

= 0.964

For example, a medium temperature, remote condensing system with 5 horsepower compressor in Zone 5, would save:

ΔkW = (1930/6387) * 0.964

= 0.2913 kW

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-FHPC-V01-220101

SUNSET DATE: 1/1/2025

[858] Annual average of hours for Iowa weather zones where temperature is below 70ºF. This is the assumed condensing temperature that is set for the floating head pressure control. Hours are deemed from TMY3 weather data. See “fhp savings extrapolation iowa.xlsx” for further details.

3.9. Compressed Air

3.9.1. Air Compressor with Integrated VSD

Description

This measure applies to the installation of an air compressor with an integrated variable frequency drive, load/no load controls, or variable displacement controls. Baseline compressors choke off the inlet air to modulate the compressor output, which is not an efficient response operation. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are sourced from DOE data in which variable speed compressor are compared to modulating compressors. This measure applies only to an individual compressor ≤ 200 hp. Only one compressor per compressed air distribution system is eligible.

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

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

Definition of Efficient Equipment

The high efficiency equipment is a compressor ≤ 200 hp with variable speed controls.

Definition of Baseline Equipment

The baseline equipment is either an oil-flooded compressor ≤ 200 hp with inlet modulating with blowdown or load/no-load controls.

Deemed Lifetime of Efficient Equipment

The expected measure life is 13 years.[859]

Deemed Measure Cost

Incremental cost = (\$127 x $\mathrm{hp}_{\mathrm{compressor}}$) + \$1,446.[860]

Where:

\$127 and \$1,446 = compressor motor nominal hp to incremental cost conversion factor and offset

$\mathrm{hp}_{\mathrm{compressor}}$ = compressor motor nominal hp

Loadshape

NRE13 – Indust. 1-shift (8/5)
NRE14 – Indust. 2-shift (16/5)
NRE15 – Indust. 3-shift (24/5)
NRE16 – Indust. 4-shift (24/7)

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[859] "Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Air Compressors", U.S. Department of Energy, December 2016 (pg. 8-12)

[860] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Values as derived from a survey conducted by several vendors to determine equipment cost, as sourced from the Efficiency Vermont TRM, December 2018.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.9 * hp_{compressor} * Hours * (CF_b - CF_e)$$

Where:

ΔkWh = gross customer annual kWh savings

0.9[861] = compressor motor nominal hp to full load kW conversion factor

$hp_{compressor}$ = compressor motor nominal hp

Hours = compressor total hours of operation depending on shift, listed in the table below

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average[862]	5,680 hours

CF_b = baseline compressor factor

Baseline Compressor	Compressor Factor (≤ 40 hp)[863]	Compressor Factor (50 - 200 hp)[864]
Modulating w/ Blowdown	0.890	0.863
Load/No Load w/ 1 Gallon/CFM	0.909	0.887

861 Conversion factor based on a review of CAGI data sheets from 200 compressors. The survey and the resulting factor are sourced from the Illinois TRM, version 8.0, October 2019 analysis file "IL TRM VSD Air Compressor – Supporting Information.xls" (4.7.1 VSD Air Compressor).

862 Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

863 Compressor factors for this size range were developed using U.S. Department of Energy part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM. (The "variable speed drive" compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

864 Compressor factors for this size range were developed using U.S. Department of Energy part-load data for different compressor control types as well as load profiles from 45 compressors and 20 facilities. This data comes from the ComEd Custom and Industrial Systems program. The compressors were filtered to reflect only rotary screw compressors, between 50 and 200 hp, and operating a minimum of 4 hour per day. Additionally, compressors with clear and consistent baseload profiles were excluded from this analysis. The evaluation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file "IL TRM VSD Air Compressor – Supporting Information.xls" (4.7.1 VSD Air Compressor).

Baseline Compressor	Compressor Factor (≤ 40 hp)[863]	Compressor Factor (50 - 200 hp)[864]
Load/No Load w/ 3 Gallon/CFM	0.831	0.811
Load/No Load w/ 5 Gallon/CFM	0.806	0.786

CF_e = efficient compressor factor

= 0.705 for compressor ≤ 40 hp

= 0.658 for compressors 50 – 200 hp

For example, a 20-horsepower compressor with inlet modulating with blowdown controls is integrated with a VSD, operating a single-shift facility would save:

ΔkWh = 0.9 x 20 x 1,976 x (0.890 – 0.705)

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0.00
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95
Unknown / Weighted average[865]	0.80

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-VSDA-V01-210101

SUNSET DATE: 1/1/2026

[865] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

3.9.2. High Efficiency Air Nozzles

DESCRIPTION

This measure is for the replacement of standard air nozzles with high efficiency air nozzles used in a compressed air system. High efficiency air nozzles reduce the amount of air required to blow off parts or for drying; pulling in free air to accomplish tasks with significantly less compressed air. These nozzles often replace simple copper tubes in a production application or on handheld guns and have added benefits of noise reduction and improved safety in systems with greater than 30 psig.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency air nozzle must replace continuous open blow-offs and meet the following SCFM ratings (or less) at an operating pressure of 80 psig for the following orifice diameters:

Orifice Diameter	SCFM
1/8"	11
1/4"	29
5/16"	56
1/2"	140

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard air nozzle, such as an open copper tube or an inefficient air gun.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 15 years.[866]

DEEMED MEASURE COST

The incremental cost, depending on the orifice diameter, is as follows:

Orifice Diameter	Incremental Cost
1/8"	$42
1/4"	$57
5/16"	$87
1/2"	$121

LOADSHAPE

NRE13 – Indust. 1-shift (8/5)
NRE14 – Indust. 2-shift (16/5)
NRE15 – Indust. 3-shift (24/5)
NRE16 – Indust. 4-shift (24/7)

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = SCFM_{Baseline} * SCFM_{Efficient} * \%Use * kW/CFM_{Saved} * Hours$$

Where:

ΔkWh = gross customer annual kWh savings

$SCFM_{Baseline}$ = Air flow through baseline nozzle. Use actual rated flow at 80 psi if known. If unknown, please see table below, which includes air flow in SCFM by orifice diameter:[867]

Baseline Orifice Diameter	$SCFM_{Baseline}$
1/8"	21
1/4"	58
5/16"	113
1/2"	280

$SCFM_{Efficient}$ = Air flow through the efficient nozzle. Use actual rated flow rate at 80 psi if known. If unknown, please see table below which includes air flow in SCFM by orifice diameter: [868]

Efficient Orifice Diameter	$SCFM_{Efficient}$
1/8"	10.5
1/4"	29.0
5/16"	56.5
1/2"	140

%Use = Percent of the compressor total operating hours that the nozzle is in use

= 5%[869]

kW/CFM_{Saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:[870]

Air Compressor Type	kW/CFM_{Saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136
Screw – Load/Unload	0.152

[867] Review of manufacturer's information and data as sourced from "Technical Reference Manual (TRM) for Ohio, Senate Bill 221: Energy Efficiency and Conservation Program", October 15, 2019 (pg. 170-171)
[868] The default efficient air flow is based on an assumed 50% reduction factor on the default baseline air flow, as sourced as a conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery's Handbook 25th Edition and manufacturer's catalogue
[869] The 5 % percent use of the total compressor operating hours is based on an estimate that nozzles are used, on average, for 3 seconds per minute of operation. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long-term open blow situation. An assumption of 3 seconds of blow-off per minute of compressor run time is used, assuming a weighting of 50% handheld air guns and 50% stationary air nozzles.
[870] Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. The calculation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file "Industrial System Standard Deemed Savings Analysis.xls" (4.7.4 Efficient Compressed Air Nozzles).

Air Compressor Type	kW/CFM_{Saved}
Screw – Inlet Modulation	0.055
Screw – Inlet Modulation w/ Unloading	0.055
Screw – Variable Displacement	0.153
Screw - VFD	0.178
Unknown / Weighted average[871]	0.107

Hours = Compressor total hours of operation. Use actual if known, otherwise, assume values depending on shift, listed in the table below:

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average[872]	5,680 hours

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0.00
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95
Unknown / Weighted average[873]	0.80

NATURAL GAS SAVINGS

[871] If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors

[872] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

[873] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-ACNZ-V01-210101

SUNSET DATE: 1/1/2026

3.9.3. No Loss Condensate Drains

DESCRIPTION

When air is compressed, water in the form of condensation squeezes out of the compressed air and collects in piping and storage tanks. The water must be drained so as not to interfere with the flow of compressed air, as well as to reduce the potential for corrosion to the piping or tank. Many drains are controlled by a timer and open an orifice for a programmed set amount of time, regardless of the level of the condensate. As a result, compressed air is allowed to escape after the condensate has drained. Timed drains typically continue to operate even when the compressor is down, effectively bleeding off useful stored air that must be remade when the compressor is restarted. No loss condensate drains are controlled by a sensor and only open and close when there is a need to drain condensate, effectively closing before compressed air can escape.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a no loss condensate drain that is controlled by a sensor and only opens when there is a need to drain condensate, closing before any compressed air is vented.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard condensate drain (open valve, timer, or both) that operates according to a preset schedule regardless of the amount or presence of condensate.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 13 years.[874]

DEEMED MEASURE COST

The average equipment cost per drain is $194 with an installation labor cost of $50 for a total incremental cost of $244 per drain.[875]

LOADSHAPE

NRE03 – Industrial Motor

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{reduced} * kW/CFM_{Saved} * Hours$$

Where:

[874] "Measure Life Study", prepared for the Massachusetts Joint Utilities, Energy & Resources Solutions, 2005. Value is based on C&I compressor retrofit effective useful lives.

[875] Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data. The cost analysis and product review is sourced from the Illinois TRM, version 8.0, October 2019 analysis file "CAS Cost Data.xls" (4.7.3 Compressed Air No-Loss Condensate Drains)

ΔkWh = gross customer annual kWh savings

$CFM_{reduced}$ = Reduced air consumption per drain

= 3 CFM[876]

kW/CFM_{saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:[877]

Air Compressor Type	kW/CFM_{Saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136
Screw – Load/Unload	0.152
Screw – Inlet Modulation	0.055
Screw – Inlet Modulation w/ Unloading	0.055
Screw – Variable Displacement	0.153
Screw - VFD	0.178
Unknown / Weighted average[878]	0.107

Hours = Compressed air system pressurized hours

= 6,136 hours[879]

Summer Coincident Peak Demand Savings

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

Where:

CF = Summer peak coincidence factor for this measure

= 0.95

Natural Gas Savings

N/A

Peak Gas Savings

N/A

[876] Reduced CFM consumption is based on a timer drain opening 10 seconds every 300 seconds as the baseline. This value is sourced from the Illinois TRM, version 8.0, October 2019 analysis file "Industrial System Standard Deemed Savings Analysis.xls" (4.7.3 Compressed Air No-Loss Condensate Drains).

[877] Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. The calculation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file "Industrial System Standard Deemed Savings Analysis.xls" (4.7.3 Compressed Air No-Loss Condensate Drains).

[878] If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors

[879] "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (pg. 19). The hours are based on an average of 118 hours per week.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-NLCD-V01-210101

SUNSET DATE: 1/1/2026

3.9.4. Low Pressure Drop Filters

Description

Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in the ability to lower a compressed air systems pressure setpoints. This reduces the compressor work required resulting in energy savings.

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

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

Definition of Efficient Equipment

The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psid when new and 3 psid at element change.

Definition of Baseline Equipment

The baseline condition is a standard coalescing filter with a pressure drop of 3 psid when new and 5 psid or more at element change

Deemed Lifetime of Efficient Equipment

The expected measure life is 10 years [880]

Deemed Measure Cost

The incremental cost for this measure is estimated to be $1,000 per filter.[881]

Loadshape

NRE03 – Industrial Motor

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = kW_{typical} * \Delta P * SF * Hours * \frac{HP_{actual}}{HP_{typical}}$$

Where:

$kW_{typical}$ = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use actual compressor control type if known:

[880] Based on survey of manufacturer claims (Zeks, Van Air, Quincy).

[881] Based on incremental cost research found in 'CAS Cost Data LPDF. xlsx'.

Control Type	$kW_{typical}$ [882]
Reciprocating - On/off Control	70.2
Reciprocating - Load/Unload	74.8
Screw - Load/Unload	82.3
Screw - Inlet Modulation	82.5
Screw - Inlet Modulation w/ Unloading	82.5
Screw - Variable Displacement	73.2
Screw - VFD	70.8
Unknown / Weighted average[883]	77.6

ΔP = Reduction in pressure differential across the filter (psi)

=2 psi[884]

SF =1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a Savings Factor of 0.005[885]

Hours = Compressor hours of operation below depending on shift

Shift	Hours
Single shift (8/5)	1976 hours 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3952 hours 7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5928 hours 24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8320 hours 24 hours per day, 7 days a week minus some holidays and scheduled down time

$HP_{typical}$ = Nominal HP for typical compressor

= 100 HP[886]

HP_{Actual} = Total HP of actual compressors distibuting air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

882 See "Industrial System Standard Deemed Saving Analysis.xls".
883 If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors
884 Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings
885 "Optimizing Pneumatic Systems for Extra Savings," Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.
886 See "Industrial System Standard Deemed Saving Analysis.xls".

Shift	Coincidence Factor
Single shift (8/5)	0.00
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95
Unknown / Weighted average[887]	0.80

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-LPDF-V01-220101

SUNSET DATE: 1/1/2026

[887] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

3.9.5. Storage Receiver Tank

Description

Using an air receiver or storage tank will buffer the air demands of the system on the compressor, thus eliminating short cycling. Although a load/no load compressor unloads in response to lowered demand, it does so over a period of time to prevent lubrication oil from foaming. Therefore, reducing the number of cycles reduces the number of transition times from load to no load and saves energy.

To qualify for this measure an existing load/no load compressor with a 1 gal/cfm storage ratio or a modulating w/ blowdown compressor must be replaced with a load/no load compressor with an improved storage capacity and ratio.

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

Definition of Efficient Equipment

The efficient equipment is an oil-flooded load/no load compressor with an improved storage capacity and ratio compared to the existing system. The cfm should reflect the rated capacity (in cfm) of all active compressors. If that value cannot be determined, compressor power can be converted to capacity using the rule-of-thumb 4.5 cfm/hp.[888]

Definition of Baseline Equipment

The baseline equipment is an oil-flooded load/no load compressor with a 1 gal/cfm storage ratio or a modulating w/ blowdown compressor.

Deemed Lifetime of Efficient Equipment

The expected measure life is 10 years [889]

Deemed Measure Cost

Incremental cost ($) = 4.67 * ($TANK_E – TANK_B$)[890]

Where:

4.67 = air receiver tank size, in gallons, to equipment cost conversion factor

$TANK_E$ = efficient tank size (gallons)

$TANK_B$ = baseline tank size (gallons)

Loadshape

NRE03 – Industrial Motor

[888] The 4.5 cfm/hp rule of thumb is based on a rotary screw compressor delivering 4 to 5 cfm per 1 hp, "Relationship Between Pressure and Flow", Compressed Air System Best Practices, Industrial Utility Efficiency.
[889] 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions
[890] 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = 0.9 * HP_{compressor} * HOURS * (CF_b - CF_e)$$

Where:

0.9[891] = compressor motor nominal HP to full load kW conversion factor

$HP_{compressor}$ = compressor motor nominal HP

= Actual

HOURS = compressor total hours of operation below depending on shift

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average[892]	5,680 hours

CF_b = baseline compressor factor[893]

= See table below for baseline compressor factor. If compressor type is unknown, default to a load/no load compressor with 1 gallon/cfm for the appropriate-sized compressor.

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[891] Conversion factor based on Survey of CAGI data sheets from 200 compressors. See "IL TRM VSD Air Compressor – Supporting Information.xls" for more information.

[892] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

[893] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM.

Baseline Compressor	Compressor Factor (≤ 40 hp)[894]	Compressor Factor (50 – 200 hp)[895]
Modulating w/ Blowdown	0.890	0.863
Load/No Load w/ 1 Gallon/CFM	0.909	0.887
Load/No Load w/ 3 Gallon/CFM	0.831	0.811
Load/No Load w/ 4 Gallon/CFM	0.812	0.792
Load/No Load w/ 5 Gallon/CFM	0.806	0.786

CF_e = efficient compressor factor

= See table above for load/no load compressors with the adequate storage capacity installed. If unknown, default to load/no load compressors w/ 4 gallons/cfm.

For example, a 2-shift facility with a 100-hp modulating (with blowdown) adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

Capacity Check: *= 2,000 gallons / (100 hp * 4.5 cfm/hp)*

= 4.4 gallons per cfm

ΔkWh = 0.9 * 100 * 3,952 * (0.863 – 0.792)

= 25,253 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0.00
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95
Unknown / Weighted average[896]	0.80

[894] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM. See "IL TRM VSD Air Compressor – Supporting Information.xls" for more information.

[895] Compressor factors for this size range were developed using DOE part-load data for different compressor control types as well as load profiles from 45 compressors and 20 facilities. This data comes from ComEd Custom and Industrial Systems programs. The compressors were filtered to reflect only rotary screw compressors, between 50 and 200 hp, and operating a minimum of 4 hour per day, Additionally, compressors with clear and consistent baseload profiles were excluded from this analysis. See "IL TRM VSD Air Compressor – Supporting Information.xls" for more information.

[896] Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of the Compressed Air Challenge Training Program", U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

For example, a 2-shift facility with a 100-hp VSD modulating (with blowdown) compressor adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

$$\Delta kW = 25{,}253 / 3{,}952 * 0.95$$
$$= 6.1 \text{ kW}$$

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

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