

Iowa Energy Efficiency Statewide Technical Reference Manual Version 11.0

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 CFM¹/watt and is derived from the thrust efficiency ratio (TER) in pounds force per watt (lbf/W).

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

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

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

¹ Cubic Feet per Minute.

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

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

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

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

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

LOADSHAPE

Loadshape NREV06 – Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * Nfans$$

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+	1,358
Unknown/Midstream ⁷	696

$Watts_{EE}^8$ = Demand (W) of efficient fan

Diameter of Fan (inches)	$Watts_{EE}$
12-23	298
24-35	440
36-47	529
48+	993
Unknown/Midstream ⁹	477

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.

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. "Ag Circ Fan Analysis.xls".

⁷ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all circulation fan installs between 2019 and April 2025. The baseline fan wattage was reverse calculated based on average claimed electrical savings per fan.

⁸ BESS fan database downloaded on 7/1/2015. Average watts from models above standard. "Ag Circ Fan Analysis.xls".

⁹ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all circulation fan installs between 2019 and April 2025. The efficient fan wattage was reverse calculated based on average claimed electrical savings per fan.

If not, the following table¹⁰ 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 provided for livestock.¹¹

Facility Type	Annual Hours of Operation
Hog	3,600
Poultry	3,072
Dairy	2,832
Unknown/Other	3,277

Nfans = Number of circulation fans
= Actual

For Example, replacing 20 16-inch fans in a Hog barn would save,

$$\begin{aligned}\Delta kWh &= ((\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}})/1,000) * \text{Hours} * \text{Nfans} \\ &= ((366 - 298) / 1,000) * 3,600 * 20 \\ &= 4,896 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}}{1,000} * CF * \text{Nfans}$$

Where:

CF = Summer Peak Coincidence Factor
= 100%¹²

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

¹⁰ Based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Des Moines represents the average of the state. 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. 2022 Agriculture Census for Iowa. For more information on the weighting, see: "Ag Op Hours_2025.xlsx".

¹¹ 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.

¹² Industrial Ventilation CF from eQuest.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-CIRC-V06-260101

SUNSET DATE: 1/1/2028

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 Labs¹³ 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 ¹⁴)
14-23	10.1
24-35	13.5
36-47	17.4
48+	20.3

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.¹⁵

DEEMED MEASURE COST

Actual full installed costs may be used along with the following baseline cost assumptions:¹⁶

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

If actual cost not available, assume an incremental total installed cost of \$150.¹⁷

¹³ University of Illinois, Department of Agricultural and Biological Engineering. <http://bess.illinois.edu/>.

¹⁴ Static Pressure in units of inches of water.

¹⁵ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 5,305 hours (see description of default run hours on following page). Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

¹⁶ 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.

¹⁷ Act on Energy Commercial Technical Reference Manual No. 2010-4.

LOADSHAPE

Loadshape NREV06 – Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * hours * Nfans$$

Where:

$Watts_{Base}^{18}$ = Demand (W) of baseline fan. If unknown or midstream, assume 40" fan. ¹⁹

Diameter of Fan (inches)	$Watts_{Base}$ (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1,353

$Watts_{EE}^{20}$ = Demand (W) of efficient fan. If unknown or midstream, assume 40" fan. ²¹

Diameter of Fan (inches)	$Watts_{EE}$ (0.05 SP)
14-23	304
24-35	383
36-47	565
48+	1,041

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. ²²

¹⁸ 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: "Ag Vent Fan Analysis.xls".

¹⁹ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all ventilation fan installs between 2019 and April 2025. The diameter of the fan is based on a weighted average of all fans installed.

²⁰ 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: "Ag Vent Fan Analysis.xls".

²¹ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all ventilation fan installs between 2019 and April 2025. The diameter of the fan is based on a weighted average of all fans installed.

²² See "Ag Op Hours_2025.xlsx" workbook for a complete description and derivation of default operating hours. EFLH based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Des Moines represents the average of the state. 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. 2022 Agriculture Census for Iowa.

Facility Type	Annual EFLH
Hog	5,570
Poultry	5,020
Dairy	4,771
Unknown/Other	5,234

Nfans = Number of ventilation fans
= Actual

For Example, replacing 20 16-inch diameter fans in a Hog barn would save:

$$\begin{aligned}\Delta kWh &= ((\text{Watts}_{\text{base}} - \text{Watts}_{\text{ee}}) / 1,000) * \text{Hours} * \text{Nfans} \\ &= ((382 - 304) / 1,000) * 5,570 * 20 \\ &= 8,689 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}}{1,000} * CF * \text{Nfans}$$

Where:

CF = Summer Peak Coincidence Factor
= 100%²³

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-VENT-V05-260101

SUNSET DATE: 1/1/2028

²³ 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.²⁴

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:²⁵

Diameter of Fan (feet)	Baseline Cost
16-17.9	\$1,210
18-19.9	\$1,460
20-23.9	\$1,840
24 +	\$2,090

If actual costs are unavailable for new construction, the incremental measure costs are as follows:²⁶

Diameter of Fan (feet)	Incremental Cost
16-17.9	\$4,100
18-19.9	\$4,130
20-23.9	\$4,190
24+	\$4,230

²⁴ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,346 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

²⁵ 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.

²⁶ 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

$$\Delta kWh = \frac{\sum(N_{Base} * Watts_{Base}) - \sum(N_{EE} * Watts_{EE})}{1,000} * Hours$$

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 Savings²⁷

Diameter of Fan (feet)	$Watts_{Base}$	$Watts_{EE}$
16-17.9	4,497	761
18-19.9	5,026	850
20-23.9	5,555	940
24+	6,613	1,119

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 ²⁸ 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
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²⁷ 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.

²⁸ See “Ag Op Hours_2025.xlsx” workbook for a complete description and derivation of default operating hours. Hours based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Des Moines represents the average of the state. 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. 2022 Agriculture Census for Iowa.

livestock.²⁹

Facility Type	Annual Hours of Operation
Hog	3,600
Poultry	3,072
Dairy	2,832
Unknown/Other	3,277

Based on default assumptions above, deemed electric energy savings would be:

Diameter of Fan (feet)	Watts _{Base}	Watts _{EE}	ΔkWh
16-17.9	4,497	761	12,501
18-19.9	5,026	850	13,973
20-23.9	5,555	940	15,442
24+	6,613	1,119	18,383
Unknown/Midstream ³⁰			16,251

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\sum(-N_{Base} * Watts_{Base}) - \sum(N_{EE} * Watts_{EE})}{1,000} * CF$$

Where:

CF = Summer Peak Coincidence Factor
= 100%³¹

Based on default assumptions above, deemed electric demand savings would be:

Diameter of Fan (feet)	Watts _{Base}	Watts _{EE}	ΔkWh
16-17.9	4,497	761	3.74
18-19.9	5,026	850	4.18
20-23.9	5,555	940	4.62
24+	6,613	1,119	5.49
Unknown/Midstream ³²			4.86

NATURAL GAS SAVINGS

N/A

²⁹ 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.

³⁰ The unknown/midstream estimate is based on a weighted average of fan distributions sourced from Wisconsin Focus on Energy historical program data, as detailed in the, 'Wisconsin Focus on Energy 2024 TRM', January 7, 2024 – Agriculture High Volume Low Speed Fans

³¹ Industrial Ventilation CF from eQuest.

³² The unknown/midstream estimate is based on a weighted average of fan distributions sourced from Wisconsin Focus on Energy historical program data, as detailed in the, 'Wisconsin Focus on Energy 2024 TRM', January 7, 2024 – Agriculture High Volume Low Speed Fans

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-V05-260101

SUNSET DATE: 1/1/2028

3.1.4 TEMPERATURE BASED ON/OFF VENTILATION CONTROLLER

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.³³

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

$$\Delta kWh = \frac{Watts_{fan}}{1,000} * (Hours_{control})$$

Where:

³³ Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 5,305 hours.

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

$Watts_{fan}$ = Total wattage of controlled fans

= Actual; if unknown, the following table can be used to estimate.³⁴ For midstream, assume 40" fan.³⁵

Diameter of Fan (inches)	$Watts_{fan}$ (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1,353

$Hours_{control}$ = Reduction in fan run hours due to controller³⁶

Facility Type	$Hours_{control}$
Hog	737
Poultry	651
Dairy	58
Unknown/Other	638

For Example, A controller installed on a 20-inch fan in a Hog barn would save,

$$\begin{aligned}\Delta kWh &= (Watts_{fan} / 1,000) * Hours_{control} \\ &= (382 / 1,000) * 737 \\ &= 282 \text{ kWh}\end{aligned}$$

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 SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

³⁴ BESS fan database downloaded on 7/1/2015. Average watts from models considered baseline. "Ag Vent Fan Controller Analysis.xls".

³⁵ Unknown or midstream values are sourced from Ameren Agriculture Program Data; representative of all ventilation fan installs between 2019 and April 2025. The diameter of the fan is based on a weighted average of all fans installed.

³⁶ See "Ag Op Hours_2025.xlsx" workbook for a complete description and derivation of default operating hours. Hours based on US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Des Moines represents the average of the state. Additional factors are incorporated into the analysis such as fan temperature settings and stagings. 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. 2022 Agriculture Census for Iowa.

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

N/A

MEASURE CODE: NR-AGE-VCON-V04-260101

SUNSET DATE: 1/1/2029

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 1995,³⁷ 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.³⁸

DEEMED MEASURE COST

Retrofit measure, actual costs will be used.

LOADSHAPE

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

CALCULATION OF SAVINGS

Electric Energy Savings:

$$\Delta kWh = kWh/cow/milking * N_{Milking} * N_{Cows}$$

Where:

kWh/cow/milking	= 50 ³⁹
$N_{Milking}$	= Number of milkings per day = Actual; if unknown use 2 ⁴⁰
N_{Cows}	= Number of milking cows per farm

³⁷ 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.

³⁸ Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.

³⁹ 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.

⁴⁰ 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 234⁴¹

For Example, a farm with 234 milking cows, which all get milked twice a day, would save,

$$\begin{aligned}\Delta kWh &= kWh/cow/milking * N_{Milking} * N_{Cows} \\ &= 50 * 2 * 234 \\ &= 23,400 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS:

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

Where:

FLH = Full Load Hours
= 2,703⁴²
CF = Coincidence Factor
= 79.3%⁴³

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-AMTO-V05-240101

SUNSET DATE: 1/1/2028

⁴¹ Entered from application form; default value is sourced from the 2022 U.S. Census of Agriculture, Iowa State and County Data, Full Report, Volume 1, Table 1. Average number of cows per farm = 238,087 cows / 1,016 farms = 234.

⁴² 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 per year. Source Milking System Air Consumption When Using a Variable Speed Vacuum Pump. Paper Number: 033014 An ASAE Meeting Presentation. July 2003.

⁴³ 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.⁴⁴

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

$$\Delta kWh = \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE}} \right) * Gal * Days_{yr} * Specific_{heat} * Density_{milk} * \Delta T * \frac{1}{1,000} * N_{Cows}$$

Where:

- EER_{Base} = Cooling efficiency of existing compressor in Btu/watt-hour
= Actual, if unknown use values from table below⁴⁵
- EER_{EE} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour
= Actual, if unknown use values from table below⁴⁶

⁴⁴ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, "Effective/Remaining Useful Life Values", California Public Utilities Commission, February 4, 2014.

⁴⁵ 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.

⁴⁶ 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 EER _{Base}	Average EER _{EE}
0-7,500	1	8.14	9.03
7,500-14,999	2	9.28	10.86
15,000-22,499	3	10.64	11.83
22,500-29,999	4	11.18	12.15
30,000-37,499	5	11.12	12.39
37,500-44,999	6	11.74	12.70
45,000-52,499	7	11.68	12.52
52,500-59,999	8	12.54	13.12
60,000-67,499	9	12.46	13.13
67,500-75,000	10	11.44	12.37

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

= 6⁴⁷

Days_{Yr} = Number of days per year

= 365

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

= 0.93⁴⁸

Density_{milk} = Density milk in lb/gal

= 8.6

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

= 19⁴⁹

Required change in temperature (without precooler) in °F

= 59⁵⁰

1000 = Conversion factor from watts to kilowatts

N_{Cows} = Number of cows

= Actual, if unknown use 234 cows⁵¹

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

$$\begin{aligned}\Delta \text{kWh} &= (1/11.12 - 1/12.39) * 6 * 365 * 0.93 * 8.6 * 19 * 1/1,000 * 90 \\ &= 276.1 \text{ kWh}\end{aligned}$$

⁴⁷ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁴⁸ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁴⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁵⁰ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁵¹ Entered from application form; default value is sourced from the 2022 U.S. Census of Agriculture, Iowa State and County Data, Full Report, Volume 1, Table 1. Average number of cows per farm = 238,087 cows / 1,016 farms = 234.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH = Full load hours; the refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3,910 hours for medium temperature applications⁵²

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

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

$$\begin{aligned} \Delta kW &= (276.1/3,910) \times 0.964 \\ &= 0.0681 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-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.

⁵² 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.⁵³

DEEMED MEASURE COST

Incremental cost is assumed to be \$0.⁵⁴

LOADSHAPE

Loadshape C04 – Nonresidential Electric Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{W_{Base} - W_{EE}}{1,000} * Hours * N_{Units}$$

Where:

W_{Base} = Wattage of baseline heat lamp

= 175 watts⁵⁵

W_{EE} = Wattage of reduced wattage heat lamp

= Actual if known; otherwise assume 125 watts⁵⁶

⁵³ The one year measure life is based on an expected lamp lifetime of approximately 5,000 hours.

⁵⁴ Internet search on QC Supply indicates no cost differential between 125 watt and 175 watt bulbs. This was benchmarked and mapped against other Midwest livestock catalogs and suppliers and there was observed to be a near negligible difference between 125 watt and 175 watt heat lamps.

⁵⁵ The 175 watt baseline is based on standard practice based on discussions with IPL's program manager Dave Warrington on October 14, 2015.

⁵⁶ 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 ⁵⁷
	= 5,105 hours
1,000	= Conversion factor from watts to kilowatts
	= 1,000
N _{Units}	= Number of units installed
	= Actual

For Example, a farm replacing 50 heating lamps with efficient lamps would save:

$$\begin{aligned}\Delta \text{kWh} &= ((W_{\text{Base}} - W_{\text{EE}}) / 1,000) * \text{Hours} * N_{\text{Units}} \\ &= ((175-125) / 1,000) * 5105 * 50 \\ &= 12,762.5 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincidence 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: 1/1/2030

⁵⁷ 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 5,120 hours." 5,120 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 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.

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.⁵⁸

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape C04 – Nonresidential Electric Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Lbs of Milk	= The pounds of milk produced per day per cow that needs to be cooled = 51.6 lbs of milk per cow per day ⁵⁹
$C_{P,\text{Milk}}$	= Specific heat of milk = 0.93 Btu/(lb-°F)
ΔT_{Milk}	= Change in milk temperature (°F) = 59°F without precooler installed; 19°F with precooler installed

⁵⁸ 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.

⁵⁹ 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).

Days = Number of milking days per year
 = 365 days

Heat Available = 1,033,422 Btu per cow per year without precooler
 = 332,797 Btu per cow per year with precooler

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

Where:

Hot Water = Gallons of hot water needed per cow per day
 = 2.75 gallons per cow per day⁶⁰

P_{Water} = Density of water
 = 8.33 lbs/gallon

$C_{P,\text{Water}}$ = Specific heat of water
 = 1 Btu/(lb-°F)

ΔT_{Water} = Change in water temperature between the incoming water and the hot water leaving the hot water heater
 = 70°F

Heat Storage = 468,229 Btu per cow per year

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

Table 1 – Reclaimable Heat

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

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

Where:

EF_{elec} = Energy factor of the electric water heater
 = Actual, if unknown use 0.90⁶¹

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

3,412 = Btu to kWh electric conversion factor

⁶⁰ Wisconsin Focus on Energy 2025 Technical Reference Manual, January 2025 – Agriculture Water Heaters

⁶¹ Entered from application form; default value based on: IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

Based on default assumptions above, the table below provides deemed savings. For midstream applications, assume a milk precooler is installed on-site. **Table 2 – Heat Reclaimer Savings**

Case	kWh/Cow
No precooler installed	152.5
Precooler installed	108.4

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-HTRE-V06-260101

SUNSET DATE: 1/1/2028

3.1.9 HEAT MAT

DESCRIPTION

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are the reduced wattage heat mat must be less than or equal to 100 watts for a single mat (typically sized at 14" x 60") and then less than or equal to 200 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.⁶²

DEEMED MEASURE COST

Incremental cost is assumed to be \$225.⁶³

LOADSHAPE

Loadshape C04 – Non-Residential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS⁶⁴

ELECTRIC ENERGY SAVINGS

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

Where:

$Mats_{Single}$	= Number of single mats at 100 watts or less, actual
$Mats_{Double}$	= Number of single mats at 200 watts or less, actual
$Savings_{SingleMat}$	= Default energy savings per single mat, dependent on baseline heat lamp (kWh/mat)

Baseline Heat Lamp	kWh Savings _{SingleMat}
175 watts	606

⁶²Professional judgment.

⁶³

⁶⁴All 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}
125 watts	287

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

Baseline Heat Lamp	kWh Savings _{DoubleMat}
175 watts	1,276
125 watts	766

$Savings_{Midstream}$ = Default energy savings for midstream applications (kWh/mat)⁶⁵

Heat Mat Type	kWh Savings
Single Mat	338
Double Mat	817
Unknown	742

Controller = Number of Controllers, actual. If unknown or midstream, assume 0.⁶⁶

Controller Impact = 383 kWh/usage per controller

Custom calculation for heat mats shown below, otherwise use deemed values listed above.⁶⁷

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

Where:

$$kWh_{Base} = \frac{Crates_{Total} * Hours_{Yr} * Fixture_{Crate} * Lamp_{Fixture} * Wattage_{Lamp}}{1,000 \frac{Watts}{kWh}}$$

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

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

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

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

⁶⁵ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all heat mat installs between 2019 and April 2025. Project-level agriculture data indicated that 95% of installed heat mats are double mats. And the baseline heat lamp distribution was predominantly 125W, representing 93% of the baseline population. For these purposes, while the unknown mat type savings are weighted between single and double mats, the default savings themselves for the individual mat types are based on a baseline of 125W heat lamp.

⁶⁶ Unknown or midstream values are sourced from Ameren Agriculture Program Data, representative of all heat mat installs between 2019 and April 2025. Project-level agriculture data showed that only one controller was installed to control 2 single mats and 8 double mats, out of 3,967 heat mats installed during the review period. As this is only representative of less than 1% of installed mats, for midstream purposes assuming no controller is installed.

⁶⁷ For the custom calculation, where actual site values are unknown, there are recommended default values. These values are sourced from an IPL implementation contractor's custom calculator, developed and used in PY2014.

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

Where:

$Crates_{Total}$	= Number of crates = 234
$Hours_{Yr}$	= Annual hours of operation = 5,105 hours ⁶⁸
$Fixture_{Crate}$	= Number of heat lamp fixtures per crate = Actual; if unknown, use 1.25
$Lamp_{Fixture}$	= Number of heat lamps per fixture = 1
$Wattage_{Lamp}$	= Wattage of heat lamp = Actual; if unknown, use 175 watts
1,000 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
$Crates_{Single-Row}$	= Number of single crates per row = Actual; if unknown, use 1
$Single_{Wattage}$	= Wattage of a 14" x 60" farrowing heat mat = 100 W
$Single_{Mat}$	= 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

⁶⁸ 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.

$\text{Crates}_{\text{Double-Row}}$	= Number of Double Crates per Row
	= Actual; if unknown, use 12
$\text{Double}_{\text{Wattage}}$	= Wattage of a 24" x 60" farrowing heat mat
	= 200 W
$\text{Double}_{\text{Mat}}$	= 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 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-V06-270101

SUNSET DATE: 1/1/2030

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 gas or electric grain dryer. Bushels per hour must be provided by the manufacturer, rated at 5 points of moisture removal per bushel. Grain dryers 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 20 years.⁶⁹

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.⁷⁰

Tier (bushels per hour)	Tier (annual bushels)	Average Incremental cost
< 500	< 170,000	\$20,000
≥ 500 and < 1,000	≥ 170,000 and < 330,000	\$30,000
≥ 1,000 and < 2,000	≥ 330,000 and < 670,000	\$40,000
≥ 2,000 and < 3,500	≥ 670,000 and < 1,200,000	\$70,000
≥ 3,500 and ≤ 5,000	≥ 1,200,000 and ≤ 1,700,000	\$100,000
Unknown/Midstream ⁷¹		\$40,000

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm**CALCULATION OF SAVINGS**

⁶⁹ Iowa State University Ag Extension, “Computing a Grain Storage Rental Rate”, October 2013. The useful life of grain storage bins was estimated to be between 15 and 25 years and the drying equipment useful life was estimated to be between 10 and 12 years. Combined with engineering judgement, the estimated measure life for a high efficiency grain dryer is estimated to be 20 years, which is corroborated by the Wisconsin Focus on Energy 2021 Technical Reference Manual, Cadmus, Public Service Commission of Wisconsin – Energy Efficient Grain Dryer.

⁷⁰ Source: Version 9_9_15 Formatted Grain Dryer Prescriptive.xls.

⁷¹ Based on a review of Alliant Agriculture Program Data from 2019-2025, based on the average throughput of installed grain dryers (1,565 bushels per hour).

ELECTRIC ENERGY SAVINGS

If grain dryer is heated exclusively with electricity:

$$\Delta \text{kWh} = Bu_{\text{Capacity}} * \text{Hours} * (MC_{\text{In}} - MC_{\text{Out}}) * \text{Moisture Weight} * 100 * \text{Btu/Lb}_{\text{Evap}} * \\ (1 / \text{Dryer Eff}_{\text{Base}} - 1 / \text{Dryer Eff}_{\text{Eff}}) / 3,412 + (\text{Dryer Fan Power}_{\text{Base}} - \\ \text{Dryer Fan Power}_{\text{Eff}}) * Bu_{\text{Capacity}} * \text{Hours}$$

Where:

Bu_{Capacity} = Capacity of grain dryer in bushels per hour when reducing grain moisture content by 5%

= Actual

Hours = Annual operating hours of the grain dryer

Savings Tier (Bushels/hour)	Savings Tier (Bushels/year)	Average Hours/year @ Rated Capacity ⁷²
< 500	170,000	340
≥ 500 and < 1,000	330,000	330
≥ 1,000 and < 2,000	670,000	335
≥ 2,000 and < 3,500	1,200,000	343
≥ 3,500 and ≤ 5,000	1,700,000	340
Unknown/Midstream		336 ⁷³

MC_{In} = Average grain moisture percentage entering grain dryer⁷⁴

= 23%⁷⁵

MC_{Out} = Average grain moisture percentage exiting grain dryer

= 15%⁷⁶

Moisture Weight = Weight of the moisture content reduction in lbs of water removed per bushel per 1% of moisture content evaporated. Value based on grain type being dried.⁷⁷

⁷² Illinois Technical Reference Manual, Volume 2, Commercial and Industrial, version 14, effective January 1, 2026 – 4.1.14 High Efficiency Grain Dryer

⁷³ The unknown/midstream annual operating hours is based on an average of the five savings tiers.

⁷⁴ The National Corn Handbook. “Energy Conservation and Alternative Sources for Corn Drying.” NCH-14, page 3, Table 4. <http://corn.agronomy.wisc.edu/Management/NCH.aspx>

⁷⁵ Wisconsin Focus on Energy project data; 13 recent grain dryer projects in Wisconsin were used as the source of average pre- and post- moisture content (23% and 15%, respectively) and baseline and proposed dryer efficiency.

⁷⁶ Wisconsin Focus on Energy project data; 13 recent grain dryer projects in Wisconsin were used as the source of average pre- and post- moisture content (23% and 15%, respectively) and baseline and proposed dryer efficiency.

⁷⁷ “Tables for Weights and Measurement: Crops”. Murhpy, William J. Table shown was modified from the original by eliminating some redundant rows for similar crops, and by adding a new column that calculates pounds of moisture evaporated per Standard Bushel per 1% moisture reduction by the dryer.

Grain Type	Weight of "Standard Bushel"	Lb Moisture/Bu/1% Evap (Moisture Weight)
Alfalfa	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Barley	48.0 Lb/Std Bu	0.48 Lb Evap/Std Bu/Delta%
Clover	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Corn, Shelled (15.5%)	56.0 Lb/Std Bu	0.56 Lb Evap/Std Bu/Delta%
Corn, Ear (15.5%)	68.4 Lb/Std Bu	0.68 Lb Evap/Std Bu/Delta%
Cotton	32.0 Lb/Std Bu	0.32 Lb Evap/Std Bu/Delta%
Cowpeas	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Flax	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Grass, Exc Timothy	14.0 Lb/Std Bu	0.14 Lb Evap/Std Bu/Delta%
Grass, Timothy	45.0 Lb/Std Bu	0.45 Lb Evap/Std Bu/Delta%
Lespedeza	45.0 Lb/Std Bu	0.45 Lb Evap/Std Bu/Delta%
Millet	80.0 Lb/Std Bu	0.80 Lb Evap/Std Bu/Delta%
Oats	32.0 Lb/Std Bu	0.32 Lb Evap/Std Bu/Delta%
Rape	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Tye	56.0 Lb/Std Bu	0.56 Lb Evap/Std Bu/Delta%
Sorghum, Forage	50.0 Lb/Std Bu	0.50 Lb Evap/Std Bu/Delta%
Sorghum, grain (13.0%)	56.0 Lb/Std Bu	0.56 Lb Evap/Std Bu/Delta%
Soybeans	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Sudan grass	28.0 Lb/Std Bu	0.28 Lb Evap/Std Bu/Delta%
Sunflower, oil type	28.0 Lb/Std Bu	0.28 Lb Evap/Std Bu/Delta%
Trefoil, Birdsfoot	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Vetch	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%
Wheat (13.5%)	60.0 Lb/Std Bu	0.60 Lb Evap/Std Bu/Delta%

Btu/Lb_{Evap} = 990 Btu per Lb of Water Evaporated; an engineering constant

Dryer Eff_{Base} = Baseline electric grain dryer efficiency of a standard-efficiency electric bin dryer, expressed as a percent, defined as Btu of moisture evaporated in the dryer divided by the heating Btu input into the dryer

=71%⁷⁸, a deemed value, based on the following table, which represents Btu/Lb evaporated and equivalent overall efficiency for the dryers and heating sources

⁷⁸ "Reducing Grain Drying Costs". Sanford, Scott., University of Wisconsin Rural Energy Program, 2013. Notes 20-30% savings in bin dryers through the use of stirrers and ambient air low temperature drying. Based on this, 71% is used as a conservative value, but Actual values can be used if available. Accessed August 19, 2020.

Grain Dryer Description	Dryer Efficiency (Dryer Efficiency)		Dryer Fan Power (Dryer Fan Power)
	Dryer Efficiency	Btu/lb Water Evaporated (Btu/lb Water)	kW / Bushel
Baseline Gas Grain Dryer w/ Constant Speed Fan Operation	44%	2,241	0.044
Efficient Gas Grain Dryer w/ Constant Speed Fan Operation	61%	1,625	0.044
Efficient Gas Grain Dryer w/ Damper Fan Operation	61%	1,625	0.035
Efficient Gas Grain Dryer w/ Fan VFD	61%	1,625	0.002
Baseline Electric Bin Grain Dryer w/ Constant Speed Fan Operation	71%	1,400	0.44
Efficient Electric Bin Grain Dryer w/ Constant Speed Fan Operation	88%	1,120	0.044
Efficient Electric Bin Grain Dryer w/ Damper Fan Operation	88%	1,120	0.035
Efficient Electric Bin Grain Dryer w/ Fan VFD	88%	1,120	0.002

Dryer Eff_{Eff} = Efficient electric grain dryer efficiency of the installed electric grain dryer, expressed as a percent, defined as Btu of moisture evaporated in the dryer divided by the heating Btu input into the dryer

= Actual. If unknown assume 88%⁷⁹

3,412 = Conversion factor of kWh to Btu; engineering constant.

Dryer Fan Powe_{SBase} = Baseline grain dryer fan power draw per bushel, as detailed in the above table and specified in the following equation:

= 0.044 kW/Bu⁸⁰

$$kW/Bu_{Base} = CFM/Bu_{Base} * in. wc_{Base} / 6354 / Fan Eff_{Base} * 0.746 / Motor Eff_{Base}$$

Where:

CFM/Bu_{Base} = 61 CFM/Bu

in. wc_{Base} = 3.0" wc

6,354 = Units conversion from cfm * in. wc. / Fan_Efficiency to BHP

Fan_Efficiency_{Base} = 60%

0.746 = Units conversion from BHP to kW

Motor_Effcy_{Base} = 80%.

$$kW/Bu = 61 * 3.0 / 6,354 / 60\% * 0.746 / 80\%$$

⁷⁹ Illinois Technical Reference Manual, Volume 2, Commercial and Industrial, version 14, effective January 1, 2026 – 4.1.14 High Efficiency Grain Dryer. "Reducing Grain Drying Costs". Sanford, Scott., University of Wisconsin Rural Energy Program, 2013. Notes 20-30% savings in bin dryers through the use of stirrers and ambient air low temperature drying.

⁸⁰ The Standard Dryer Fan Power using the fan brakehorsepower equation.

$$= 0.044 \text{ kW/Bu}$$

Dryer_Fan_Power_{Efficient} = 0.035 kW/Bu, if fan volume is controlled using outlet damper, or

= 0.002 kW/Bu, if fan volume is controlled using VFD.

Above values are deemed constants, based on the following average high-efficiency bin dryer operational parameters, and the engineering equation:

$$kW/Bu_{Eff} = CFM/Bu_{Eff} * in.wc_{Eff} / 6354 / Fan\ Eff_{Eff} * 0.746 / Motor\ Eff_{Eff}$$

In the above equation, the following deemed constants are assumed to apply to high-efficiency Grain Dryers:

Where:

$$CFM/Bu_{Eff} = 22$$

$$in.wc_{Eff} = 4.4'' \text{ if Outlet Damper control; } 0.4'' \text{ if VFD control}$$

$$6,354 = \text{Units conversion from cfm * in. wc. / Fan_Efficiency to BHP}$$

$$Fan_Efficiency_{Eff} = 60\%$$

$$0.746 = \text{Units conversion from BHP to kW}$$

$$Motor_Effcy_{Eff} = 80\%$$

$$Drive_Effcy_{Eff} = 100\% \text{ if Outlet Damper control; } 95\% \text{ if VFD control.}$$

For high-efficiency dryer with VFD control:

$$\begin{aligned} kW/Bu &= 22 * 0.4 / 6,354 / 60\% * 0.746 / 80\% / 95\% \\ &= 0.002 \text{ kW/Bu} \end{aligned}$$

For example, using the default assumptions on the installation of a 3,000 bushels/hr electric grain dryer with Outlet Damper used for Alfalfa:

$$\begin{aligned} \Delta kWh &= (3,000 * 336.3 * (0.23 - 0.15) * 0.60 * 990 * (1/0.71 - 1/0.88)/3,412) + \\ &((0.044 - 0.035) * 3,000 * 336.3) \\ &= 12,903 \text{ kWh} \end{aligned}$$

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 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-V04-270101

SUNSET DATE: 1/1/2028

3.1.11 LIVESTOCK 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.⁸¹

DEEMED MEASURE COST

Actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, assume an incremental capital cost of \$535.⁸²

LOADSHAPE

Loadshape C04 – Nonresidential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Watts_{Base} = Power consumption of baseline equipment; actual, if known
 = If unknown, use 500⁸³

Watts_{EE} = Power consumption of efficient equipment; actual, if known

⁸¹ Act on Energy Commercial Technical Reference Manual No. 2010-4. Typical warranty on waterers is 10 years.

⁸² Based on internet review of leading manufacturers, 03/2023.

⁸³ Wisconsin Focus on Energy 2023 TRM, p. 83.

- 1,000 = If unknown, use 250 for energy-efficient, 0 watts for energy free installation⁸⁴
- Hours = Kilowatt conversion factor
- Hours = Average annual run hours of heater; actual if known
- = If unknown, use the table below⁸⁵

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	2,736
Zone 6 (Mason City)	3,960
Average/Unknown	2,904

Based on default assumptions above, the table below provides deemed savings. For midstream applications, assume installed livestock waterer is the energy efficient option.

Measure Type	Efficient Option	ΔkWh
Time of Sale	Energy Efficient	726
	Energy Free	1,452

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-LSWT-V05-260101

SUNSET DATE: 1/1/2028

⁸⁴ Wisconsin Focus on Energy 2023 TRM, p. 83.

⁸⁵ The number of days in the use season in which the temperature drops below 35°F in the state of Iowa. The data is sourced as an average from TMYx weather data for three different weather zones within the state, see "IA Livestock Waterers Analysis.xlsx". Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

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.⁸⁶

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.746 * hours * \frac{Pressure * \frac{Flow}{Acre} * Acres}{1,715 * Pump_{eff}}$$

Where:

Hours	= hours irrigation system runs per season = 864 hr/yr ⁸⁷
Pressure	= reduction in pump pressure resulting from retrofit = Actual (PSI)
Acres	= Actual
Flow per Acre	= 5 gallons/minute/acre ⁸⁸

⁸⁶ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014.

⁸⁷ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353.

⁸⁸ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353.

1,715 = Conversion factor from PSI x GPM ((lb x gallons) / (sq. in. x min)) to horsepower

Pump_{eff} = Actual, if unknown use 0.70⁸⁹

For Example, a low-pressure irrigation system that reduced the previous irrigation systems pump pressure by 25 PSI (50%) on a 100-acre farm would save:

$$\begin{aligned}\Delta kWh &= 0.746 * \text{Hours} * ((\text{Pressure} * (\text{Flow/Acre}) * \text{Acres}) / (1,715 * \text{Pump}_{\text{eff}})) \\ &= 0.746 * 864 * ((25 * 5 * 100) / (1,715 * 0.71)) \\ &= 6,616.7 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

FLH = Full Load Hours

= 6,768⁹⁰

CF = Summer System Peak Coincidence Factor 79.3%⁹¹

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-LIRR-V03-240101

SUNSET DATE: 1/1/2027*

* 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.

⁸⁹ Appendix F Program Evaluations Group 1 Vol 2; page 354.

⁹⁰ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls.

⁹¹ IA_Electric_Loadshapes.xls.

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

3.1.13 VARIABLE SPEED FREQUENCY DRIVE FOR DAIRY VACUUM PUMP AND MILKING MACHINE

DESCRIPTION

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

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

This measure applies to the following markets: RF.

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing pump without a VFD.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD is 15 years.⁹²

DEEMED MEASURE COST

Actual material and labor costs should be used. If actual costs are not known, as a default, the average equipment cost of a milk vacuum pump variable speed drive is \$3,871 with an installation cost of \$1,177, for a total default incremental measure cost of \$5,048.⁹³

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Hp = Motor horsepower of the pump

⁹² 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014.

⁹³ The default equipment and labor costs are source from the PG&E Workpaper – Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013.

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

	= Actual; if unknown, default to 10 hp ⁹⁴
0.25	= Constant; the amount of horsepower required per milking unit ⁹⁵ = 0.25 hp/milking unit
Milking Unit	= Number of milking units controlled by the vacuum pump = Actual; if unknown, default to 15.8 ⁹⁶
0.746	= Constant; conversion factor from hp to kW = 0.746 kW/hp
LF	= Motor load factor = 90%
η_{motor}	= Motor efficiency = Actual; if unknown, default to 89.5% ⁹⁷
hours _{milk}	= Daily run hours of vacuum pump during milking = Actual; if unknown, default to 7.4 hours ⁹⁸
days _{milk}	= Milking days per year = 365 days

For Example, using the default assumptions for the variable above, the standard dairy vacuum pump and milking machine VFD would save:

$$\begin{aligned}\Delta \text{kWh} &= (((\text{Hp} - (0.25 * \text{Milking Unit})) * 0.746 * \text{LF}) / \eta_{\text{motor}}) * \text{hours}_{\text{milk}} * \text{days}_{\text{milk}} \\ &= (((10 - (0.25 * 15.8)) * 0.746 * 90\%) / 89.5\%) * 7.4 * 365 \\ &= 12,471.3 \text{ kWh}\end{aligned}$$

⁹⁴ The average vacuum pump motor horsepower is sourced from; “Energy Efficiency for Dairy Enterprises”, Sanford, Scott (University of Wisconsin-Madison), Presentation to Agricultural Life Sciences Program staff, December 2014. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁹⁵ The amount of horsepower required per milking unit is sourced from the PG&E Workpaper – Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013.

⁹⁶ The default number of milking units is sourced as an average of participating sites for the Wisconsin Focus on Energy program from January 2013 through May 2015. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁹⁷ The motor efficiency is based on motor horsepower and NEMA energy efficient full load motor ratings. The default value is sourced as an average of participating sites for the Wisconsin Focus on Energy program from January 2013 through May 2015. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁹⁸ The default daily run time of the vacuum pump during milking is based on an average run time of 3.7 hours per milking and 2 milkings per day. The average run time per milking is sourced from “Milking System Air Consumption When Using a Variable Speed Vacuum Pump”, Paper Number: 033014 - ASAE Meeting Presentation, July 2003. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus. The number of milkings per day is consistent through other dairy measures in this TRM and is sourced from: Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH = Full Load Hours
 = 2,703⁹⁹
 CF = coincidence factor
 = 79.3%¹⁰⁰

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-VDVP-V05-230101

SUNSET DATE: 1/1/2028

⁹⁹ The annual full load hours equal the vacuum pump run time during milking multiplied by the number of milkings per day multiplied by the number of milking days per year [(2,703 hours) = (3.7 hours per milking) x (2 milkings per day) x (365.25 milking days per year)].

¹⁰⁰ 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 precool 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.¹⁰¹

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 \$3,444.¹⁰²

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = \text{kWh/Cow} * N_{\text{Cows}}$$

Where:

kWh/Cow = Per cow annual energy savings from plate-style milk precooler in kWh/cow/yr¹⁰³

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 scroll compressor installed	65.0

¹⁰¹ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014

¹⁰² The equipment and labor costs are sourced from the PG&E Workpaper – Milk Pre Cooler (PGE3PAGR114), February 2013.

¹⁰³ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

Equipment Type	kWh/cow/year
Default if type not known ¹⁰⁴	66.5

N_{Cows} = Number of milking cows per farm

= Actual; if unknown use 234¹⁰⁵

Savings Analysis:

$$\frac{\Delta kWh}{Cow} = (Days * C_{P,Milk} * Lbs\ of\ Milk * \Delta T - Btuh\ of\ Heat\ Recovery) * \frac{1}{EER} * \frac{1}{1,000}$$

Where:

Days = Number of milking days per year

= 365 days¹⁰⁶

C_{P,Milk} = Specific heat of milk¹⁰⁷

= 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 day¹⁰⁸

ΔT = Temperature reduction of the milk across precooler

= 40°F¹⁰⁹

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

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

= 131,562 Btu/hr per cow per year if electric water heater and a heat reclaimer are present on-site¹¹⁰

1,000 = Conversion factor from watts to kilowatts¹¹¹

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

¹⁰⁴ 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.

¹⁰⁵ Entered from application form; default value is sourced from the 2022 U.S. Census of Agriculture, Iowa State and County Data, Full Report, Volume 1, Table 1. Average number of cows per farm = 238,087 cows / 1,016 farms = 234.

¹⁰⁶ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹⁰⁷ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

¹⁰⁸ 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.

¹⁰⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹¹⁰ 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.

¹¹¹ 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 8.4¹¹²

= if installed with unknown compressor type, use EER of 9.3¹¹³

= if installed with scroll compressor, use EER of 10.9¹¹⁴

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.¹¹⁵

= 3,910

CF = Coincidence factor

= 79%¹¹⁶

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-DYPC- V05-210101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

¹¹² Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM – Plate Heat Exchanger and Well Water Pre-Cooler, 2017.

¹¹³ Typical milk precooling 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.

¹¹⁴ Typical milk precooling 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.

¹¹⁵ 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 .

¹¹⁶ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls.

3.1.15 LED GROW LIGHTS

DESCRIPTION

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

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

- Third-party tested and UL listed
- Power factor (PF) ≥ 0.90
- Photosynthetic photon efficacy (PPE) of no less than 2.5 micromoles per joule
- Minimum rated lifetime of 50,000 hours and a minimum warranty of 5 years for luminaires
- LED fixture must be on the Design Lights Consortium qualifying products list¹¹⁷

DEFINITION OF BASELINE EQUIPMENT

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

Crop Type	Baseline Technology Type	Baseline PPE ($\mu\text{mol/J}$) ¹¹⁸	Baseline Watts per Square Foot ¹¹⁹	Baseline Fixture Wattage ¹²⁰
Flowering Crops (Tomatoes and Peppers)	High Pressure Sodium	1.7	52.5	840 W
Vegetative Growth	Metal Halide	1.25 ¹²¹	40	640 W
Microgreens ¹²²	T5 HO Fixture	0.84 ¹²³	22.5	360 W

¹¹⁷ Design Light Consortium – Horticultural Lighting, Testing and Reporting Requirements of LED-Based Horticultural Lighting, version 4.0, effective April 18, 2025.

¹¹⁸ Erik Runkle and Bruce Bugbee “Plant Lighting Efficiency and Efficacy: μmol per joule”. Accessed 4/21/2020.

¹¹⁹ 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).

¹²⁰ 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).

¹²¹ 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.

¹²² Microgreens T5 fixture is based on a 6-lamp high output fixture, based on program experience.

¹²³ Jacob A. Nelson, Bruce Bugbee, “Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures.” Utah State University. Accessed 5/6/2020.

Crop Type	Baseline Technology Type	Baseline PPE ($\mu\text{mol/J}$) ¹¹⁸	Baseline Watts per Square Foot ¹¹⁹	Baseline Fixture Wattage ¹²⁰
Propagation ¹²⁴	T5 HO Fixture	0.84 ¹²⁵	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.¹²⁶

DEEMED MEASURE COST

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

$$\text{Incremental cost}^{127} = (\$1.42 * \text{Watts}_{\text{LED}}) - \$65$$

Where:

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

\$65 = LED fixture wattage to incremental cost offset

Watts_{LED} = LED fixture wattage

LOADSHAPE

Loadshape NRE11 – Nonresidential Agricultural

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (\text{Watts}_{\text{Base}} - (\text{Watts}_{\text{EE}} * \% \text{Dimming})) * \text{Area} * \text{Hours} * \text{WHF}_e / 1,000$$

Where:

ΔkWh = gross customer annual kWh savings

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

= Use actual if known; if unknown, default is 16 square feet per fixture multiplied by the

¹²⁴ Propagation T5 fixture is based on a 4-lamp high output fixture, based on program experience.

¹²⁵ 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.

¹²⁶ 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.

¹²⁷ 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”

number of installed fixtures¹²⁸
 Hours = Annual hours of operation
 = Use actual if known; if unknown, default by crop type:

Crop Types	Annual Hours ¹²⁹
Flowering Crops	4,200
Vegetative/Propagation Crops	6,300
Microgreens	6,300
Cannabis – Flowering Stage	4,200
Other	3,650
Average	5,250

1,000 = Conversion from watts to kilowatts (W/kW)
 WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting. If unknown assume space is being cooled.

HVAC Cooling Type	WHF _e ¹³⁰
Cooling	1.21
No Cooling	1.00

Watts_{Base} = Baseline wattage per square foot of coverage/canopy area; see typical baseline wattages by crop type in baseline equipment definition. If unknown or midstream, default value is 53.7 watts per square foot.¹³¹
 Watts_{EE} = Efficient wattage per square foot of coverage/canopy area
 = Actual; if crop type is unknown, default value is 36 watts per square foot¹³²
 %Dimming = Average seasonal light intensity of the installed lights
 = Actual; if unknown, default to 100%.

For Example, a flowering barn with 50 fixtures installed would save,

$$\begin{aligned} \Delta \text{kWh} &= (\text{Watts}_{\text{base}} - (\text{Watts}_{\text{EE}} * \% \text{ Dimming})) * \text{Area} * \text{Hours} * \text{WHF}_e / 1,000 \\ &= (53.7 - (36 * 100\%)) * 800 * 4,200 * 1.21 / 1,000 \\ &= 71,961.1 \text{ kWh} \end{aligned}$$

¹²⁸ Default illuminated area is based on an average canopy grow area of 4 ft. x 4 ft.

¹²⁹ 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.

¹³⁰ Waste heat factor for cooling savings calculation is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

¹³¹ The default baseline watts per square foot represents an average of the most likely sites and plant growth stages to participate in this measure; flowering crops, vegetative growth stages, and cannabis flowering/full cycle.

¹³² "Cannabis Energy Guidance", Massachusetts Department of Energy Resources, February 2019.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (Watts_{Base} - (Watts_{EE} * \%Dimming)) * Area * CF * WHF_d / 1,000$$

Where:

CF = 100%

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings. If unknown, assume space is being cooled.

HVAC Cooling Type	WHF _d ¹³³
Cooling	1.22
No Cooling	1.00

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Any costs associated with moving the LED lighting fixture to different heights throughout the different growing phases should also be included as an O&M consideration. See table below for default replacement assumptions:¹³⁴

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

¹³³ Waste heat demand factor for cooling savings calculation is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

¹³⁴ 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.

MEASURE CODE: NR-AGE-GROW-V04-260101

SUNSET DATE: 1/1/2029

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.

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.¹³⁵

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Table – Default Annual kWh Savings Based on Bin Size – No Supplemental Heating

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

Table – Default Annual kWh Savings Based on Bin Size – With Supplemental Heating

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	1,090	1,381	2,570	3,342	4,234	5,244	6,373	9,418	10,146	10,904	14,662	19,921
20	1,164	1,487	2,807	3,666	4,656	5,779	7,464	10,369	11,178	12,450	16,148	22,373

¹³⁵ 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”.

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
30	1,531	2,015	3,996	5,714	7,199	9,313	11,625	16,414	17,627	19,320	25,727	35,065
35	1,714	2,279	5,020	6,953	8,686	11,081	13,706	20,081	21,497	23,400	31,162	42,701
40	1,897	2,543	6,045	8,191	10,603	13,708	16,647	24,178	26,226	28,340	37,456	51,197
45	2,081	3,237	7,069	9,860	12,949	16,335	20,018	28,706	31,386	33,710	45,041	61,413
50	2,694	3,931	8,523	11,529	15,296	19,392	23,819	34,093	36,975	40,370	53,485	72,919
55	3,308	4,626	9,978	13,628	18,072	22,879	28,050	40,340	43,855	47,460	63,220	86,144
60	3,491	5,320	11,862	16,157	21,279	26,797	33,141	47,877	51,594	55,840	74,674	101,520
65	4,105	6,014	14,176	19,116	24,915	31,574	38,662	55,845	60,624	65,510	87,419	119,046
70	5,148	7,138	16,490	22,075	28,982	36,781	45,472	65,532	70,943	76,900	102,313	139,152
75	5,761	8,262	18,805	25,894	33,909	42,848	52,713	76,079	82,553	89,150	118,928	161,838
80	6,805	9,816	21,979	30,143	39,265	49,346	61,244	87,917	95,452	103,550	137,692	187,104
85	7,848	11,370	25,583	34,392	45,052	57,133	70,635	101,474	110,072	119,240	158,607	215,810
90	8,892	12,925	29,188	39,501	51,698	65,780	80,886	116,751	126,411	137,080	182,101	247,955
95	10,365	14,909	33,222	45,470	59,205	74,857	92,427	133,318	144,901	156,640	208,606	283,541
100	11,839	16,893	38,116	51,869	67,571	85,654	105,688	152,036	164,680	178,350	237,260	322,997

For midstream applications, the assumption is there is no supplemental heating and default savings is 25,445 kWh.¹³⁶

Table – Default Annual kWh Savings Based on Fan Aeration System

Grain Bin Fan Aeration System (Total System Hp)	Assumed Bin Hp	Default Annual kWh Savings
< 10 hp	5	3,763
10 to 29.9 hp	20	15,050
≥ 30 hp	50	37.625

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

Where:

ΔkWh = gross customer annual kWh savings

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

Where:

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

= Default value is 430 kWh/Hp

0.746 = Conversion factor from hp to kW

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

¹³⁶ Midstream savings value is sourced from Ameren Agriculture Program Data, representative of all grain bin fan aeration controls installs between 2019 and April 2025. The default savings were based on an average bin diameter of 66 feet and an average eave height of 69 feet.

	= 720 hours ¹³⁷
Hours _{Control}	= Annual hours of operation for grain storage bin aeration fans with controls
	= 180 hours ¹³⁸
Eff _{Motor}	= Efficiency of the fan motor
	= 93.6% ¹³⁹
kWh _{Heat}	= Electric savings associated with the reduced run time of the supplemental electric heater

Where;

$$kWh_{Heat} = \frac{Design\ CFM * \Delta T}{3,413 / 1.08} * (Hours_{Manual} - Hours_{Control})$$

Where grain bin fan aeration system horsepower is known:

$$Fan_{BHP} = \frac{Fan_{HP}}{Eff_{Fan}} * (1 + Exhaust\ Fan\ Factor)$$

Where grain bin fan aeration system horsepower is unknown:

$$Fan_{BHP} = \frac{Design\ CFM * Static\ Pressure}{6,356 * Eff_{Fan}} * (1 + Exhaust\ Fan\ Factor)$$

Where:

Fan _{HP}	= Fan horsepower
	= Actual
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 ¹⁴⁰
6,356	= Conversion factor from CFM-(in. wg) to horsepower
Eff _{Fan}	= Efficiency of the fan
	= 60% ¹⁴¹
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% ¹⁴²

¹³⁷ The default manual control hours are sourced from Alliant Energy Custom Rebate Project Data from 2013-2015.

¹³⁸ 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.

¹³⁹ Motor efficiency is based on a NEMA Premium Efficient, 60 hp, ODP, 3,600 RPM motor. This is a typical fan motor for larger bin sizes, as supported by Alliant Energy Custom Rebate Project Data from 2013-2015.

¹⁴⁰ If the calculated fan brake horsepower resulted in a fractional value below 1, it was rounded up to 1 hp.

¹⁴¹ Typical rule of thumb for fans with high static pressure.

¹⁴² The fan exhaust factor is sourced from Alliant Energy Custom Rebate Project Data from 2013-2015.

ΔT	= The temperature rise provided by the supplemental heater = 5 °F ¹⁴³
3,413	= Conversion factor to convert Btu to kW
1.08	= Air density in units of lbs/ft ³
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 0.17 ¹⁴⁴ = $ax^2 + bx + c$ a = 0.002142472 b = -0.0679226 c = 1.212104147

Table – Default Static Pressure

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

$$\text{Design CFM} = \text{Bushel Capacity} * \text{CFM per Bushel}$$

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 ¹⁴⁵

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

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

¹⁴³ Agriculture and Natural Resources, University of Arkansas, Low Temperature Grain Drying, August 2017. Because overdrying should be avoided, the amount of heat to be added to outside air should vary with the condition of this air. A temperature rise of 7°F for outside air temperatures between 40°F and 50°F is recommended. Of this 7°F temperature rise, 2 degrees are provided with heat added by the fan and motor, so only a 5-degree temperature rise must be furnished by the gas or electric heater

¹⁴⁴ Kansas State University Research and Extension, “Aeration of Grain”, April 2012.

¹⁴⁵ Typical vendor design information, as supported by Alliant Energy Custom Rebate Project Data from 2013-2015.

= See table below for Bushel Capacity default values

Table – Bushel Capacity

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	4,547	6,547	14,731	20,050	26,188	33,144	40,919	58,923	63,935	69,152	92,067	125,313
20	5,052	7,274	16,367	22,278	29,098	36,827	45,465	65,470	71,039	76,836	102,297	139,237
30	7,578	10,912	24,551	33,417	43,647	55,240	68,198	98,205	106,559	115,254	153,445	208,855
35	8,840	12,730	28,643	38,986	50,921	64,447	79,564	114,572	124,319	134,463	179,019	243,665
40	10,103	14,549	32,735	44,556	58,195	73,654	90,930	130,940	142,079	153,672	204,593	278,474
45	11,366	16,367	36,827	50,125	65,470	82,860	102,297	147,307	159,838	172,881	230,167	313,283
50	12,629	18,186	40,919	55,695	72,744	92,067	113,663	163,674	177,598	192,090	255,741	348,092
55	13,892	20,005	45,010	61,264	80,019	101,274	125,029	180,042	195,358	211,299	281,315	382,902
60	15,155	21,823	49,102	66,834	87,293	110,480	136,395	196,409	213,118	230,508	306,890	417,711
65	16,418	23,642	53,194	72,403	94,567	119,687	147,762	212,777	230,878	249,717	332,464	452,520
70	17,681	25,460	57,286	77,973	101,842	128,894	159,128	229,144	248,637	268,926	358,038	487,329
75	18,944	27,279	61,378	83,542	109,116	138,100	170,494	245,512	266,397	288,135	383,612	522,139
80	20,207	29,098	65,470	89,112	116,391	147,307	181,861	261,879	284,157	307,344	409,186	556,948
85	21,470	30,916	69,562	94,681	123,665	156,514	193,227	278,247	301,917	326,553	434,760	591,757
90	22,733	32,735	73,654	100,251	130,940	165,720	204,593	294,614	319,677	345,762	460,334	626,566
95	23,995	34,553	77,745	105,820	138,214	174,927	215,959	310,981	337,437	364,971	485,909	661,376
100	25,258	36,372	81,837	111,390	145,488	184,134	227,326	327,349	355,196	384,180	511,483	696,185

Diameter = Diameter of the storage bin, in feet

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

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

Table – Fan BHP Based on Bin Size

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	1	1	1	1	1	1	1	2	2	2	3	4
20	1	1	1	1	1	1	2	2	2	3	3	5
30	1	1	1	2	2	3	4	5	5	6	8	11
35	1	1	2	3	3	4	5	8	8	9	12	17
40	1	1	3	4	5	7	8	12	13	14	18	25
45	1	2	4	6	8	10	12	17	19	20	27	37
50	2	3	6	8	11	14	17	24	26	29	38	52
55	3	4	8	11	15	19	23	33	36	39	52	71
60	3	5	11	15	20	25	31	45	48	52	70	95
65	4	6	15	20	26	33	40	58	63	68	91	124
70	6	8	19	25	33	42	52	75	81	88	117	159
75	7	10	23	32	42	53	65	94	102	110	147	200
80	9	13	29	40	52	65	81	116	126	137	182	247
85	11	16	36	48	63	80	99	142	154	167	222	302

Iowa Energy Efficiency Statewide Technical Reference Manual—3.1.16 Grain Bin Fan Aeration Controls

	Bin Diameter (ft)											
Bin Eave Height (ft)	20	24	36	42	48	54	60	72	75	78	90	105
90	13	19	43	58	76	97	119	172	186	202	268	365
95	16	23	51	70	91	115	142	205	223	241	321	436
100	19	27	61	83	108	137	169	243	263	285	379	516

Table – Design CFM

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

Table – Supplemental Heater kW

	Bin Diameter (ft)											
Bin Eave Height (ft)	20	24	36	42	48	54	60	72	75	78	90	105
18	1.2	1.8	4.0	5.4	7.0	8.9	11.0	15.8	17.2	18.6	24.8	33.7
20	1.4	2.0	4.4	6.0	7.8	9.9	12.2	17.6	19.1	20.7	27.5	37.5
30	2.0	2.9	6.6	9.0	11.7	14.9	18.3	26.4	28.7	31.0	41.3	56.2
35	2.4	3.4	7.7	10.5	13.7	17.3	21.4	30.8	33.4	36.2	48.2	65.5
40	2.7	3.9	8.8	12.0	15.7	19.8	24.5	35.2	38.2	41.3	55.0	74.9
45	3.1	4.4	9.9	13.5	17.6	22.3	27.5	39.6	43.0	46.5	61.9	84.3
50	3.4	4.9	11.0	15.0	19.6	24.8	30.6	44.0	47.8	51.7	68.8	93.6
55	3.7	5.4	12.1	16.5	21.5	27.2	33.6	48.4	52.5	56.8	75.7	103.0
60	4.1	5.9	13.2	18.0	23.5	29.7	36.7	52.8	57.3	62.0	82.5	112.4
65	4.4	6.4	14.3	19.5	25.4	32.2	39.7	57.2	62.1	67.2	89.4	121.7
70	4.8	6.8	15.4	21.0	27.4	34.7	42.8	61.6	66.9	72.3	96.3	131.1
75	5.1	7.3	16.5	22.5	29.3	37.1	45.9	66.0	71.7	77.5	103.2	140.4
80	5.4	7.8	17.6	24.0	31.3	39.6	48.9	70.4	76.4	82.7	110.1	149.8
85	5.8	8.3	18.7	25.5	33.3	42.1	52.0	74.8	81.2	87.8	116.9	159.2
90	6.1	8.8	19.8	27.0	35.2	44.6	55.0	79.2	86.0	93.0	123.8	168.5
95	6.5	9.3	20.9	28.5	37.2	47.1	58.1	83.6	90.8	98.2	130.7	177.9

	Bin Diameter (ft)											
Bin Eave Height (ft)	20	24	36	42	48	54	60	72	75	78	90	105
100	6.8	9.8	22.0	30.0	39.1	49.5	61.1	88.0	95.5	103.3	137.6	187.3

Table – Supplemental Heater kWh Savings Only

	Bin Diameter (ft)											
Bin Eave Height (ft)	20	24	36	42	48	54	60	72	75	78	90	105
18	660	951	2,140	2,912	3,804	4,814	5,943	8,558	9,286	10,044	13,372	18,201
20	734	1,057	2,377	3,236	4,226	5,349	6,604	9,509	10,318	11,160	14,858	20,223
30	1,101	1,585	3,566	4,854	6,339	8,023	9,905	14,264	15,477	16,740	22,287	30,335
35	1,284	1,849	4,160	5,663	7,396	9,361	11,556	16,641	18,057	19,530	26,002	35,391
40	1,467	2,113	4,755	6,471	8,453	10,698	13,207	19,018	20,636	22,320	29,716	40,447
45	1,651	2,377	5,349	7,280	9,509	12,035	14,858	21,396	23,216	25,110	33,431	45,503
50	1,834	2,641	5,943	8,089	10,566	13,372	16,509	23,773	25,795	27,900	37,145	50,559
55	2,018	2,906	6,538	8,898	11,622	14,709	18,160	26,150	28,375	30,690	40,860	55,614
60	2,201	3,170	7,132	9,707	12,679	16,047	19,811	28,527	30,954	33,480	44,574	60,670
65	2,385	3,434	7,726	10,516	13,735	17,384	21,462	30,905	33,534	36,270	48,289	65,726
70	2,568	3,698	8,320	11,325	14,792	18,721	23,112	33,282	36,113	39,060	52,003	70,782
75	2,751	3,962	8,915	12,134	15,849	20,058	24,763	35,659	38,693	41,850	55,718	75,838
80	2,935	4,226	9,509	12,943	16,905	21,396	26,414	38,037	41,272	44,640	59,432	80,894
85	3,118	4,490	10,103	13,752	17,962	22,733	28,065	40,414	43,852	47,430	63,147	85,950
90	3,302	4,755	10,698	14,561	19,018	24,070	29,716	42,791	46,431	50,220	66,861	91,005
95	3,485	5,019	11,292	15,370	20,075	25,407	31,367	45,168	49,011	53,010	70,576	96,061
100	3,669	5,283	11,886	16,179	21,131	26,744	33,018	47,546	51,590	55,800	74,290	101,117

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-V04-270101

SUNSET DATE: 1/1/2030

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
- 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.¹⁴⁶

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 \$194.¹⁴⁷

LOADSHAPE

Loadshape NRE01 – Non-Residential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

¹⁴⁶ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

¹⁴⁷ 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.

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

Where:

Days	= Number of milking days per year = 365 days ¹⁴⁸
C _{P,Milk}	= Specific heat of milk ¹⁴⁹ = 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 ¹⁵⁰
Cows	= Number of cows = Actual, if unknown use 234 cows ¹⁵¹
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 ¹⁵²
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 8.4 ¹⁵³ = if tune-up with unknown compressor type, use EER of 9.3 ¹⁵⁴ = if tune-up with scroll compressor, use EER of 10.9 ¹⁵⁵
SF	= Energy savings factor = 5% ¹⁵⁶

¹⁴⁸ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹⁴⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

¹⁵⁰ 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 lbs (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.

¹⁵¹ Entered from application form; default value is sourced from the 2022 U.S. Census of Agriculture, Iowa State and County Data, Full Report, Volume 1, Table 1. Average number of cows per farm = 238,087 cows / 1,016 farms = 234.

¹⁵² IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹⁵³ Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM – Plate Heat Exchanger and Well Water Pre-Cooler, 2017.

¹⁵⁴ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The baseline EER of 9.3 is from the Scroll Refrigerant Compressor measure baseline for 2HP compressor.

¹⁵⁵ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.9 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

¹⁵⁶ 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.

For Example, a dairy system with a milk pre-cooler, a scroll compressor, and the default assumptions from above would save:

$$\begin{aligned}\Delta \text{kWh} &= (\text{Days} * C_{p,\text{Milk}} * \text{Lbs of Milk} * \text{Cows} * \Delta T) * 1/\text{EER} * 1/1000 * \text{SF} \\ &= (365 * 0.93 * 51.6 * 234 * 29) * 1/10.9 * 1/1000 * 5\% \\ &= 545.2 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2029

3.1.18 ECM VENTILATION FAN AND STAGING CONTROLS

DESCRIPTION

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

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.¹⁵⁷

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape NREV06 – Industrial Ventilation

¹⁵⁷ Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 5,305 hours.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base}}{1,000} * hours_{Total} * Nfans - \sum \left(\frac{Nfans * Watts_{EE}}{1,000} * \% Speed^{2.5} * Hours_{Speed} \right)$$

Where:

$Watts_{Base}$ = Connected load of baseline ventilation fans (watts).¹⁵⁸ If existing fans are not being replaced, and are ECM fans, use actual fan wattage.

Diameter of Fan (inches)	Watts_fan (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1,353

$hours_{Total}$ = 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.¹⁵⁹

Existing Control Strategy	Facility Type	Annual EFLH
No Control Strategy	Hog	5,570
	Poultry	5,020
	Dairy	4,771
	Unknown/Other	5,234
Temperature On/Off Staging	Hog	4,834
	Poultry	4,369

¹⁵⁸ 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: “Ag Vent Fan Analysis.xls”.

¹⁵⁹ See “Ag Op Hours_2025.xlsx” workbook for a complete description and derivation of default operating hours. EFLH based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. 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. 2022 Agriculture Census for Iowa. The temperature on/off staging control run hours represent the difference between the fan run time if no control strategy is in place and the reduction in fan run hours associated with an on/off temperature controller, as sourced from the ‘3.1.4 Temperature Based On/Off Ventilation Controller’ measure.

Existing Control Strategy	Facility Type	Annual EFLH
Control	Dairy	4,713
	Unknown/Other	4,596

N_{fans} = Number of ventilation fans

= Actual

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

= Actual

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

= Actual

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

= Actual

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

Number of Fans	Temperature Bin	Annual Operating Hours	Fan Speed
30	$\geq 70^{\circ}\text{F}$	2,099	100%
20	$\geq 60^{\circ}\text{F}$ and $< 70^{\circ}\text{F}$	2,230	75%
15	$\geq 55^{\circ}\text{F}$ and $< 60^{\circ}\text{F}$	1,115	75%
15	$\geq 50^{\circ}\text{F}$ and $< 55^{\circ}\text{F}$	1,115	50%
8	$< 50^{\circ}\text{F}$	2,202	100%

$$\Delta kWh = \frac{879}{1,000} * 4,205 * 30 - \sum \left(\frac{30 * 565}{1,000} * 1^{2.5} * 2,099 \right), \left(\frac{20 * 565}{1,000} * 0.75^{2.5} * 2,230 \right), \left(\frac{15 * 565}{1,000} * 0.75^{2.5} * 1,115 \right), \left(\frac{15 * 565}{1,000} * 0.5^{2.5} * 1,115 \right), \left(\frac{8 * 565}{1,000} * 1^{2.5} * 2,202 \right)$$

$$= 46,806 \text{ kWh}$$

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 SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2028

3.1.19 GRAIN DRYER TUNE-UP

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 1 year.¹⁶⁰

DEEMED MEASURE COST

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used. If unknown, the default incremental cost is estimated to be \$317.¹⁶¹

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

¹⁶⁰ The expected measure life is sourced from “Low-Cost Energy Conservation: Grain Drying”, University of Wisconsin-Madison Extension, Scott Sanford (A3784-10), 2003.

¹⁶¹ Incremental cost is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is historical Wisconsin project data from 2019, and represents a weighted average in tune-up costs between natural gas- and propane-fueled grain dryers.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Acres	= Number of acres planted that will be dried using the grain dryer
	= Actual
Bushels/Acre	= Average number of bushels per acre of grain
	= Actual; if unknown, default is 182.4 bushels per acre. ¹⁶²
Lbs _{Bushels}	= Initial bushel weight determined from grain moisture content percentage and corresponding weight.
	= Actual; if unknown, default is 61.37 lbs per bushel. ¹⁶³
3,412	= Constant conversion factor from Btus to kW
Eff	= Existing grain dryer efficiency in Btus per pounds of water removed.
	= See table below for assumed values as efficiency varies depending on type and functionality of heated grain dryer:

Grain Dryer Type	Grain Dryer Efficiency (Btus/Lbs _{H₂O}) ¹⁶⁴
Continuous Cross Flow Dryer (included Tower Dryers)	2,800
Batch Cross Flow Dryer	2,450
High Temperature Batch Bin Dryer	2,430
Mixed Flow Dryer	2,050
Continuous Flow In-Bin Dryer	2,000

%Elec	= Percentage of total energy consumed that is electric
	= 2% ¹⁶⁵
SF	= Energy savings factor

¹⁶² The average bushels per acre assumes corn as the grain commodity and is sourced from the U.S. Department of Agriculture, National Agricultural Statistics Services Quick Stats Ad-hoc Query Tool, as accessed on April 7, 2022. Queried bushels per acre of corn yields, annually, for Iowa spanning from 2010 through 2021.

¹⁶³ Tables for Weights and Measurement – Crops, University of Missouri-Columbia, Department of Agronomy, William Murphy, October 1, 1993.

¹⁶⁴ Grain dryer efficiencies are approximate as they can vary slightly depending on grain commodity, harvested and initial moisture content, final moisture content, and system calibration. The assumed grain dryer efficiencies are sourced from; “Improving Energy Efficiency in Grain Drying: Continuous Flow Dryers (Fact Sheet)”, University of Wisconsin-Madison, Extension, December 2012. Additionally, “Energy Self-Assessment, Step 2: Informational Section”, U.S. Department of Agriculture – Grain Drying Energy Efficiency and Energy Cost Graph.

¹⁶⁵ “Energy Conservation and Alternative Sources for Corn Drying”, The National Corn Handbook, March 14, 2016 (NCH-14, page 3, Table 4).

$$= 5\%^{166}$$

MS

= Moisture shrink is the percent weight reduction of wet grain as it is dried in the grain dryer. Use equation below if initial and final moisture contents are known. If unknown, default is 9.51%.¹⁶⁷

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

Where:

MC_i

= Initial moisture content

= Actual; if unknown, default is 22.9%¹⁶⁷

MC_f

= Final moisture content

= Actual; if unknown, default is 14.8%¹⁶⁷

For Example, a mixed flow dryer managing the crop from 500 acres, using the default assumptions from above would save:

$$\begin{aligned} \Delta kWh &= ((\text{Acres} * \text{Bushels/Acre} * \text{Lbs_bushels} * \text{Eff} * \text{MS}) / 3,412) * \%Elec * SF \\ &= ((500 * 182.4 * 61.37 * 2050 * 9.5\%) / 3,412) * 2\% * 5\% \\ &= 319 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS SAVINGS

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

Where:

¹⁶⁶ Energy savings factor is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is an anecdotal conservative estimate from a grain dryer manufacturer sales director.

¹⁶⁷ Moisture contents and moisture removed through the grain drying process is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is derived from actual project data for the program, spanning 2014 through 2020.

100,000

= Constant conversion factor from Btus to natural gas therms

For Example, a mixed flow dryer managing the crop from 500 acres, using the default assumptions from above would save:

$$\begin{aligned}\Delta\text{Therms} &= ((\text{Acres} * \text{Bushels/Acre} * \text{Lbs_bushels} * \text{Eff} * \text{MS}) / 100,000) * (1 - \% \text{Elec}) * \text{SF} \\ &= ((500 * 182.4 * 61.37 * 2050 * 9.5\%) / 100,000) * (1 - 2\%) * 5\% \\ &= 534 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2029

3.1.20 THERMAL CURTAINS FOR GREENHOUSES

DESCRIPTION

Greenhouses with existing polyethylene (PE) roof construction can experience substantial heat loss during unoccupied or nighttime periods. While PE coverings transmit solar radiation that helps warm the growing area during the day, they also provide limited resistance to heat transfer when outdoor temperatures drop, allowing energy to escape through the roof and other envelope surfaces at night.

Installing interior thermal curtains reduces nighttime heat loss by adding an insulating layer above the crop zone and limiting heat transfer mechanisms including conduction, convection, and long-wave radiation. Thermal curtains are typically installed as fabric panels that run the length of the greenhouse and deploy horizontally over the growing area.

Curtain operation may be manual or motor-driven; in either case, the installation should minimize gaps at edges and seams so the curtain forms an effective barrier when deployed. For this measure, the project case is the addition of a single-layer insulating heat curtain in a greenhouse area that previously did not have a heat curtain. The curtains are assumed to be closed during nighttime hours and retracted during daytime hours.

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 condition is the installation of a thermal curtain in a greenhouse with PE siding that previously did not have a thermal curtain.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a gas-heated greenhouse with PE siding and no thermal curtains.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 5 years.¹⁶⁸

DEEMED MEASURE COST

Measure cost for greenhouse thermal curtains is \$0.76 per square foot.¹⁶⁹

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

Baseline and efficient energy models were developed for each Iowa climate zone using inputs for key greenhouse construction characteristics and sources as listed in the following table. Energy savings are normalized and reproduced on a per square foot of greenhouse floor area depending on whether or not the project application is

¹⁶⁸ DEER 2014

¹⁶⁹ Itron, Inc. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Prepared for the California Public Utilities Commission.

retrofitting an existing greenhouse or a new construction greenhouse.¹⁷⁰

Retrofit:

Input Parameter	Baseline Value	Efficient Value
Roof Glazing	Double PE film, U-value 0.7 (Btu/h · ft ² · °F) ¹⁷¹	Same as baseline.
Thermal Curtain	None.	Sunset - Sunrise, U-value 0.483 (Btu/h · ft ² · °F) ¹⁷²
Wall Glazing	Single PE film, U-value 1.1 (Btu/h · ft ² · °F) ¹⁷³	Same as baseline.
Infiltration	1.5 Air Change per Hour (ACH) ¹⁷⁴	Same as baseline.
Ventilation	10 cubic feet per minute (CFM) per area (ft ²) ¹⁷⁵	Same as baseline.
Heating System	Gas-fired unit heater, 0.8 efficiency	Same as baseline.
Thermostat Setpoint	Heating setpoint 70°F	Same as baseline.
Cooling System	Natural Ventilation	Same as baseline.
Occupancy Schedule	8am – 4pm	Same as baseline.
Lighting Power Density	1.83 watts per square foot ¹⁷⁶	Same as baseline.
Lighting Schedule	Varies monthly based on available daylight hours, supplemental lighting operates between 5 – 11 hours per day to target 20 total light hours. ¹⁷⁷	Same as baseline.

New Construction:¹⁷⁸

Input Parameter	Baseline Value	Efficient Value
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¹⁷⁰ Energy savings are estimated using EnergyPlus version 9.4 whole-building energy simulation. The greenhouse geometry used in the EnergyPlus model consists of 4 connected bays, each bay with a gable type roof construction, measuring 36 feet wide by 100 feet long. The total conditioned floor area of the modeled greenhouse is 14,210 square feet, and savings are normalized per square foot floor area. The greenhouse is conditioned by gas-fired unit heaters and no cooling system. Greenhouse thermal curtain U values vary depending on the material type like spunbonded polyester, double-knit cloth, aluminized vinyl, aluminum strips, etc. They can have U values as low as 0.26 up to as high as 0.77. However, an average case of 0.483 U value has been simulated here which is assumed to represent a majority of thermal curtains. The area of the thermal curtain equals the conditioned floor area of the greenhouse.

¹⁷¹ Bartok, Table 1-2 Heat flow u-value for double layer polyethylene film.

¹⁷² Bartok, Table 4-1 Heat loss through blanket and roof, average of all material types.

¹⁷³ Bartok, Table 1-2 Heat flow u-value for single layer polyethylene film.

¹⁷⁴ ASHRAE HVAC Applications, Design for Greenhouses, ch. 25.2.1 Table 4, Suggested Design Air Changes for old construction with good maintenance.

¹⁷⁵ Bartok, Chapter 6, page 42.

¹⁷⁶ ASHRAE ch. 25.2.2 Table 10, Suggested Radiant Energy, Duration, and Time of Day for Supplemental Lighting in Greenhouses, average of all W/ft².

¹⁷⁷ ASHRAE ch. 25.2.2 Table 10, Suggested Radiant Energy, Duration, and Time of Day for Supplemental Lighting in Greenhouses, average of all hours.

¹⁷⁸ New construction greenhouses are compliant with IECC 2021 thermal envelope requirements. As code requirements and adoption can differ from municipality to municipality, the user should verify which version of code is applicable given these constraints.

Roof Glazing	Double PE film, U-value 0.5 (Btu/h · ft ² · °F)	Same as baseline.
Thermal Curtain	None.	Sunset - Sunrise, U-value 0.483 (Btu/h · ft ² · °F)
Wall Glazing	Double PE film, U-value 0.7 (Btu/h · ft ² · °F)	Same as baseline.
Infiltration	1.5 Air Changes per Hour (ACH)	Same as baseline.
Ventilation	10 cubic feet per minute (CFM) per area (ft ²)	Same as baseline.
Heating System	Gas-fired unit heater, 0.8 efficiency	Same as baseline.
Thermostat Setpoint	Heating setpoint 70°F	Same as baseline.
Cooling System	Natural Ventilation	Same as baseline.
Occupancy Schedule	8am – 4pm	Same as baseline.
Lighting Power Density	1.83 watts per square foot	Same as baseline.
Lighting Schedule	Varies monthly based on available daylight hours, supplemental lighting operates between 5 – 11 hours per day to target 20 total light hours.	Same as baseline.

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Natural gas savings are presented for each climate zone per square foot of greenhouse floor area, which constitutes all floor space under the thermal curtains, including pathways and growing canopy.

$$\Delta \text{Therms} = \text{ft}^2 \times \text{therms/ft}^2$$

Zone	Retrofit Therm Savings per Square Foot	NC Therm Savings per Square Foot
Des Moines	0.416	0.279
Burlington	0.385	0.261
Mason City	0.507	0.341

For Example, an existing 5,000 sq. ft. greenhouse located in Des Moines is installing a thermal curtain, which would save:

$$\begin{aligned}\Delta\text{Therms} &= 5,000 * 0.416 \\ &= 2,080 \text{ therms}\end{aligned}$$

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:

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

Where:

ΔTherms = Therm impact calculated above
 Days = Days in operating season
 = Actual

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-TCGRN-V01-270101

SUNSET DATE: 1/1/2028

3.1.21 INFRARED FILM FOR GREENHOUSES

DESCRIPTION

Greenhouses with polyethylene (PE) roof systems can experience substantial heat loss. PE glazing admits solar radiation that contributes to daytime warming, but it provides limited resistance to long-wave heat loss after sunset, allowing heat to escape through the roof during nighttime hours.

Infrared-inhibiting (IR) film additives can mitigate these losses. When incorporated into or applied on the interior side of a double-inflated PE roof, the IR treatment reduces long-wave radiative heat transfer by absorbing and re-emitting infrared energy back toward the growing area. This can reduce overnight roof heat loss, thereby lowering the greenhouse heating load. This measure applies to greenhouses with PE roof construction.

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 condition is the installation of infrared film in a greenhouse with PE siding that previously did not have a IR film.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a gas-heated greenhouse with PE roof glazing and no infrared film.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 5 years.¹⁷⁹

DEEMED MEASURE COST

Incremental cost for IR films installed in new/retrofit applications is \$0.02 per square foot of IR film.¹⁸⁰

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

Baseline and efficient energy models were developed for each Iowa climate zone using inputs for key greenhouse construction characteristics and sources as listed in the following table. Energy savings are normalized and reproduced on a per square foot of greenhouse floor area depending on whether or not the project application is retrofitting an existing greenhouse or a new construction greenhouse.¹⁸¹

¹⁷⁹ Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study – Final Report*. Prepared for Southern California Edison.

¹⁸⁰ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

¹⁸¹ Energy savings are estimated using EnergyPlus version 9.4 whole-building energy simulation. The greenhouse geometry used in the EnergyPlus model consists of 4 connected bays, each bay with a gable type roof construction, measuring 36 feet wide by 100 feet long. The total conditioned floor area of the modeled greenhouse is 14,210 square feet, and savings are

Retrofit:

Input Parameter	Baseline Value	Efficient Value
Roof Glazing	Double PE film, U-value 0.7 (Btu/h · ft ² · °F) ¹⁸²	IR-treated double PE film, U-value 0.5 (Btu/h · ft ² · °F) ¹⁸³
Wall Glazing	Single PE film, U-value 1.1 (Btu/h · ft ² · °F) ¹⁸⁴	Same as baseline.
Infiltration	1.5 Air Change per Hour (ACH) ¹⁸⁵	Same as baseline.
Ventilation	10 cubic feet per minute (CFM) per area (ft ²) ¹⁸⁶	Same as baseline.
Heating System	Gas-fired unit heater, 0.8 efficiency	Same as baseline.
Thermostat Setpoint	Heating setpoint 70°F	Same as baseline.
Cooling System	Natural Ventilation	Same as baseline.
Occupancy Schedule	8am – 4pm	Same as baseline.
Lighting Power Density	1.83 watts per square foot ¹⁸⁷	Same as baseline.
Lighting Schedule	Varies monthly based on available daylight hours, supplemental lighting operates between 5 – 11 hours per day to target 20 total light hours. ¹⁸⁸	Same as baseline.

New Construction:¹⁸⁹

Input Parameter	Baseline Value	Efficient Value
Roof Glazing	Double PE film, U-value 0.5 (Btu/h · ft ² · °F)	IR-treated double PE film, U-value 0.3 (Btu/h · ft ² · °F)
Wall Glazing	Double PE film, U-value 0.7 (Btu/h · ft ² · °F)	Same as baseline.
Infiltration	1.5 Air Change per Hour (ACH)	Same as baseline.
Ventilation	10 cubic feet per minute (CFM) per area (ft ²)	Same as baseline.

normalized per square foot of conditioned floor area. The greenhouse is conditioned by gas-fired unit heaters and has no dedicated cooling system. Cooling is typically achieved by natural ventilation and exhaust/ventilations fans in the greenhouse space.

¹⁸² Bartok, Table 1-2 Heat flow u-value for double layer polyethylene film.

¹⁸³ Bartok, Table 1-2 Heat flow u-value for IR-inhibited double layer polyethylene film.

¹⁸⁴ Bartok, Table 1-2 Heat flow u-value for single layer polyethylene film.

¹⁸⁵ ASHRAE HVAC Applications, Design for Greenhouses, ch. 25.2.1 Table 4, Suggested Design Air Changes for old construction with good maintenance.

¹⁸⁶ Bartok, Chapter 6, page 42.

¹⁸⁷ ASHRAE ch. 25.2.2 Table 10, Suggested Radiant Energy, Duration, and Time of Day for Supplemental Lighting in Greenhouses, average of all W/ft².

¹⁸⁸ ASHRAE ch. 25.2.2 Table 10, Suggested Radiant Energy, Duration, and Time of Day for Supplemental Lighting in Greenhouses, average of all hours.

¹⁸⁹ New construction greenhouses are compliant with IECC 2021 thermal envelope requirements. As code requirements and adoption can differ from municipality to municipality, the user should verify which version of code is applicable given these constraints.

Input Parameter	Baseline Value	Efficient Value
Heating System	Gas-fired unit heater, 0.8 efficiency	Same as baseline.
Thermostat Setpoint	Heating setpoint 70°F	Same as baseline.
Cooling System	Natural Ventilation	Same as baseline.
Occupancy Schedule	8am – 4pm	Same as baseline.
Lighting Power Density	1.83 watts per square foot	Same as baseline.
Lighting Schedule	Varies monthly based on available daylight hours, supplemental lighting operates between 5 – 11 hours per day to target 20 total light hours.	Same as baseline.

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Natural gas savings are presented for each climate zone per square foot of greenhouse floor area, which constitutes all floor space under the thermal curtains, including pathways and growing canopy.

$$\Delta\text{Therms} = \text{ft}^2 \times \text{therms/ft}^2$$

Zone	Retrofit Therm Savings per Square Foot	NC Therm Savings per Square Foot
Des Moines	0.221	0.269
Burlington	0.193	0.248
Mason City	0.266	0.325

For Example, an existing 5,000 sq. ft. greenhouse located in Des Moines is retrofitting its roof glazing material with infrared film, which would save:

$$\begin{aligned}\Delta\text{Therms} &= 5,000 * 0.269 \\ &= 1,345 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

Days = Days in operating season

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-IRGRN-V01-270101

SUNSET DATE: 1/1/2028

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)¹⁹⁰ 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 GPM¹⁹¹ 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 10 years.¹⁹²

DEEMED MEASURE COST

The incremental installed cost for this measure is \$16,¹⁹³ 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.¹⁹⁴

¹⁹⁰ IPL program product data for 2014 Iowa Residential Energy Assessments.

¹⁹¹ DOE Energy Cost Calculator for Faucets and Showerheads:

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

¹⁹² n**Navigant** 'ComEd Effective Useful Life Research Report' May 2018.

¹⁹³ 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 (20 min @ \$40/hr)).

¹⁹⁴ 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	47% ¹⁹⁵

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

= Measured full throttle flow * 0.83 throttling factor¹⁹⁶

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 factor¹⁹⁷

= 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 ¹⁹⁸ (A)	Unit	Estimated % Total Building Hot Water Use from Faucets ¹⁹⁹ (B)	Multiplier ²⁰⁰ (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	9,588
Sit-Down Rest	2.4	Meal/day	50%	36	Meals per faucet	365	15,779
Retail	2	Employee	100%	5	Employees per faucet	365	3,653
Grocery	2	Employee	100%	5	Employees per faucet	365	3,653
Warehouse	2	Employee	100%	5	Employees per faucet	250	2,500

¹⁹⁵ Default assumption for unknown fuel is based on NREL ComStock baseline metadata for 2023. 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.

¹⁹⁶ 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.

¹⁹⁷ 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.

¹⁹⁸ Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

¹⁹⁹ Estimated based on data provided in Appendix E; “Waste Not, Want Not: The Potential for Urban Water Conservation in California”.

²⁰⁰ 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 ¹⁹⁸ (A)	Unit	Estimated % Total Building Hot Water Use from Faucets ¹⁹⁹ (B)	Multiplier ²⁰⁰ (C)	Unit	Days per Year (D)	Annual Gallons Mixed Water per Faucet (A*B*C*D)
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	16,436
Motel	20	Room	25%	1	Faucet per room	365	1,826
Hotel	14	Room	25%	1	Faucet per room	365	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)

= (γ_{Water} * 1.0 * (WaterTemp - SupplyTemp)) / (RE_{electric} * 3,412)

= 0.0790 kWh/gal if resistance tank (or unknown)²⁰¹

= 0.0387 kWh/gal if heat pump water heater

Where:

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

= 8.33 lbs/gallon

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

WaterTemp = Assumed temperature of mixed water

= 86°F for Bath, 93°F for Kitchen

SupplyTemp = Assumed temperature of water entering building

= 57.8²⁰²

RE_{electric} = Recovery efficiency of electric water heater

= 98% for electric resistance (or unknown)²⁰³

= 200% for heat pump water heaters²⁰⁴

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

ISR = In service rate of faucet aerators

²⁰¹ Assumes 50:50 kitchen and bathroom usage.

²⁰² Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

²⁰³ Electric water heaters have recovery efficiency of 98%: See AHRI directory for more details.

²⁰⁴ 200% 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.

= Assumed to be 1.0

Based on defaults provided above:²⁰⁵

Building Type	ΔkWh		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	44.9	15.7	23.8
Large Office	202.2	70.8	107.1
Fast Food Rest	172.2	60.3	91.2
Sit-Down Rest	283.3	99.2	150.2
Retail	65.6	23.0	34.8
Grocery	65.6	23.0	34.8
Warehouse	44.9	15.7	23.8
Elementary School	53.9	18.9	28.6
Jr High/High School	161.7	56.6	85.7
Health	295.1	103.3	156.4
Motel	32.8	11.5	17.4
Hotel	23.0	8.0	12.2
Other	89.8	31.4	47.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = calculated value above on a per faucet basis

Hours = Annual electric DHW recovery hours for faucet use

$$= (Usage * 0.469^{206}) / GPH$$

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70°F temp rise (126.5-57.8), 98% for resistance (or unknown) and 200% for heat pump water tanks recovery efficiency, and typical 12 kW electric resistance storage tank.²⁰⁷

= 70.1 if resistance tank, 143.1 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	6.1
Large Office	78.3	27.4
Fast Food Rest	66.7	23.3
Sit-Down Rest	109.8	38.4
Retail	25.4	8.9
Grocery	25.4	8.9
Warehouse	17.4	6.1
Elementary School	20.9	7.3

²⁰⁵ See “Commercial Faucet Aerator Calculations - 2025.xlsx” for details.

²⁰⁶ 46.9% is the proportion of hot 126.5F water mixed with 57.8F supply water to give 90°F mixed faucet water.

²⁰⁷ See “Calculation of GPH Recovery - 2025.xlsx” for more information.

Building Type	Annual Recovery Hours	
	Resistance Tank	Heat Pump Tank
Jr High/High School	62.7	21.9
Health	114.4	40.0
Motel	12.7	4.4
Hotel	8.9	3.1
Other	34.8	12.2

CF = Coincidence Factor for electric load reduction

= Dependent on building type:²⁰⁸

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

Based on defaults provided above.²⁰⁹

Building Type	ΔkW		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	0.0115	0.0040	0.0061
Large Office	0.0615	0.0215	0.0326
Fast Food Rest	0.0295	0.0103	0.0156
Sit-Down Rest	0.0647	0.0226	0.0343
Retail	0.0150	0.0052	0.0079
Grocery	0.0150	0.0052	0.0079
Warehouse	0.0154	0.0054	0.0082
Elementary School	0.0138	0.0048	0.0073
Jr High/High School	0.0415	0.0145	0.0220
Health	0.0505	0.0177	0.0268
Motel	0.0022	0.0008	0.0012
Hotel	0.0016	0.0006	0.0008
Other	0.0308	0.0108	0.0163

²⁰⁸ 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 - 2025.xlsx" for details.

²⁰⁹ See "Commercial Faucet Aerator Calculations - 2025.xlsx" for details.

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	53% ²¹⁰

EPG_{gas} = Energy per gallon of mixed water used by faucet (gas water heater)

$$= (8.33 * 1.0 * (WaterTemp^{211} - SupplyTemp)) / (RE_{gas} * 100,000)$$

= 0.0034 Therm/gal for buildings with storage tank, 0.0045 Therm/gal if hot water through central boiler or 0.0038 Therm/gal if unknown

Where:

RE_{gas} = Recovery efficiency of gas water heater

$$= 69\%^{212}$$

= 78% for buildings with storage tank, 59% if hot water through central boiler, or 69% if unknown²¹³

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

Other variables as defined above.

Based on defaults provided above:²¹⁴

Building Type	$\Delta Therms$			
	Buildings with Storage Tank	Buildings with Central Boiler DHW	Unknown Gas DHW	Unknown DHW
Small Office	1.9	2.5	2.2	1.0
Large Office	8.7	11.5	9.8	4.6
Fast Food Rest	7.4	9.8	8.3	3.9
Sit-Down Rest	12.1	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

²¹⁰ Default assumption for unknown fuel is based on NREL ComStock baseline metadata for 2023. 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.

²¹¹ Assumes 50:50 kitchen and bathroom usage.

²¹² 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 0.59 and the 0.78 for single family home. An average is used for this analysis by default.

²¹³ 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.

²¹⁴ See "Commercial Faucet Aerator Calculations - 2025.xlsx" for details.

Building Type	ΔTherms			
	Buildings with Storage Tank	Buildings with Central Boiler DHW	Unknown Gas DHW	Unknown DHW
Jr High/High School	6.6	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:

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

Where:

ΔTherms = Therm impact calculated above

365 = Days per year

Based on defaults provided above:²¹⁵

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Variables as defined above

Based on defaults provided above:²¹⁶

²¹⁵ See “Commercial Faucet Aerator Calculations - 2025.xlsx” for details.

²¹⁶ See “Commercial Faucet Aerator Calculations - 2025.xlsx” for details.

Building Type	ΔGallons
Small Office	546
Large Office	2,459
Fast Food Rest	2,094
Sit-Down Rest	3,447
Retail	798
Grocery	798
Warehouse	546
Elementary School	656
Jr High/High School	1,967
Health	3,590
Motel	399
Hotel	279
Other	1,093

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-LFFA-V06-260101

SUNSET DATE: 1/1/2029

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.²¹⁷

DEEMED MEASURE COST

The incremental installed cost for this measure is \$20²¹⁸ 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%
Unknown	47% ²¹⁹

²¹⁷ Navigant 'ComEd Effective Useful Life Research Report' May 2018.

²¹⁸ Direct-install price per showerhead assumes cost of showerhead (Market research average of \$7 and assess and install time of \$13 (20 min @ \$40/hr).

²¹⁹ Default assumption for unknown fuel is based on NREL ComStock baseline metadata for 2023. 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.

GPM_{Base} = Flow rate of the baseline showerhead

= Actual measured flow rate; if not measured, assume 2.5 GPM²²⁰

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 min²²¹

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:²²²

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

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

= $(\gamma_{Water} * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_{electric} * 3,412)$

= 0.0790 kWh/gal for resistance (or unknown) unit, 0.0387 kWh/gal for heat pump water heaters

Where:

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

= 8.33 lbs/gallon

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

²²⁰ The Energy Policy Act of 1992 (EPAAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

²²¹ 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.

²²² 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.

ShowerTemp	= Assumed temperature of water = 101°F ²²³
SupplyTemp	= Assumed temperature of water entering house = 57.8 ²²⁴
RE _{electric}	= Average Recovery efficiency of electric water heater = 98% for electric resistance (or unknown) ²²⁵ = 200% for heat pump water heaters ²²⁶
3412	= Converts Btu to kWh (Btu/kWh)
ISR	= In service rate of showerhead = 1.0

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

$$\begin{aligned}\Delta kWh &= 1 * ((2.5 - 1.5) * 7.8 * 3 * 365) * 0.0790 * 1.0 \\ &= 674.7 \text{ kWh}\end{aligned}$$

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 * 0.629²²⁷) / GPH

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 68.7°F temp rise (126.5-57.8), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 12kW electric resistance storage tank.²²⁸
= 70.1 if resistance tank, 143.1 if heat pump

²²³ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

²²⁴ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

²²⁵ Electric water heaters have recovery efficiency of 98%: See AHRI directory for more details.

²²⁶ 200% 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.

²²⁷ 62.9% is the proportion of hot 126.5°F water mixed with 57.8°F supply water to give 101°F shower water.

²²⁸ See "Calculation of GPH Recovery - 2025.xlsx" for more information.

CF = Coincidence Factor for electric load reduction
= 1.6%²²⁹

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

$$\begin{aligned}\Delta kW &= (674.7/191.7) * 0.016 \\ &= 0.056 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

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

Where:

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

DHW Fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	53% ²³⁰

EPG_{gas} = Energy per gallon of hot water supplied by gas
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_{gas} * 100,000)
= 0.0034 Therm/gal for buildings with storage tank, 0.0045 Therm/gal if hot water through central boiler or 0.0038 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 unknown²³¹

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

Other variables as defined above.

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

$$\begin{aligned}\Delta Therms &= 1.0 * (2.5 - 1.5) * 7.8 * 3 * 365 * 0.0038 * 1.0 \\ &= 32.5 \text{ Therms}\end{aligned}$$

²²⁹ 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.

²³⁰ Default assumption for unknown fuel is based on NREL ComStock baseline metadata for 2023. 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.

²³¹ Water heating in multifamily buildings is often provided by a larger central boiler. An average efficiency of 0.69 is used for this analysis as a default for multifamily buildings where the water heating system is unknown.

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

365 = Days per year

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

$$\begin{aligned}\Delta PeakTherms &= 32.5/365 \\ &= 0.0890 \text{ Therms}\end{aligned}$$

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:

$$\begin{aligned}\Delta Gallons &= (2.5 - 1.5) * 7.8 * 3 * 365 * 1.0 \\ &= 8,541 \text{ gallons}\end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-LFSH-V07-260101

SUNSET DATE: 1/1/2029

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 (10/2026 federal standard is planned to be adopted for baseline water heaters in volume 12 of the TRM). 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	Subcategory	Draw Pattern	Federal Standard ²³²
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters >75,000 Btu/hr	≤120 gallon tanks	Very small	$UEF = 0.2674 - (0.0009 * \text{Rated Storage Volume in Gallons})$
		Low	$UEF = 0.5362 - (0.0012 * \text{Rated Storage Volume in Gallons})$
		Medium	$UEF = 0.6002 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		High	$UEF = 0.6597 - (0.0009 * \text{Rated Storage Volume in Gallons})$
Commercial Gas Storage Water Heaters >75,000 Btu/hr and ≤155,000 Btu/hr	>120 gallon tanks	All	80% E_{thermal} , Standby Losses = $(Q / 800 + 110) \times \text{Rated Storage Volume in Gallons}$
Commercial Gas Storage Water Heaters >155,000 Btu/hr		All	
Commercial Gas Instantaneous Water Heaters >200,000 Btu/hr	<10 gal	All	80% E_{thermal}
	≥10 gal	All	80% E_{thermal}
Residential Sized Electric Storage Water Heaters	≤55 gallon tanks	Very small	$UEF = 0.8808 - (0.0008 * \text{Rated Storage Volume in Gallons})$

²³² Federal Standard are as follows: Table 2 to § 431.110(c)—Residential-Duty Commercial Water Heater Energy Conservation Standards, Table 1 to § 431.110(a)—Commercial Water Heater Energy Conservation Standards and for the Residential-Sized Electric Storage Water Heaters (≤ 75,000 Btu/hr), please see the table in 10 CFR § 430.32 (d) Water Heaters for Electric Storage Water Heaters.

Equipment Type	Subcategory	Draw Pattern	Federal Standard ²³²
≤75,000 Btu/hr		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 ²³³	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)

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/hr 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:

Storage Water Heater Draw Pattern ²³⁴	
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 ²³⁵	
Draw Pattern	Max GPM
Very Small	≥0 and <1.7
Low	≥1.7 and <2.8
Medium	≥2.8 and <4
High	≥4

²³³ 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.

²³⁴ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table I—Draw Pattern To Be Used Based on First-Hour Rating.

²³⁵ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table II—Draw Pattern To Be Used Based on Maximum GPM Rating.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for water heaters is assumed to be:

Equipment Type	Measure Life ²³⁶ (years)
Commercial Gas Storage	10
Residential-duty Gas Storage	12
Commercial Gas Instantaneous Tankless	17
Commercial Gas Instantaneous circulating & HW supply boilers	25
Residential Gas Storage	15
Residential Gas Instantaneous Tankless	20

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:²³⁷

Equipment Type	Category	Install Cost	Incremental Cost
Gas Storage Water Heaters ≤75,000 Btu/hr, ≤55 Gallons	Baseline	\$2,473	N/A
	Efficient	\$2,723	\$250
	92% ≤ x < 95%	\$7,474	N/A
	96% ≤ x < 99%	\$7,551	\$77
	99%	\$7,691	\$216
Gas Tankless Water Heaters >50,000 Btu/hr and <200,000 Btu/hr	Tankless Baseline	\$2,320	N/A
	Efficient	\$2,436	\$115
	Incremental using Storage Baseline		\$912
Gas Tankless Water Heaters ≥200,000 Btu/hr	Tankless Baseline	\$3,012	N/A
	Efficient	\$3,032	\$20

²³⁶ DOE "Energy Conservation Program: Energy Conservation Standards for Commercial Water Heating Equipment" 10/06/23. Docket #EERE-2021-BT-STD-0027. For the Residential, smaller-sized options please see DOE "Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters" 7/28/23. Docket #EERE-2017-BT-STD-0019.

²³⁷ Cost information sources as follow: "Gas Storage & Gas Tankless ≥= 200 kBtu/hr" used data from DOE "Energy Conservation Program: Energy Conservation Standards for Commercial Water Heating Equipment" 10/06/23. Docket #EERE-2021-BT-STD-0027, in support of their upcoming standard update. Please see supporting document "Commercial Water Heater (CWH) Life Cycle Cost (LCC) and Payback Period Analysis Spreadsheet (Final Rule)" for more details. For the Gas Tankless >50 kBtu/hr and <200 kBtu/hr option, costs are sourced from "2023-07-21 Consumer Water Heater Life-Cycle Cost (LCC) and Payback Period Results Analysis (NOPR)" spreadsheet, supporting the 7/28/23 DOE ruling "Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters". Docket # EERE-2017-BT-STD-0019-0061. 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 efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study; See "HPWH Cost Estimation.xls" for more information.

Equipment Type	Category	Install Cost	Incremental Cost
	Incremental using Storage Baseline		-\$2,990
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)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(\frac{1}{UEF_{elecbase}} - \frac{1}{UEF_{Eff}} \right)}{3,412} + kWh_{cool} - kWh_{heat}$$

Where:

T_{out} = Unmixed Outlet Water Temperature

= Custom; otherwise assume 140²³⁸

T_{in} = Inlet Water Temperature

= Custom; otherwise assume 57.8²³⁹

$HotWaterUse_{Gallon}$ = 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

²³⁸ Ideally the actual set point of the water heater should be used. If not, 140°F 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°F. Generally speaking, code limits the temperature to fixtures to 120°F and 140°F for applications like laundry or dishwashing.

²³⁹ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

= Actual²⁴⁰

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:²⁴¹

Building Type ²⁴²	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/1,000) * 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:²⁴³

Building Type ²⁴⁴	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440

²⁴⁰ If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.

²⁴¹ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁴² According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

²⁴³ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁴⁴ 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 ²⁴⁴	Consumption/1,000 sq.ft.
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

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

= 8.33 lbs/gal

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

$\text{UEF}_{\text{elecbase}}$ = 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 ²⁴⁵
Residential Electric Storage Water Heaters ≤ 75,000 Btu/hr	≤55 gallon tanks	Very small	$\text{UEF} = 0.8808 - (0.0008 * \text{Rated Storage Volume in Gallons})$
		Low	$\text{UEF} = 0.9254 - (0.0003 * \text{Rated Storage Volume in Gallons})$
		Medium	$\text{UEF} = 0.9307 - (0.0002 * \text{Rated Storage Volume in Gallons})$
		High	$\text{UEF} = 0.9349 - (0.0001 * \text{Rated Storage Volume in Gallons})$
	>55 gallon and ≤120 gallon tanks ²⁴⁶	Very small	$\text{UEF} = 1.9236 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		Low	$\text{UEF} = 2.0440 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		Medium	$\text{UEF} = 2.1171 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		High	$\text{UEF} = 2.2418 - (0.0011 * \text{Rated Storage Volume in Gallons})$

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum

²⁴⁵ All Residential sized Federal Standards are from DOE Standard 10 CFR § 430.32 (d) Water Heaters, Electric Storage Water Heaters.

²⁴⁶ 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.

flow (GPM) for instantaneous as shown below:²⁴⁷

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 heat²⁴⁸

$$= \left[\frac{\left((T_{OUT} - T_{IN}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(1 - \frac{1}{UEF_{eff}} \right) \right) * LF * 40\% * LM}{COP_{COOL} * 3,412} \right] * Cool$$

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location²⁴⁹

= 0.0 for installation in an unconditioned space

40% = Portion of reduced waste heat that results in cooling savings²⁵⁰

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

²⁴⁷ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

²⁴⁸ This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling, and latent cooling demands.

²⁴⁹ Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

²⁵⁰ 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 (1.13) and assuming an average cooling COP of 3.08 (1.13 = 1 + 0.4004/3.08).

$$= 1.33^{251}$$

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

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

$$= \left(\frac{\left((T_{OUT} - T_{IN}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(1 - \frac{1}{UEF_{Eff}} \right) \right) * LF * 29\%}{COP_{HEAT} * 3,412} \right) * ElectricHeat$$

Where:

29% = Portion of reduced waste heat that results in increased heating load²⁵²

COP_{HEAT} = COP of electric heating system

= Actual system efficiency including duct loss; if not available, use:²⁵³

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

²⁵¹ 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.

²⁵² 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 29%.

²⁵³ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

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

$$\begin{aligned}
 \text{UEF}_{\text{elecbase}} &= 2.2418 - (0.0011 * \text{Rated Storage Volume in Gallons}) \\
 &= 2.2418 - (0.0011 * 50) \\
 &= 2.187 \\
 \text{kWh}_{\text{cool}} &= ((140 - 57.8) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1 - 1/4.3) * 1 * 0.18 * 1.33)/(3.08 * 3,412) * 1 \\
 &= 484 \text{ kWh} \\
 \text{kWh}_{\text{heat}} &= 0 \text{ kWh} \\
 \Delta \text{kWh} &= ((140 - 57.8) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/2.187 - 1/4.3))/3,412 + 484 - 0 \\
 &= 2,305 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$$\begin{aligned}
 \text{Hours} &= \text{Full load hours of water heater} \\
 &= 2,791^{254}
 \end{aligned}$$

$$\begin{aligned}
 CF &= \text{Summer Peak Coincidence Factor for measure} \\
 &= 41\%^{255}
 \end{aligned}$$

NATURAL GAS SAVINGS

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

Where:

$$\mu_{\text{base}} = \text{Rated efficiency of baseline water heater}$$

Equipment Type	Subcategory	Draw Pattern	μ_{base}^{256}
Residential-Duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters >75,000 Btu/hr	≤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/hr and ≤155,000 Btu/hr	>120 gallon tanks	All	80% E _{thermal} , Standby Losses = (Q / 800 + 110V)

²⁵⁴ Water heater full load hour assumption is based on loadshape information provided by Cadmus.

²⁵⁵ Water heater coincidence factor assumption is based on loadshape information provided by Cadmus.

²⁵⁶ Federal Standard are as follows: 10 CFR Part 431 Table I.1 - Residential-Duty Commercial Water Heater Energy Conservation Standards, 10 CFR Part 431 Table I.2—Commercial Water Heater Energy Conservation Standards

Equipment Type	Subcategory	Draw Pattern	μ_{base}^{256}
Commercial Gas Storage Water Heaters >155,000 Btu/hr		All	
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/hr	<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 capacity²⁵⁷

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/hr and Gas Tankless Water Heaters $\geq 200,000$ Btu/hr and with ≥ 10 gal tank can claim additional savings due to lower standby losses.

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

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

Where:

SL_{Base} = Standby loss of baseline unit

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

Q = Nameplate input rating in Btu/hr

V = Rated volume in gallons

SL_{EE} = Nameplate standby loss of new water heater, in BTU/hr

8,760 = Hours per year

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

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/hr installed in a 1,500 ft² restaurant:

$$\begin{aligned}\Delta\text{Therms}_{\text{Unit}} &= ((140 - 57.8) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/0.8 - 1/0.95))/100,000 \\ &= 54.6 \text{ Therms} \\ \Delta\text{Therms}_{\text{Standby}} &= (((130,000/800 + 110 * \sqrt{100}) - 1,079) * 8,760)/100,000 \\ &= 16.1 \text{ Therms} \\ \Delta\text{Therms} &= 54.6 + 16.1 \\ &= 70.7 \text{ Therms}\end{aligned}$$

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

$$\begin{aligned}\text{Draw Pattern} &= \text{High (First hour rating} > 75 \text{ gallons)} \\ \text{UEF}_{\text{Base}} &= 0.6597 - (0.0009 \times 74) \\ &= 0.5931 \\ \Delta\text{Therms}_{\text{Unit}} &= ((140 - 57.8) * ((6,000/1,000) * 13,133) * 8.33 * 1 * (1/0.5934 - 1/0.86))/100,000 \\ &= 281.9 \text{ Therms} \\ \Delta\text{Therms}_{\text{Standby}} &= 0 - \text{This is a Residential-Duty Commercial Water heater which does not qualify for standby loss savings} \\ \Delta\text{Therms} &= 281.9 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

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

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

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Therm impact calculated above} \\ 365 &= \text{Days per year}\end{aligned}$$

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

$$\begin{aligned}\Delta\text{PeakTherms} &= 70.7/365 \\ &= 0.1936 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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

The deemed O&M cost adjustment for a gas fired tankless heater is assumed to be \$100.²⁵⁸

MEASURE CODE: NR-HWE-GHWH-V07-250101

SUNSET DATE: 1/1/2028

²⁵⁸ 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.²⁵⁹

DEEMED MEASURE COST

Actual material and labor costs should be used if available. If actual costs are unknown the average cost of the demand controller circulation kit is \$1,442 with an installation cost of \$768 for a total measure cost of \$2,210.²⁶⁰

LOADSHAPE

Loadshape NREW08 – Nonresidential Electric Hot Water – Multifamily

Loadshape NRGW08 – Nonresidential Gas Hot Water – Multifamily

Algorithm

CALCULATION OF ENERGY SAVINGS²⁶¹

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh.²⁶²

²⁵⁹ 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.

²⁶⁰ The incremental costs were averaged based on the following multi-family, dormitory and hospitality building studies- Gas Technology Institute. (2014). 1003: Demand-based domestic hot water recirculation Public project report. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014. Studies performed in multiple dormitory buildings in the California region for Southern California Gas' PREPS Program, 2012. Evaluation of New DHW System Controls in Hospitality and Commercial Buildings. Prepared for: Minnesota Department of Commerce, Division of Energy Resources, 2018.

²⁶¹ Gas Technology Institute. (2014). 1003: Demand-based domestic hot water recirculation Public project report. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

²⁶² Based on results from the Nicor Gas Emerging Technology Program study, this value is the average kWh saved per pump. Note this value does not reflect savings from electric units but electrical savings from gas-fired units.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Summer coincident peak demand savings are expected to be negligible.

NATURAL GAS SAVINGS

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

Where:

$$55.9 = \text{Therms saved per dwelling unit}^{263}$$

$$\text{Number of dwelling units} = \text{Number of dwelling units at the site}$$

$$= \text{Actual}$$

For example, an apartment building with 53 units:

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

PEAK GAS SAVINGS

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

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

Where:

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

$$365 = \text{Days per year}$$

For example, an apartment building with 53 units:

$$\begin{aligned} \Delta \text{PeakTherms} &= 2,962.7 / 365 \\ &= 8.11 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-DHWC-V04-250101

SUNSET DATE: 1/1/2028

²⁶³ 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.²⁶⁴

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:

\$ /sq.ft. ²⁶⁵	
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

Note: Indoor pool covers may also save electricity due to positive interactions with the building's HVAC system.

²⁶⁴ 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.

²⁶⁵ Based on the average costs used by the U.S. DOE's Energy Smart Pools software.

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:²⁶⁶

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

Sqft = surface area of the pool in ft²

= Actual

η_{heat} = Efficiency of gas heating system

= Actual

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

Days = Days in operating season

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

Water savings result from a reduction in evaporative losses:

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

Where:

Sqft = surface area of the pool in ft²

²⁶⁶ The calculations are based on modeling runs using Energy Smart Pools Software that was created by the U.S. DOE. See “Commercial Pool Cover Calcs.xlsx” for additional details.

	= 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^{267}	= 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: 1/1/2029

²⁶⁷ As listed on US Department of Energy Swimming Pool Covers Energy Saver page.

3.2.6. DRAINWATER HEAT RECOVERY

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is no drainwater heat recovery system.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for recovery devices is 30 years.²⁶⁸

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 140²⁶⁹

²⁶⁸ Codes and Standards Enhancement (CASE) Initiative, 2019 California Building Energy Efficiency Standards, Title 24, Part 6 Report. "Drain Water Heat Recovery - Final Report." Published July 2017.

²⁶⁹ Ideally the actual set point of the water heater should be used. If not, 140°F 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°F. Generally speaking, code limits the temperature to fixtures to 120°F and 140°F for applications like laundry or dishwashing.

T_{in} = Inlet Water Temperature to the DHW system

= Actual; otherwise assume 57.8²⁷⁰

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:²⁷¹

Building Type ²⁷²	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/1,000) * Consumption/1,000 sq.ft.

Where:

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

= Actual

²⁷⁰ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

²⁷¹ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁷² According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:²⁷³

Building Type ²⁷⁴	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

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

= 8.33 lbs/gal

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

= Actual

η_{PRA} = Practical effectiveness of drainwater heat recovery (percentage of DHW output energy that the device can recover)

= 25%.²⁷⁵ Note: practical effectiveness is generally lower than the effectiveness reported by manufacturers, which assume steady state operation, typically with equal flow rates. In practice, however, flow rates are rarely steady state and are unequal, and as a result effectiveness is constantly changing. Practical effectiveness can therefore be thought of the time-averaged value of effectiveness and could only be definitely determined through on-site data collection.

3,412 = Conversion from Btu to kWh

RE_{electric} = Recovery efficiency of electric DHW system

= Actual if known; if not, assume:

²⁷³ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁷⁴ According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

²⁷⁵ 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.

= 98% for electric resistance ²⁷⁶

= 200% for heat pump water heaters ²⁷⁷

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

$$\begin{aligned}\Delta kWh &= (140 - 57.8) * (377 * 100) * 8.33 * 1 * 0.25 / (3,412 * 0.98) \\ &= 1,930.0 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

Hours = 8,760

CF = Summer Peak Coincidence Factor for measure
= 41%²⁷⁸

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

$$\begin{aligned}\Delta kW &= 1,930.0 / 8,760 * 0.41 \\ &= 0.0903 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

For sites with natural gas DHW:

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

Where:

100,000 = Converts Btu to Therms

RE_{gas} = Recovery efficiency of gas DHW system

= Actual if known; if not, assume:

= 78% for buildings with storage tank, 59% if hot water through central boiler, or 69% if unknown²⁷⁹

²⁷⁶ Electric water heaters have recovery efficiency of 98%: See AHRI directory for more details.

²⁷⁷ 200% 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.

²⁷⁸ Coincidence factor is in line with the Residential Hot Water measure, 3.2.3.

²⁷⁹ Water heating in multifamily buildings is often provided by a larger central boiler. An average efficiency of 0.69 is used for this analysis as a default for multifamily buildings where water heating system is unknown. Commercial properties are often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.78 for single family home. An average is used for this analysis by default.

Other terms as defined above.

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

$$\begin{aligned}\Delta\text{Therms} &= (140 - 57.8) * (377 * 100) * 8.33 * 1 * 0.25 / (100,000 * 0.85) \\ &= 75.9 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

365 = Days per year

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

$$\begin{aligned}\Delta\text{PeakTherms} &= 75.9 / 365 \\ &= 0.2079 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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

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

SUNSET DATE: 1/1/2029

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 ²⁸⁰	Model Source ²⁸¹
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Education	1,196	1,158	1,442	1,034	1,259	1,088	9%	OpenStud
Grocery	1,632	504	1,714	469	1,613	457	0%	OpenStud
Health	1,233	1,455	1,348	1,215	1,191	1,449	0%	OpenStud
Hospital	798	2,231	832	1,844	746	2,160	0%	OpenStud
Lodging	1,511	1,928	1,519	1,667	1,333	1,747	0%	OpenStud
Multifamily	1,660	1,771	1,907	1,413	1,616	1,719	0%	OpenStud
Office - Large	1,392	1,531	1,756	1,332	1,495	1,512	0%	OpenStud
Office - Small	1,361	1,060	1,516	904	1,369	1,016	26%	OpenStud
Restaurant	1,086	1,430	1,314	1,158	1,096	1,418	7%	OpenStud
Retail - Large	1,341	1,003	1,490	848	1,357	946	5%	OpenStud
Retail - Small	1,292	931	1,440	801	1,240	924	11%	OpenStud
Warehouse	1,280	962	1,550	767	1,321	964	26%	OpenStud

²⁸⁰ The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging. Values rounded in table; see model reference files for exact values.

²⁸¹ In modeled eQuest building types, values were updated based on a comparable percent change from all Open Studios building type models.

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average/Unknown		Weighting Factors for Nonresidential Average ²⁸⁰	Model Source ²⁸¹
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Convenience	800	1,726	1,204	1,599	990	1,636	0%	eQuest
Industrial	865	1,385	1,254	1,213	1,094	1,287	0%	eQuest
Religious	1,347	1,296	1,842	1,130	1,660	1,248	16%	eQuest
Nonresidential Average	1,296	1,086	1,547	916	1,360	1,057	N/A	N/A

New Construction

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average ²⁸²	Model Source
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Education	371	1,243	532	1,040	427	1,136	10%	OpenStudio
Health	1,683	1,867	1,449	1,694	1,495	1,757	0%	OpenStudio
Hospital	1,721	2,462	1,336	2,090	1,495	2,355	0%	OpenStudio
Lodging	972	2,648	1,128	2,342	979	2,541	0%	OpenStudio
Office - Large	514	1,642	640	1,301	551	1,576	0%	OpenStudio
Office - Small	462	956	595	800	511	894	31%	OpenStudio
Restaurant	857	1,067	1,109	917	976	1,014	8%	OpenStudio
Retail - Large	679	1,182	749	1,021	681	1,136	6%	OpenStudio
Retail - Small	819	854	964	742	784	817	13%	OpenStudio
Warehouse	827	691	1,147	545	871	580	31%	OpenStudio
Convenience	N/A ²⁸³							
Industrial								
Religious								
Grocery								
Multifamily								
Nonresidential Average	660	911	861	760	699	834	N/A	N/A

²⁸² 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.

²⁸³ Constraints related to prototype building information availability results in New Construction assumptions being unavailable for these building types. These building types will be added in a future cycle when prototype information becomes available.

3.3.1. BOILER

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency source is a natural gas non-condensing boiler used for space heating, not process, meeting the federal equipment standards. The Federal Standard applicable to commercial boilers imported to, or manufactured in, the United States designates a minimum AFUE rating of 84% for boilers <300,000 Btu/hr capacity,²⁸⁴ 80% E_T for boilers ≥300,000 Btu/hr and ≤2,500,000 Btu/hr, and 82% E_c for boilers >2,500,000 Btu/hr.²⁸⁵

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.²⁸⁶

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.²⁸⁷

AFUE	Full Install Cost	Incremental Install Cost
84%	\$5,635	N/A
85%	\$5,891	\$256
86%	\$6,123	\$488
87%	\$6,356	\$721
88%	\$6,588	\$953
89%	\$6,820	\$1,185
90%	\$7,053	\$1,418

²⁸⁴ [Code of Federal Regulations, 10 CFR 430.32\(e\)\(2\)\(iii\)\(A\).](#)

²⁸⁵ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

²⁸⁶ [U.S. Department of Energy, "Chapter 8. Life Cycle Cost and Payback Period Analysis," ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: COMMERCIAL WATER HEATING EQUIPMENT, April 2022. Table 8.2.16.](#)

²⁸⁷ Based on data provided in U.S. Department of Energy, "Chapter 8. Life Cycle Cost and Payback Period Analysis," ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: COMMERCIAL WATER HEATING EQUIPMENT, April 2022. Table 8.4.20. See "3.3.1 Version 8_Boiler_DOE Chapter 8_Cost Info.xlsx" for more information.

AFUE	Full Install Cost	Incremental Install Cost
91%	\$7,285	\$1,650
92%	\$7,517	\$1,882
93%	\$7,750	\$2,115
94%	\$8,124	\$2,489
95%	\$8,214	\$2,579
96%	\$8,328	\$2,693
97%	\$8,679	\$3,044
98%	\$8,911	\$3,276
99%	\$9,143	\$3,508

For boilers ≥300,000 Btu/hr input capacity, use the following table²⁸⁸:

Boiler Type	Full Install Cost (\$/KBtu)	Incremental Cost (\$/KBtu)
Hot Water Boiler ≥85% E _c and <90% E _c	\$12.94	\$2.17
Hot Water Boiler ≥90% E _c	\$22.95	\$12;17

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 SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS 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*

²⁸⁸ Sourced from the Illinois TRM, v14.0: Consistent with DOE assumption determined through a literature review in Appendix 8-F of the Department of Energy Commercial Technical Support Document.

= Actual

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

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE ²⁸⁹
≥300,000 Btu/hr and ≤2,500,000 Btu/hr	80% E _T ²⁹⁰
>2,500,000 Btu/hr	82% E _C ²⁹¹

EfficiencyRating(EE) = Efficient equipment efficiency rating

= Actual

100,000 = Conversion of Btu to Therms

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

$$\begin{aligned}\Delta\text{Therms} &= 1,495 * 150,000 * ((0.90/0.84) - 1) / 100,000 \\ &= 160.2 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁹²	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio

²⁸⁹ Code of Federal Regulations, 10 CFR 430.32(e)(2).

²⁹⁰ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

²⁹¹ Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87.

²⁹² Calculated as the percentage of total savings in the maximum saving day, from models.

Warehouse	1.6883%	eQuest
Nonresidential Average ²⁹³	1.5713%	N/A

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

$$\begin{aligned}\Delta \text{Peak Therms} &= 160.2 * 0.011592 \\ &= 1.8570 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-BOIL-V06-250101

SUNSET DATE: 1/1/2028

²⁹³ For weighting factors, see HVAC variable table in section 3.3.

3.3.2. FURNACE

DESCRIPTION

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

This measure was developed to be applicable to the following program types: TOS, 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%.²⁹⁴

DEFINITION OF MEASURE LIFE

The expected equipment measure life is assumed to be 18 years.²⁹⁵

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below:²⁹⁶

AFUE	Full Install Cost	Incremental Install Cost
85%	\$4,030	N/A
86%	\$4,086	\$56
87%	\$4,143	\$113
88%	\$4,199	\$169
89%	\$4,256	\$226
90%	\$4,312	\$282
91%	\$4,369	\$339
92%	\$4,425	\$395
93%	\$4,482	\$452
94%	\$4,538	\$508
95%	\$4,595	\$565
96%	\$4,888	\$858

²⁹⁴ 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.

²⁹⁵ Based on "ASHRAE Equipment Life Expectancy chart".

²⁹⁶ 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
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 SAVINGS

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

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use. If building type unknown (e.g. mid or upstream) assume Nonresidential average.
- Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit, not existing unit
= Actual
- AFUE_{EE} = 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
- HeatLoadFactor = Portion of HeatLoad displaced by ASHP in partial displacement applications. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26F.
= 0.0 if no heat pump is present on-site
= 1.0 if cold climate heat pump is present on-site
= 1.0 if full displacement by the heat pump or if Switchover Temperature is lower than 17°F

Climate Zone (City Based Upon)	HeatLoadFactor (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	8%	14%	20%	26%	39%	52%	59%	71%	79%	82%	89%
Zone 6 (Mason City)	6%	11%	15%	19%	25%	33%	35%	43%	49%	54%	61%
Average/Unknown	7%	12%	17%	22%	34%	46%	50%	59%	66%	71%	78%

For example, for a 150,000 Btu/hr 92% efficient furnace installed at an existing small office building with no supplemental heating system in an unknown location:

$$\Delta \text{Therms} = (1,369 * 150,000 * (0.92/0.85 - 1)) / 100,000 * (1 - 0)$$

$$= 169.1 \text{ Therms}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁹⁷	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ²⁹⁸	1.5713%	N/A

For example, for a 150,000 Btu/hr 92% efficient furnace installed at an existing small office building with no supplemental heating system in an unknown location:

$$\Delta \text{PeakTherms} = 169.1 * 0.016211$$

$$= 2.7413 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

²⁹⁷ Calculated as the percentage of total savings in the maximum saving day, from models.

²⁹⁸ For weighting factors see HVAC variable table in section 3.3.

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FRNC-V07-250101

SUNSET DATE: 1/1/2028

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 years²⁹⁹ minus furnace age.

DEEMED MEASURE COST

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

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

$$\text{Cost} = -\$0.09 * \text{Watts} + \$175.8^{300}$$

Where:

Watts = Nominal wattage of the efficient motor

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

LOADSHAPE

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

²⁹⁹ Consistent with assumed life of a new gas furnace. Table 8.3.3. The Technical support documents for federal residential appliance standards.

³⁰⁰ Incremental costs established by comparing prices as listed on granger.com, reviewed April 2022. See “ECM costs_2022.xlsx” for complete analysis methodology.

Algorithm

CALCULATION OF 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% ³⁰¹
Hours	= Annual motor operating hours
	= 4,000 ³⁰²
SF	= Savings factor
	= 0.2 ³⁰³
η _{basemotor}	= Efficiency rating of the baseline motor
	= 0.85 ³⁰⁴

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

³⁰¹ 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.

³⁰² 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.

³⁰³ 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 0.2 for C&I applications.

³⁰⁴ 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.

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FBLM-V04-230101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

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: 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.³⁰⁵

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,³⁰⁶ and \$935.98 per ton for CEE Tier 2 and higher class products.³⁰⁷ The incremental cost for all other equipment types should be determined on a site-specific basis.

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

³⁰⁵ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

³⁰⁶ For specification details see Commercial Unitary AC and HP Specification via the CEE library.

³⁰⁷ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}} \right)}{1,000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * HeatLoadFactor * \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE} * PD_{Adj}} \right)}{1,000} \right]$$

For units with cooling capacities less than 65 kBtu/hr using the M1 Testing Method:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER2_{Base}} - \frac{1}{SEER2_{EE}} \right)}{1,000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * HeatLoadFactor * \left(\frac{1}{HSPF2_{Base}} - \frac{1}{HSPF2_{EE} * PD_{Adj}} \right)}{1,000} \right]$$

Where:

- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.
- Capacity_{Cool} = Cooling output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000 Btu/hr)
- SEER_{Base} = Seasonal Energy Efficiency Ratio of the baseline equipment; see table below for values.³⁰⁸
- SEER_{EE} = Seasonal Energy Efficiency Ratio of the energy efficient equipment.
= Actual installed
- SEER2_{Base} = Seasonal Energy Efficiency Ratio 2 of the baseline equipment; see table below for values.
- SEER2_{EE} = Seasonal Energy Efficiency Ratio 2 of the energy efficient equipment.
= Actual installed
- EFLH_{heat} = heating mode equivalent full load hours are provided in section 3.3 HVAC End Use.
- Capacity_{Heat} = Heating output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000 Btu/hr)
- HeatLoadFactor = Portion of HeatLoad displaced by ASHP in partial displacement applications. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26°F.
= 1.0 if cold climate heat pump
= 1.0 if full displacement or if Switchover Temperature is lower than 17°F

HeatLoadFactor (by Switchover Temperature)

³⁰⁸ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

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

Climate Zone (City Based Upon)	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	8%	14%	20%	26%	39%	52%	59%	71%	79%	82%	89%
Zone 6 (Mason City)	6%	11%	15%	19%	25%	33%	35%	43%	49%	54%	61%
Average/Unknown	7%	12%	17%	22%	34%	46%	50%	59%	66%	71%	78%

$HSPF_{Base}$ = Heating Seasonal Performance Factor of the baseline equipment; see table below for values.

$HSPF_{EE}$ = Heating Seasonal Performance Factor of the energy efficient equipment.
= Actual installed

$HSPF2_{Base}$ = Heating Seasonal Performance Factor 2 of the baseline equipment; see table below for values

$HSPF2_{EE}$ = Heating Seasonal Performance Factor 2 of the energy efficient equipment.
= Actual installed

PD_{Adj} = Adjustment multiplier to account for increased heat pump efficiency in Partial Displacement applications when there is no electric resistance backup and Switchover Temperature is higher than 17°F. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26°F.
= 1.0 if full displacement, in Cold Climate Heat Pump application, or if Switchover Temperature is lower than 17°F

Climate Zone (City Based Upon)	PD_{Adj} (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	155%	151%	147%	145%	140%	136%	134%	131%	129%	128%	126%
Zone 6 (Mason City)	155%	151%	148%	145%	142%	137%	136%	132%	129%	127%	124%
Average/Unknown	155%	151%	148%	145%	139%	136%	135%	132%	129%	128%	125%

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{E_{Base}} - \frac{1}{E_{EE}} \right)}{1,000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{EE}} \right)}{3,412} \right]$$

Where:

E_{Base} = Baseline equipment efficiency. Use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio (EER2) shall be used; see the table below for values.

E_{EE} = Efficient equipment efficiency.
= Actual installed; use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio 2 (EER2) shall be used

3,412 = kBtu per kWh

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

COP_{EE} = coefficient of performance of the energy efficient equipment
= Actual installed

All other variables as defined above.

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

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

Equipment Type	Cooling Capacity	Heating Type	Cooling Efficiency Level	Heating Efficiency Level	Compliance Date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/hr and <135,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 14.1	N/A	1/1/2023
		All Other Types of Heating	IEER = 13.9	COP = 3.4	1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/hr and <240,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 13.5	N/A	1/1/2023
		All Other Types of Heating	IEER = 13.3	COP = 3.3	1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/hr and <760,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 12.5	N/A	1/1/2023
		All Other Types of Heating	IEER = 12.3	COP = 3.2	1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/hr	All	SEER2 = 14.3 (SEER = 15)	HSPF2 = 7.5 (HSPF = 8.8)	1/1/2025
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000 Btu/hr	All	SEER2 = 13.4 (SEER = 14)	HSPF2 = 6.7 (HSPF = 8)	1/1/2025
Small Commercial Packaged Air-Conditioning and Heating Equipment (Water Source: Water-to-Air, Water-Loop)	<17,000 Btu/hr	All	EER = 12.2	COP = 4.3	10/9/2015
	≥17,000 Btu/hr and <65,000 Btu/hr	All	EER = 13.0	COP = 4.3	10/9/2015
	≥65,000 Btu/hr and <135,000 Btu/hr	All	EER = 13.0	COP = 4.3	10/9/2015

IECC 2012 Specifications:

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE*
Air cooled (cooling mode)	< 65,000 Btu/h ^b	All	Split System	13.0 SEER	AHRI 210/240
			Single Packaged	13.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h ^b	All	Split System	13.0 SEER	
			Single Packaged	13.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h ^b	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	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*
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/hr heating capacity with a SEER2 of 15 and an HSPF2 of 9 in a full displacement scenario saves:

$$= [(60,000) * [(1/13.4) - (1/15)] * 1,418] + [(60,000) * 1 * [(1/6.7) - (1/9*1)] * 1,096]/1,000$$

$$= 3,186 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE}} \right)}{1,000} \right] * CF$$

Where:

Capacity_{Cool} = Cooling output capacity of Air Source Heat Pump (Btu/hr)

= Actual (where 1 ton = 12,000 Btu/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 8 EER2 (8.32 EER)³⁰⁹

EER_{EE} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled air conditioners < 65 kBtu/hr, if the actual EER_{EE} is unknown, assume the following conversion from SEER to EER: EER = -0.02 × SEER² + 1.12 × SEER.

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

³⁰⁹ Based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025.

Building Type	CF ³¹⁰	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ³¹¹	91.5%	N/A

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

$$\begin{aligned}\Delta kW &= [(60,000) * [(1/8.32) - (1/12.3)] / 1,000 * 0.997 \\ &= 2.92 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-HPSY-V09-260101

SUNSET DATE: 1/1/2029

³¹⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³¹¹ 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 STAR³¹² 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) 2012.³¹³

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.

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]³¹⁴

³¹² In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

³¹³ The Federal Standard does not include an EER requirement, for units less than 65,000 Btu/h, the value is approximated based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025. Equivalent EER for units greater than 65,000 Btu/h 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/hr and 1.01 for units 240,000 to 760,000 Btu/hr).

³¹⁴ The new compliance standards set by the Code of Federal Regulations for commercial air source heat pumps are more aggressive and have a higher minimum cooling and heating efficiency requirements as compared to IECC 2012. In this instance, federal standards supersede state code conservation requirements, and the baseline equipment is defined as an air source heat pumping meeting the minimum qualifying criteria as detailed in the Code of Federal Regulations.

Equipment Type	Cooling Capacity	Heating Type	Cooling Efficiency Level	Heating Efficiency Level	Compliance Date
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/hr	All	SEER2 = 14.3 (SEER = 15) EER2 = 8 (EER = 8.32)	HSPF2 = 7.5 (HSPF = 8.8)	1/1/2025
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000 Btu/hr	All	SEER2 = 13.4 (SEER = 14.0) EER2 = 8 (EER = 8.32)	HSPF2 = 6.7 (HSPF = 8.0)	1/1/2025
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/hr and <135,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 14.1 EER = 11.0	COP = 3.4	1/1/2023
		All Other Types of Heating	IEER = 13.9 EER = 10.8		1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/hr and <240,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 13.5 EER = 10.6	COP = 3.3	1/1/2023
		All Other Types of Heating	IEER = 13.3 EER = 10.4		1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/hr and <760,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 12.5 EER = 9.5	COP = 3.2	1/1/2023
		All Other Types of Heating	IEER = 12.3 EER = 9.3		1/1/2023

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life for Time of Sale or New Construction is assumed to be 25 years.³¹⁵

DEEMED MEASURE COST

The actual installed cost of the Geothermal Source Heat Pump should be used (default of \$4,081 per ton)³¹⁶, minus the assumed installation cost of the baseline equipment (\$1,867 per ton for ASHP).³¹⁷ 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,³¹⁸ and \$935.98 per ton for CEE Tier 2 and higher class products.³¹⁹

³¹⁵ 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).

³¹⁶ 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).

³¹⁷ 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.

³¹⁸ For specification details see the Commercial Unitary AC and Heat Pump Specification on the CEE Library.

³¹⁹ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

An estimate of additional cost required for a desuperheater is \$1,500.³²⁰

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\begin{aligned} \Delta kWh &= [Cooling\ savings] + [Heating\ savings] + [DHW\ savings\ if\ displacing\ electric\ DHW] \\ &= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{EER2_{Base}} - \frac{1}{EER_{EE-PL}} \right) + FLF_{Cool} * \left(\frac{1}{EER2_{Base}} - \frac{1}{EER_{EE-FL}} \right) \right)}{1,000} \right] \\ &+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{HSPF2_{Base}} - \frac{1}{(COP_{EE-PL} * 3.412)} \right) + FLF_{Heat} * \left(\frac{1}{HSPF2_{Base}} - \frac{1}{(COP_{EE-FL} * 3.412)} \right) \right)}{1,000} \right] \\ &+ \left[\frac{ElecDHW * \%DHW * \frac{1}{EF_{elecbase}} * HotWaterUseGallon * \gamma_{Water} * (T_{Out} - T_{In})}{3,412} \right] \end{aligned}$$

Where:

- $EFLH_{Cool}$ = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use
- $Capacity_{Cool}$ = Cooling output capacity of Geothermal Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000 Btu/hr)
- PLF_{Cool} = Part load cooling mode operation
= 0.85 if variable speed GSHP³²¹
= 0 if single/constant speed GSHP
= 0.71 if unknown speed type³²²
- FLF_{Cool} = Full load cooling mode operation factor
= 0.15 if variable speed GSHP
= 1 if single/constant speed GSHP
= 0.29 if unknown speed type³²³

³²⁰ Based on web review on sites including 123zeroenergy.

³²¹ 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.

³²² Based on distribution of 2022 IPL program participation data.

³²³ Based on distribution of 2022 IPL program participation data.

EER_{2Base}	= Energy Efficiency Ratio 2 (EER2) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in “Definition of Baseline Equipment” section ³²⁴
EER_{EE-PL}	= Part Load EER Efficiency of efficient GSHP unit = Actual installed with adjustment for pumping energy: ³²⁵ Adjusted EER (closed loop) = $0.0000315 * EER^3 - 0.0111 * EER^2 + 0.959 * EER$ Adjusted EER (open loop) = $0.00005 * EER^3 - 0.0145 * EER^2 + 0.93 * EER$
EER_{EE-FL}	= Full Load EER Efficiency of ENERGY STAR GSHP unit = Actual installed with adjustment for pumping energy described above
$EFLH_{Heat}$	= Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
$Capacity_{Heat}$	= Full Load heating output capacity of Geothermal Source Heat Pump (Btu/hr) = Actual (1 ton = 12,000 Btu/hr)
PLF_{Heat}	= Part load heating mode operation = 0.5 if variable speed GSHP ³²⁶ = 0 if single/constant speed GSHP = 0.42 if unknown speed type ³²⁷
FLF_{Heat}	= Full load heating mode operation factor = 0.5 if variable speed GSHP = 1 if single/constant speed GSHP = 0.58 if unknown speed type ³²⁸
$HSPF2_{Base}$	= Heating System Performance Factor 2 of new replacement baseline heating system (kBtu/kWh); use minimum standard efficiencies as specified in the table in “Definition of Baseline Equipment” section ³²⁹
COP_{EE-PL}	= Part Load Coefficient of Performance of efficient unit = Actual Installed with adjustment for pumping energy: ³³⁰ 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

³²⁴ The Federal Standard does not include an EER requirement, for units less than 65,000 Btu/h, the value is approximated based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025. Equivalent EER for units greater than 65,000 Btu/h 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/hr and 1.01 for units 240,000 to 760,000 Btu/hr).

³²⁵ The methodology provided is based upon REMRate protocol “Auxiliary Electric Energy of Ground Source Heat Pumps”

³²⁶ 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.

³²⁷ Based on distribution of 2022 IPL program participation data.

³²⁸ Based on distribution of 2022 IPL program participation data.

³²⁹ 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.

³³⁰ The methodology provided is based upon REMRate protocol ‘Auxiliary Electric Energy of Ground Source Heat Pumps.’

	= 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)
$E_{elecDHW}$	= 1 if building has electric DHW = 0 if building has nonelectric DHW = 0 if one to one replacement of existing Ground Source Heat Pump = 0.478 if unknown ³³¹
%DHW	= Percentage of total DHW load that the GSHP will provide = Actual if known = If unknown and if desuperheater installed, assume 44% ³³² = if unknown and if unknown whether desuperheater is installed, assume 23% (e.g. midstream program application) ³³³ = 0% if no desuperheater installed
$E_{elecbase}$	= 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 (gallons) = Actual ³³⁴ Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type: ³³⁵

³³¹ Percentage of commercial buildings in Iowa that utilize electric as their primary water heater fuel type, as sourced from NREL ComStock (data accessed on May 16, 2023).

³³² 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.

³³³ The 23% estimate is based on desuperheaters providing two thirds of hot water needs for eight months of the year (44%) multiplied by the estimate that desuperheaters will be installed in 51.5% of GSHP installations. Desuperheaters were installed in 51.5% of GSHP installations as sourced from IPL 2022 program participation data.

³³⁴ If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.

³³⁵ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

Building Type ³³⁶	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894
Nonresidential Weighted Average	438 ³³⁷

2. Consumption per unit area by building type

$$= (\text{Area}/1,000) * \text{Consumption}/1,000 \text{ sq.ft.}$$

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:³³⁸

Building Type ³³⁹	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

³³⁶ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

³³⁷ Consumption values weighted for the nonresidential average are sourced from the EFLH weighting tables in the 3.3 HVAC End Use section.

³³⁸ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

³³⁹ 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 ³³⁹	Consumption/1,000 sq.ft.
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133
Nonresidential Weighted Average	3,420 ³⁴⁰

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

= 8.33 lbs/gal

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

T_{out} = Unmixed Outlet Water Temperature

= custom, otherwise assume 140³⁴¹

T_{in} = Inlet Water Temperature

= custom - otherwise assume 57.8³⁴²

³⁴⁰ Consumption values weighted for the nonresidential average are sourced from the EFLH weighting tables in the 3.3 HVAC End Use section.

³⁴¹ Ideally the actual set point of the water heater should be used. If not, 140°F 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°F. Generally speaking, code limits the temperature to fixtures to 120°F and 140°F for applications like laundry or dishwashing.

³⁴² Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

For example, for a 5 ton closed loop GSHP with desuperheater unit with 24 Part Load EER, 18 Full Load EER and 4.2 Part Load COP, 3.8 Full Load COP installed in an existing school in Burlington, IA with an electric 0.95 UEF 80 gallon DHW tank:

$$\begin{aligned}\text{Adjusted Part Load EER} &= 0.0000315 * 24^3 - 0.0111 * 24^2 + 0.959 * 24 \\ &= 17.1\end{aligned}$$

$$\begin{aligned}\text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8\end{aligned}$$

$$\begin{aligned}\text{Adjusted Part Load COP} &= 0.000416 * 4.2^3 - 0.041 * 4.2^2 + 1.0086 * 4.2 \\ &= 4.2\end{aligned}$$

$$\begin{aligned}\text{Adjusted Full Load COP} &= 0.000416 * 3.8^3 - 0.041 * 3.8^2 + 1.0086 * 3.8 \\ &= 3.3\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh} &= [(1,158 * 60,000 * (0.85 * ((1/8) - (1/17.1)) + 0.15 * ((1/8) - (1/13.8)))) / 1,000] + [(1,196 \\ &\quad * 60,000 * ((0.5 * ((1/8.2) - (1/(4.2 * 3.412)))) + (0.5 * ((1/8.2) - (1/(3.3 * 3.412)))))) / 1,000] \\ &\quad + [(1 * 0.44 * (1/0.95) * (100 * 568) * 8.33 * (140 - 57.8)) / 3,412] \\ &= 12,832 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER}_{2\text{Base}}} - \frac{1}{\text{EER}_{\text{EE-FL}}} \right)}{1,000} \right) * CF$$

Where:

$\text{EER}_{2\text{Base}}$ = Energy Efficiency Ratio 2 (EER2) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in “Definition of Baseline Equipment” section³⁴³

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit
= Actual

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

Building Type	CF ³⁴⁴	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest

³⁴³ The Federal Standard does not include an EER requirement, for units less than 65,000 Btu/h, the value is approximated based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025. Equivalent EER for units greater than 65,000 Btu/h is also approximated with this formula: $\text{EER} = \text{IEER}/F$ 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/hr and 1.01 for units 240,000 to 760,000 Btu/hr).

³⁴⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ³⁴⁴	Model Source
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ³⁴⁵	91.5%	N/A

For example, for a 5 ton closed loop GSHP unit with 18 Full Load EER installed in an existing school in Burlington, IA:

$$\begin{aligned}\text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8\end{aligned}$$

$$\begin{aligned}\Delta kW &= (60,000 * (1/8 - 1/13.8) / 1,000) * 0.958 \\ &= 3.0198 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therm} = [\text{DHW savings if displacing gas DHW}]$$

$$= \frac{\text{GasDHW} * \% \text{DHW} * \frac{1}{\text{EF}_{\text{GasBase}}} * \text{HotWaterUseGallon} * \gamma_{\text{Water}} * (T_{\text{Out}} - T_{\text{In}}) * 1.0}{100,000}$$

Where:

$$\text{GasDHW} = 1 \text{ if building has gas DHW}$$

$$= 0 \text{ if building has electric DHW}$$

$$= 0 \text{ if one to one replacement of existing Ground Source Heat Pump}$$

$$\text{EF}_{\text{GasBase}} = \text{Energy factor of baseline of existing natural gas DHW heater}$$

$$= \text{Actual; if unknown assume federal standard as defined in 3.2.3 Hot Water Heater measure}$$

$$100,000 = \text{Converts Btu to Therms}$$

$$\text{Other variables as provided above.}$$

PEAK GAS SAVINGS

It is assumed that savings from a desuperheater will occur throughout the year. The Peak Gas Savings is therefore assumed to be:

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

Where:

³⁴⁵ For weighting factors, see HVAC variable table in section 3.3.

Δ Therms = Therm impact calculated above

365 = Days per year

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR- HVAC-GSHP-V10-270101

SUNSET DATE: 1/1/2029

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.

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 authoritative source for specification of baseline efficiency in instances where IECC 2012 requires less aggressive efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.³⁴⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is based upon capacity and efficiency level (defined by CEE specifications),³⁴⁷ as outlined in the following table:³⁴⁸

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

³⁴⁶ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

³⁴⁷ For specification details see the Commercial Unitary AC and Heat Pump Specification on the CEE Library.

³⁴⁸ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

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

The full installation costs are provided in the following table:

Capacity	Full Install Cost (\$/ton)		
	Base Units	Up to and Including CEE Tier 1 Units	CEE Tier 2 and Above
<135,000 Btu/hr	\$895	\$958	\$1,021
135,000 Btu/hr to > 250,000 Btu/hr	\$762	\$825	\$889
250,000 Btu/hr and greater	\$673	\$691	\$710

LOADSHAPE

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}} \right)}{1,000} \right]$$

For units with cooling capacities less than 65 kBtu/hr using the M1 Testing Method:

$$\Delta kWh = \left[\frac{EFLH_{cool} \cdot Capacity_{cool} \cdot \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{ee}} \right)}{1,000} \right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}} \right)}{1,000} \right]$$

Where:

Capacity_{cool} = Cooling output capacity of new equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)
= Actual installed

SEER_{base} = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values³⁴⁹

SEER_{ee} = Seasonal Energy Efficiency Ratio of installed unit (kBtu/kWh)
= Actual installed

SEER2_{base} = Seasonal Energy Efficiency Ratio 2 of baseline unit (kBtu/kWh); see table below for

³⁴⁹ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

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

	default values
SEER _{2ee}	= Seasonal Energy Efficiency Ratio 2 of installed unit (kBtu/kWh) = Actual installed
IEER _{base}	= Integrated Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values ³⁵⁰ . Where heating type is unknown (e.g., mid or upstream program), assume “All other types”.
IEER _{ee}	= Integrated Energy Efficiency Ratio of ENERGY STAR ³⁵¹ 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/hr and <135,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 14.8	1/1/2023
		All Other Types of Heating	IEER = 14.6	1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/hr and <240,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 14.2	1/1/2023
		All Other Types of Heating	IEER = 14.0	1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/hr and <760,000 Btu/hr	Electric Resistance Heating or No Heating	IEER = 13.2	1/1/2023
		All Other Types of Heating	IEER = 13.0	1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/hr	All	SEER2 = 13.4 (SEER = 14)	1/1/2025
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000 Btu/hr	All	SEER2 = 13.4 (SEER = 14)	1/1/2025

³⁵⁰ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

³⁵¹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

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

IECC 2012 Specifications:
TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE ^a
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, air cooled	< 65,000 Btu/h ^b	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	13.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h ^b	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h ^b	All	Split System	10.0 SEER	10.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	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	
	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	
		All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	
Air conditioners, water cooled	≥ 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	
	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	
		All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	

(continued)

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

TABLE C403.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE ^a
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, evaporatively cooled	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.1 IEER	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER	10.5 EER 14.0 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

For example, a 5 ton air cooled split system with a SEER2 of 14.3 at an existing small retail building in Burlington would save

$$\Delta \text{kWh} = (931 * 60,000 * [(1/13.4) - (1/14.3)]) / 1,000$$

$$= 262 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{\text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1,000} \right] * CF$$

Where:

EER_{base} = Energy Efficiency Ratio of the baseline equipment; see table above for default values. Where heating type is unknown (e.g. mid or upstream program), assume “All other types”. Since IECC 2012 does not provide EER requirements for air-cooled air conditioners < 65 kBtu/hr, assume 9 EER2 (9.36 EER)³⁵²

EER_{ee} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled air conditioners < 65 kBtu/hr, if the actual EER_{ee} is unknown, assume the following conversion from SEER to EER: $\text{EER} = -0.02 \times \text{SEER}^2 + 1.12 \times \text{SEER}$.

³⁵² Based on the lowest EER2 of products listed on the California Appliance Database, accessed April 2025.

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= Actual installed

CF

= Summer System Peak Coincidence Factor for Cooling (dependent on building type). If unknown (e.g. mid or upstream program) assume nonresidential average.

Building Type	CF ³⁵³	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ³⁵⁴	91.5%	N/A

For example, a 5 ton air cooled split system with a SEER2 of 14.3 (EER unknown) at an existing small retail building in Burlington would save:

$$\begin{aligned}
 \text{EER2base} &= 9 \\
 \text{EER2ee} &= -0.02 \times 14.3^2 + 1.12 \times 14.3 \\
 &= 11.9 \text{ EER} \\
 \Delta \text{kW} &= (60,000 * [(1/11.4) - (1/11.9)] / 1,000 * 1.00 \\
 &= 1.6246 \text{ kW}
 \end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-SPUA-V09-260101

SUNSET DATE: 1/1/2029

³⁵³ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³⁵⁴ 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 chiller or chillers in an existing building (i.e. time of sale), or new construction.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements of the 2012 International Energy Conservation Code, Table C403.2.3(7).

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to meet the minimum efficiency requirements of the IECC code in effect for the date and location of the building permit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.³⁵⁵

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below:

Air Cooled, Electrically Operated (\$/ton) ³⁵⁶				
Capacity (tons)	9.9 EER	10.2 EER	10.52 EER	10.70 EER
50	\$229	\$457	\$701	\$838
100	\$114	\$229	\$350	\$419
150	\$76	\$152	\$234	\$279
200	\$47	\$93	\$143	\$171
400	\$23	\$47	\$71	\$85

Air-Cooled Chiller Incremental Costs (\$/Ton)		
Efficient EER (Baseline Path B IPLV) ³⁵⁷		
Capacity (Tons)	Efficient IPLV	\$/Ton
<150	17.7	\$84.86
	19.0	\$147.50
≥150	18.0	\$38.55
	19.3	\$64.92

³⁵⁵ California Public Utilities Commission, Workpaper and Disposition Archive, Updated April 11, 2022, SWHC020-02 Air-Cooled Chiller-Final.docx.

³⁵⁶ Based on Navigant Consulting's NEEP "Incremental Cost Study Phase Two Final Report" from January 16, 2013. Adjusted for inflation to January 2026 values.

³⁵⁷ Sourced from the Illinois TRM v14 and based on the San Diego Gas & Electric (SDG&E) "SWHC052 2022 CostAnalysis.xlsx", January 2022. Adjusted for inflation to January 2026 values.

Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll) (\$/ton) ³⁵⁸				
Capacity (tons)	0.72 kW/ton	0.68 kW/ton	0.64 kW/ton	0.60 kW/ton
50	\$107	\$178	N/A	N/A
100	\$54	\$89	N/A	N/A
150	\$35	\$59	N/A	N/A
200	N/A	\$86	\$172	\$258
400	N/A	\$44	\$86	\$130

Water Cooled, Electrically Operated, Positive Displacement (Reciprocating) (\$/ton) ³⁵⁹			
Capacity (tons)	0.60 kW/ton	0.58 kW/ton	0.54 kW/ton
100	\$103	\$155	\$258
150	\$69	\$103	\$172
200	\$52	\$78	\$130
300	\$86	\$129	\$215
600	\$42	\$65	\$107

Water Cooled Chiller Incremental Costs (Baseline Path B IPLV) ³⁶⁰					
Scroll/Screw Chiller			Centrifugal Chiller		
Capacity (Tons)	Efficient kW/Ton	\$/Ton	Capacity (Tons)	Efficient kW/Ton	\$/Ton
< 75	0.45	\$132	< 150	0.40	\$231
	0.43	\$241		0.37	\$329
75 to 149	0.44	\$26	150 to 299	0.36	\$90
	0.42	\$49		0.34	\$344
150 to 299	0.40	\$36	300 to 399	0.35	\$197
	0.37	\$209		0.33	\$282
300 to 599	0.37	\$225	400 to 599	0.34	\$242
	0.35	\$402		0.32	\$312
>= 600	0.34	\$202	>= 600	0.34	\$82
	0.32	\$370		0.32	\$124

LOADSHAPE

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

The enhanced electric energy savings calculation should be used as the primary method for more accurate energy savings, with the efficiencies calculated for the specific climate zone and building type for the chiller application.

³⁵⁸ Based on Navigant Consulting’s NEEP “Incremental Cost Study Phase Two Final Report” from January 16, 2013. Adjusted for inflation to January 2026 values.

³⁵⁹ Ibid.

³⁶⁰ Sourced from the Illinois TRM v14 and based on “Water-Cooled Chiller (WCC) (SWHC005-02) Cost Data” by Southern California Edison, November 2020 (SWHC005_Water-Cooled_Chiller_Cost_Data_2020Q3.xlsx). Adjusted for inflation to January 2026 values.

Where the calculated NPLV efficiency of the chiller at the specific conditions is unknown, the basic electric energy savings calculation can be used as a secondary method where the traditional industry-standard IPLV ratings may be more readily available.

ELECTRIC ENERGY SAVINGS

Basic Electric Energy Savings for Air or Water-Cooled Chillers:

$$\Delta kWh = TONS * ((IPLV_{base}) - (IPLV_{ee})) * EFLH$$

Where:

TONS	= chiller nominal cooling output capacity in tons (note: 1 ton = 12,000 Btu/hr) = Actual installed
$IPLV_{base}^{361}$	= efficiency of baseline equipment as Integrated Part Load Value (use kW/ton for water-cooled chillers, and use 12/EER for air-cooled chillers) obtained from current IECC Minimum Efficiency Table – Path (A). Refer to “Baseline Efficiency Values by Chiller Type and Capacity in the Reference Tables & Equations” section.
$IPLV_{ee}^{362}$	= efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton or EER) ³⁶³ = Actual installed
EFLH	= Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller in an existing warehouse with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) in unknown location would save:

$$\begin{aligned}\Delta kWh &= 100 * ((12/12.5) - (12/14)) * 964 \\ &= 9,915 kWh\end{aligned}$$

Enhanced Electric Energy Savings for Air or Water-Cooled Chillers:

$$\Delta kWh = TONS * ((IPLV_{base} * IA_{adj}) - (NPLV - IA_{ee})) * EFLH$$

Where:

TONS	= chiller actual installed cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)
IA_{adj}	= adjustment factor to align IPLV _{base} to Iowa climate and building type; refer to Table 1 below = $NPLV - IA / IPLV_{ee}$
$NPLV - IA_{ee}^{364}$	= efficiency of proposed high efficiency equipment as Non-Standard Part Load Value (use

³⁶¹ 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.

³⁶² 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.

³⁶³ Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetl.org.

³⁶⁴ Calculation to be performed using manufacturer-provided efficiency ratings at custom part-load operating points specific to Iowa climate and building type. All other variables to remain at AHRI standard conditions. These custom part-load operating points are based on building load profiles generated from public domain EnergyPlus files developed by Pacific Northwest National Labs in conjunction and with oversight from ASHRAE. The different building types are reflective of certain typical occupancy schedules. See Reference Tables & Equations section at the end of this measure for additional info and supporting equations.

kW/ton for water-cooled chillers, and use EER for air-cooled chillers) evaluated at Iowa adjusted conditions. All other variables to remain at AHRI standard conditions. Chiller manufacturer shall evaluate their chiller's efficiencies at the four unique part-load operating points using entering condenser water temperatures (ECWT) for water-cooled chillers, and outdoor dry-bulb temperatures (ODDB) for air-cooled chillers. The adjusted weighted percentages can be found in Table 1 or Table 2 below, for the applicable climate zone and building space type listed. Refer to following NPLV equation:

$$\text{NPLV (kW/ton)} = 1/[a/A + b/B + c/C + d/D]$$

$$\text{NPLV (EER)} = a*A + b*B + c*C + d*D$$

Where: the lowercase letters are the decimal values for weighting and the upper case letters are the chiller efficiency rating at each unique operating point.

EFLH = Equivalent Full Load Hours for cooling in Existing Buildings or New Construction are provided in section 3.3 HVAC End Use

Table 1³⁶⁵

Water-Cooled Chillers								
NPLV Part-Load Evaluation Conditions Adjusted to Iowa by Building Type								
	25% (A)		50% (B)		75% (C)		94% (D)	
	Weight	ECWT [F]	Weight	ECWT [F]	Weight	ECWT [F]	Weight	ECWT [F]
Office (or Unknown) Z5	40.1%	68.1	38.3%	74.8	17.9%	80.4	3.7%	84.8
Hospital Z5	15.0%	62.2	44.6%	69.8	35.6%	76.7	4.8%	83.7
High-Rise Apts Z5	30.1%	68.7	41.6%	73.8	21.3%	78.7	7.0%	83.4
Primary School Z5	25.3%	67.0	26.3%	71.9	31.2%	76.1	17.2%	81.5
Hotel Z5	47.8%	67.0	39.2%	76.1	12.2%	82.2	0.80%	86.9
Office (or Unknown) Z6	43.1%	66.0	35.1%	73.1	15.8%	78.6	6.0%	83.0
Hospital Z6	18.1%	61.7	37.9%	67.3	37.1%	74.8	7.0%	81.8
High-Rise Apts Z6	36.7%	67.2	37.1%	72.8	19.3%	78.2	6.9%	82.8
Primary School Z6	34.9%	65.5	27.3%	71.4	23.7%	75.6	14.1%	81.5
Hotel Z6	53.6%	65.5	32.0%	75.1	13.3%	81.1	1.1%	84.4

Table 2³⁶⁶

Air-Cooled Chillers								
NPLV Part-Load Evaluation Conditions Adjusted to Iowa by Building Type								
	25% (A)		50% (B)		75% (C)		94% (D)	
	Weight	ODDB [F]	Weight	ODDB [F]	Weight	ODDB [F]	Weight	ODDB [F]
Office (or Unknown) Z5	40.1%	69.1	38.3%	77.2	17.9%	83.9	3.7%	89.2
Hospital Z5	15.0%	60.0	44.6%	70.2	35.6%	77.5	4.8%	86.6
High-Rise Apts Z5	30.1%	67.2	41.6%	75.9	21.3%	83.2	7.0%	89
Primary School Z5	25.3%	68.1	26.3%	74.1	31.2%	79.6	17.2%	85.6

³⁶⁵ Ibid.

³⁶⁶ Ibid.

Hotel Z5	47.8%	65.3	39.2%	76.9	12.2%	84.6	0.80%	
Office (or Unknown) Z6	43.1%	66.2	35.1%	74.6	15.8%	80.7	6.0%	86.8
Hospital Z6	18.1%	59.1	37.9%	67.7	37.1	73.9	7.0%	84.1
High-Rise Apts Z6	36.7%	66.0	37.1%	74.2	19.3%	80.8	6.9%	87.0
Primary School Z6	34.9%	65.9	27.3%	73.2	23.7%	77.7	14.1%	84.5
Hotel Z6	53.6%	63.2	32.0%	74.5	13.3%	81.7	1.1%	91.2

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

PE_{base} = Peak efficiency of baseline equipment expressed as Full Load (kW/ton or 12/EER)
= 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 or 12/EER)
= Actual installed

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

Building Type	CF ³⁶⁷	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ³⁶⁸	91.5%	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:

$$\begin{aligned}\Delta kW &= 100 * ((12/9.5) - (12/12)) * 0.768 \\ &= 20.21 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

³⁶⁷ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³⁶⁸ For weighting factors, see HVAC variable table in section 3.3.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.7 Electric Chiller

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

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	Units
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

IPLV Equations and Standard Rating Conditions per AHRI 550/590:

Expression Of Chiller Efficiency	Equation				
Coefficient Of Performance–COP, W/W, or Energy Efficiency Ratio–EER, Btu/h/W	$IPLV \text{ or } NPLV = 0.01A + 0.42B + 0.45C + 0.12D$				
Power Per Ton, kW/ton	$IPLV \text{ or } NPLV = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$				
Chiller Energy Efficiency, Load					
A at 100%	B at 75%	C at 50%	D at 25%	— at 0%	
IPLV Rating Conditions					
Condenser, water-cooled only: ^a					
Entering water temperature, F [C]	85 [29.4] ^b	75 [23.9]	65 [18.3]	65 [18.3]	65 [18.3]
Flow rate, gpm/ton [Lps per kW]	3.0 [0.054] ^c				
Fouling factor, h-ft ² -F/Btu [m ² -C/W]	0.00025 [0.000044]				
Evaporator:					
Leaving water temperature, F [C]	44 [6.7] ^b	—	—	—	44 [6.7]
Flow rate, gpm/ton [Lps per kW]	2.4 [0.043] ^c	—	—	—	2.4 [0.043]
Fouling factor, h-ft ² -F/Btu [m ² -C/W]	0.0001 [0.000018]				

Building Types – Generalized Occupancy Schedules for NPLV Part-Load Evaluation Conditions:

Office – 12 hour operation; 5 days per week

Hospital – 24 hour operation; 7 days per week; heavier occupancy during the day

High-Rise Apts – 24 hour operation; 7 days per week; lighter occupancy during the day

Primary School – 12 hour operation; 5 days per week; seasonal

Hotel –24 hour operation; 7 days per week

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

IECC 2012 SPECIFICATIONS

TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS:
WATER CHILLING PACKAGES*

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010 ^b				TEST PROCEDURE
			FULL LOAD	IPLV	PATH A		PATH B		
					FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.4 16	≥ 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.

- 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.
- 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.
- 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-V05-270101

SUNSET DATE: 1/1/2030

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 condition is provided in the Federal Baseline reference table provided below.

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.³⁶⁹

Remaining life of existing equipment is assumed to be 5 years.³⁷⁰

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be \$84/ton.³⁷¹

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.³⁷²

The assumed deferred cost (after 3 years) of replacing existing equipment with new baseline unit is assumed to be \$1,039 per ton.³⁷³ This cost should be discounted to present value using the utilities' discount rate.

³⁶⁹ Based on California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020.

³⁷⁰ Standard assumption of one third of effective useful life.

³⁷¹ DEER 2008. This assumes that baseline shift from IECC 2006 to IECC 2012 carries the same incremental costs. Values should be verified during evaluation.

³⁷² Based on DCEO – IL PHA Efficient Living Program Data.

³⁷³ Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

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

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.

Time of Sale:

$$\text{PTAC } \Delta \text{kWh}^{374} = \text{Annual kWh Savings}_{\text{cool}}$$

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

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1,000} \right]$$

$$\Delta \text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{base}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3,412} \right]$$

Early Replacement:

$$\Delta \text{kWh for remaining life of existing unit (1}^{\text{st}} \text{ 3 years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{exist}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1,000} \right]$$

$$\Delta \text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{exist}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3,412} \right]$$

$$\Delta \text{kWh for remaining measure life (next 5 years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1,000} \right]$$

$$\Delta \text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{base}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3,412} \right]$$

Where:

$\text{EFLH}_{\text{cool}}$ = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use

$\text{Capacity}_{\text{Cool}}$ = Cooling output capacity of Air Source Heat Pump (Btu/hr)

= Actual (where 1 ton = 12,000 Btu/hr)

³⁷⁴ There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COP_{base} and COP_{ee} would be 1.

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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 ³⁷⁵ If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ³⁷⁶
EFLH _{heat}	= Heating mode equivalent full load hours are provided in section 3.3 HVAC End Use
Capacity _{Heat}	= Heating output capacity of Air Source Heat Pump (Btu/hr) = Actual (where 1 ton = 12,000 Btu/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 ³⁷⁷ If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ³⁷⁸
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	<7,000 Btu/hr	11.9 EER
		≥7,000 and ≤15,000 Btu/hr	14.0 – (0.300 x Cap/1,000) EER
		>15,000 Btu/hr	9.5 EER
	Non-Standard Size*	<7,000 Btu/hr	9.4 EER
		≥7,000 and ≤15,000 Btu/hr	10.9 – (0.213 x Cap/1,000) EER
		>15,000 Btu/hr	7.7 EER
PTHP (Cooling mode)	Standard Size	<7,000 Btu/hr	11.9 EER
		≥7,000 and ≤15,000 Btu/hr	14.0 – (0.300 x Cap/1,000) EER
		>15,000 Btu/hr	9.5 EER
	Non-Standard Size*	<7,000 Btu/hr	9.3 EER
		≥7,000 and ≤15,000 Btu/hr	10.8 – (0.213 x Cap/1,000) EER

³⁷⁵ 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.

³⁷⁶ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

³⁷⁷ 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.

³⁷⁸ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

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

Equipment Type	Category	Cooling Capacity	Minimum Efficiency
		>15,000 Btu/hr	7.6 EER
PTHP (Heating mode)	Standard Size	<7,000Btu/hr	3.3 COP
		≥7,000 and ≤15,000 Btu/hr	3.7 – (0.052 x Cap/1,000) COP
		>15,000 Btu/hr	2.9 COP
	Non-Standard Size*	<7,000 Btu/hr	2.7 COP
		≥7,000 and ≤15,000 Btu/hr	2.9 – (0.026 x Cap/1,000) COP
		>15,000 Btu/hr	2.5 COP

“Cap” = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7,000 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 (406 mm) in height and less than 42 inches (1,067 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:

$$= (1,928 * 12,000 * ((1/10.4) - (1/12)))/1,000$$

$$= 297 \text{ kWh}$$

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

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

ΔkWh for remaining life of existing unit (first 3 years)

$$= (1,096 * 12,000 * (1/8.1 - 1/12)) / 1,000 + (1,418 * 12,000 * (1/1.0 - 1/3.0))/ 3,412$$

$$= 528 + 3,325$$

$$= 3,853 \text{ kWh}$$

ΔkWh for remaining measure life (next 5 years)

$$= (1,096 * 12,000 * (1/8.3 - 1/12)) / 1,000 + (1,418 * 12,000 * (1/1.0 - 1/3.0))/3,412$$

$$= 489 + 3,325$$

$$= 3,814 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

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

Early Replacement:

ΔkW for remaining life of existing unit (1st 3 years):

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

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

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 ³⁷⁹	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ³⁸⁰	91.5%	N/A

Time of Sale:

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

$$\begin{aligned} \Delta kW &= (12,000 * (1/10.4 - 1/12) / 1,000 * 0.955 \\ &= 0.15 \text{ kW} \end{aligned}$$

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

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

ΔkW for remaining life of existing unit (1st 3 years):

$$\begin{aligned} \Delta kW &= 12,000 * (1/8.1 - 1/12) / 1,000 * 0.997 \\ &= 0.48 \text{ kW} \end{aligned}$$

ΔkW for remaining measure life (next 5 years):

$$\begin{aligned} \Delta kW &= 12,000 * (1/8.3 - 1/12) / 1,000 * 0.997 \\ &= 0.44 \text{ kW} \end{aligned}$$

³⁷⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³⁸⁰ For weighting factors, see HVAC variable table in section 3.3.

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

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-PTAC-V05-270101

SUNSET DATE: 1/1/2030

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.³⁸¹

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.³⁸²

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 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,

³⁸¹ DEER 2008 value for energy management systems.

³⁸² This value was extracted from Smart Ideas projects in PY1 and PY2.

additional savings result. The basis of savings is the 2013 California Building Energy Standards, which used EnergyPro 5 simulation.³⁸³ 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

= 95.5% (for Lodging)

Other variables as defined above.

NATURAL GAS 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 ³⁸⁴ [therms/room/year]
Zone 5 (Burlington)	4.7
Zone 6 (Mason City)	6.5
Average/Unknown	5.8

³⁸³ 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.

³⁸⁴ Savings include the assumption that the thermal efficiency of the heating unit is 80%, per IECC 2012 code.

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above
 GCF = Gas Coincidence Factor for Heating
 = 1.4956% for Lodging³⁸⁵

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-GREM-V04-250101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

³⁸⁵ Calculated as the percentage of total savings in the maximum savings day, from model.

3.3.10. BOILER TUNE-UP

DESCRIPTION

This measure is for a nonresidential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The recommended tune up requirements are listed below. It is recommended that utility programs require technicians performing the work are appropriately certified.

- Measure combustion efficiency using an electronic flue gas analyzer.
- Adjust airflow and reduce excessive stack temperatures.
- Adjust burner and gas input, manual or motorized draft control.
- Check for proper venting.
- Complete visual inspection of system piping and insulation.
- Check safety controls.
- Check adequacy of combustion air intake.
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel.
- Verify boiler delta T is within system design limits.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 12 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 1 year.

DEEMED MEASURE COST

The cost of this measure is the actual tune up cost.

LOADSHAPE

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{Capacity * EFLH * \left(\frac{Eff_{before} + E_i}{Eff_{before}} - 1 \right)}{100,000}$$

Where:

Capacity	= Gas Boiler input size (Btu/hr)
	= Actual
EFLH	= Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
Eff _{before}	= Combustion Efficiency of the boiler before the tune-up
	= Actual
E _i	= Combustion Efficiency Improvement of the boiler tune-up measure ³⁸⁶
	= Actual
100,000	= Converts Btu to Therms

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta therms &= (200,000 * 1,369 * (((0.82 + 0.018)/0.82) - 1))/100,000 \\ &= 60.1 Therms \end{aligned}$$

PEAK GAS SAVINGS

³⁸⁶ 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.

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³⁸⁷	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ³⁸⁸	1.5713%	N/A

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned}\Delta PeakTherms &= 60.1 * 0.016211 \\ &= 0.97428 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there is likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: NR-HVC-BLRT-V04-250101

SUNSET DATE: 1/1/2028

³⁸⁷ Calculated as the percentage of total savings in the maximum saving day, from models.

³⁸⁸ 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.³⁸⁹

DEEMED MEASURE COST

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

LOADSHAPE

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

³⁸⁹ Based on VEIC professional judgment.

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

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$\Delta Therms$	= as calculated below
F_e	= Furnace Fan energy consumption as a percentage of annual fuel consumption = 3.14% ³⁹⁰
29.3	= kWh per Therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{Capacity * EFLH * \left(\frac{Eff_{before} + E_i}{Eff_{before}} - 1 \right)}{100,000}$$

Where:

EFLH	= Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
Capacity	= Nominal Heating Input Capacity Furnace Size (Btu/hr) = Actual
Eff _{before}	= Combustion Efficiency of the furnace before the tune-up = Actual
E_i	= Combustion Efficiency Improvement of the furnace tune-up measure ³⁹¹ = Actual
100,000	= Conversion of Btu to Therms

For example, for a 200 kBtu furnace in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta Therms &= (200,000 * 1,369 * (((0.82 + 0.018)/ 0.82) - 1))/100,000 \\ &= 60.1 Therms \end{aligned}$$

³⁹⁰ 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 1,495 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.

³⁹¹ The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³⁹²	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ³⁹³	1.5713%	N/A

For example, for a 200 kBtu furnace in a small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta PeakTherms &= 60.1 * 0.016211 \\ &= 0.97428 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there is likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: NR-HVC-FTUN-V04-250101

SUNSET DATE: 1/1/2028

³⁹² Calculated as the percentage of total savings in the maximum saving day, from models.

³⁹³ 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,³⁹⁴ 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.³⁹⁵

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 \$181.³⁹⁶

LOADSHAPE

Loadshape NREC17 – Nonresidential Cooling – Small Programmable Thermostat

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

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

³⁹⁴ The square footage of the small office prototype building modeled in is 7,500 sq.ft.

³⁹⁵ 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.

³⁹⁶ 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 (IECC 2012)
Savings Factor _{cool}	= Cooling savings factor = 0.53 kBtu/sf-yr ³⁹⁷

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 ³⁹⁸
3.142	= Conversion from kBtu to kWh
EfficiencyRating(exist) _{electric heat}	= Efficiency rating of existing heating system (COP) = Actual; if unknown assume code minimum (IECC 2012). 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:

$\Delta Therms$	= Gas savings calculated with equation below
Fe	= Percentage of heating energy consumed by fans, assume 3.14% ³⁹⁹

³⁹⁷ 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 sq.ft.) and converted to kBtu.

³⁹⁸ 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 sq.ft.) and converted to kBtu.

³⁹⁹ Fe is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based

29.3 = Conversion from Therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

0.0⁴⁰⁰

NATURAL GAS 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 (IECC 2012)
 Savings Factor_{heat} = 0.85 kBtu/sf-yr⁴⁰¹

PEAK GAS SAVINGS

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

Where:

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

Building Type	GCF ⁴⁰²	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴⁰³	1.5713%	N/A

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.

⁴⁰⁰ Modeling work used to simulate savings for this measure showed no summer peak demand savings.

⁴⁰¹ 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 sq.ft.) and converted to kBtu.

⁴⁰² Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁰³ 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-PROG-V06-250101

SUNSET DATE: 1/1/2029

3.3.13. VARIABLE FREQUENCY DRIVES FOR HVAC PUMPS AND COOLING TOWER FANS

DESCRIPTION

This measure applies to variable frequency drives (VFDs)/[variable speed drives \(VSDs\)](#) installed on HVAC chilled water and hot water distribution pumps (centrifugal pumps only) and cooling tower fans. There is a separate measure for HVAC supply and return fans. The VFD/VSD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VFD/VSD installation in existing cooling towers with 2-speed motors. (current code requires 2-speed motors for cooling towers with motors greater than 7.5 HP).
- VFD/VSD installation in new cooling towers with motors greater than 7.5 HP.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD/VSD is applied to a pump motor 1-100 HP that [is not currently controlled by](#) a VFD/VSD. The hydronic system that the VFD/VSD is applied to must have a variable or reduced load. Installation is to include the necessary control points and parameters (example: differential pressure, differential temperature, return water temperature) as determined by a qualified engineer. The savings are based on the application of VFDs/VSDs applied to a range of baseline systems, including no control, inlet or outlet guide vanes, throttling valves, and three-way valves with bypass.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD/VSD. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs/VSDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.⁴⁰⁴

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.⁴⁰⁵

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default incremental VFD/VSD costs are listed below for 1 to 100 HP motors.⁴⁰⁶

⁴⁰⁴ 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".

⁴⁰⁵ (PG&E, 2019) "SWHC018-02 - Variable Speed Drive For HVAC Fan Controls, Commercial.pdf", pg. 8.

⁴⁰⁶ Incremental costs are sourced from the "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013" and adjusted to account for inflation and regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.13 Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

HP	Cost
1-9 HP	\$2,538
10-19 HP	\$3,640
20-29 HP	\$4,989
30-39 HP	\$5,855
40-49 HP	\$6,721
50-59 HP	\$7,683
60-69 HP	\$8,801
70-79 HP	\$9,527
80-89 HP	\$10,253
90-100 HP	\$11,162

LOADSHAPE

Loadshape NRE07 – VFD - Boiler feedwater pumps

Loadshape NRE08 – VFD - Chilled water pumps

Loadshape NRE09 – VFD - Boiler circulation pumps

Loadshape NRE18 – VFD - Cooling Tower Fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{BHP}{EFFi} * Hours * ESF$$

Where:

BHP = System Brake Horsepower

= (Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.⁴⁰⁷ 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.⁴⁰⁸ When available, actual hours should be used.

The type of hours to apply depends on the VFD/VSD application, according to the table below:

Application	Hours Type
Hot Water Pump	Heating

⁴⁰⁷ 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.

⁴⁰⁸ Based on outputs from OpenStudio modeling. Building types noted by an asterisk rely on values originally derived from eQuest modeling and were updated based on a comparable percent change from all OpenStudio building type models. For weighting factors, see HVAC variable table in section 3.3.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.13 Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

Application	Hours Type
Chilled Water Pump	Cooling
Cooling Tower Fan	Cooling

Building Type	Heating Run Hours	Cooling Run Hours
Convenience*	3,523	2,779
Education	5,968	2,933
Grocery	6,319	2,801
Health	8,709	4,912
Hospital	7,847	8,760
Industrial*	3,862	3,182
Lodging	5,236	8,039
Multifamily	5,303	5,153
Office - Large	5,233	4,705
Office - Small	1,935	2,195
Religious*	4,626	2,297
Restaurant	2,928	2,948
Retail – Large*	4,096	2,485
Retail - Small	2,957	2,401
Warehouse*	3,982	1,847
Nonresidential Average	3,546	2,271

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

Application	ESF ⁴⁰⁹
Hot Water Centrifugal Pump	0.194
Chilled Water Centrifugal Pump	0.095
Cooling Tower Fan	0.390

For example, a VFD operating 2,386 hours annually driving a 50-horsepower motor with 95% efficiency and a load factor of 70% on a chilled water pump would save:

$$\begin{aligned}\Delta \text{kWh} &= 50/0.95 * 0.70 * 2,386 * 0.095 \\ &= 8,351 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

DSF = Demand Savings Factor varies by VFD/VSD application.⁴¹⁰ Units are kW/HP. Values listed below are based on typical peak load for the listed application.

Application	DSF
Hot Water Centrifugal Pump	0.00

⁴⁰⁹ Based on OpenStudio Large Office model, finding difference in energy use for each VSD application. See “VSD Savings Factor Calc.xls”.

⁴¹⁰ Based on OpenStudio Large Office model, finding difference in maximum demand during peak period for each VSD application. See “VSD Savings Factor Calc.xls”.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.13 Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

Application	DSF
Chilled Water Centrifugal Pump	0.01
Cooling Tower Fan	0.34

For example, a VFD operating 2,386 hours annually driving a 50-horsepower motor with 95% efficiency and a load factor of 70% on a cooling tower fan would save:

$$\begin{aligned}\Delta kW &= 50/0.95 * 0.7 * 0.34 \\ &= 12.53 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

There are no expected fossil fuel impacts for this measure.⁴¹¹

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-V06-260101

SUNSET DATE: 1/1/2028

⁴¹¹ Consider updating measure to include heating and cooling savings in future revisions.

3.3.14. VARIABLE FREQUENCY DRIVES FOR HVAC SUPPLY AND RETURN FANS**DESCRIPTION**

This measure applies to variable frequency drives (VFDs) installed on HVAC supply fans and return fans. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is applicable to the following program types: TOS, RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to an HVAC fan motor 1-100 HP that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (e.g., differential pressure, temperature, or volume). Savings are based on the application of VFDs to a range of baseline system conditions, including no control, inlet guide vanes, outlet guide vanes, relief dampers, and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.⁴¹²

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD in HVAC application is 15 years.⁴¹³

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 HP motors.⁴¹⁴

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

⁴¹² 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".

⁴¹³ "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013."

⁴¹⁴ 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.

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

HP	Cost
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 SAVINGS⁴¹⁵

$$\begin{aligned}
 kWh_{Base} &= \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{Base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Base}) \\
 kWh_{Retrofit} &= \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Retrofit}) \\
 \Delta kWh_{fan} &= kWh_{Base} - kWh_{Retrofit} \\
 \Delta kWh_{total} &= \Delta kWh_{fan} * (1 + IE_{energy})
 \end{aligned}$$

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%) ⁴¹⁶
η_{motor}	= Installed nominal/nameplate motor efficiency
	= Actual
$RHRS_{Base}$	= Annual operating hours for fan motor based on building type

⁴¹⁵ 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.

⁴¹⁶ Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). "Improving Motor and Drive System Performance; A Sourcebook for Industry". U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory.

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

= Default hours are provided for HVAC applications which vary by building type;⁴¹⁷
when available, actual hours should be used

Building Type	Fan Run Hours
Convenience*	5,171
Education	3,905
Grocery	5,840
Health	4,205
Hospital	5,328
Industrial*	3,183
Lodging	5,564
Multifamily	8,760
Office - Large	4,929
Office - Small	6,925
Religious*	2,694
Restaurant	7,301
Retail - Large*	4,540
Retail - Small	6,268
Warehouse*	3,261
Nonresidential Average ⁴¹⁸	4,848

%FF = Percentage of run-time spent within a given flow fraction range:⁴¹⁹

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)

⁴¹⁷ 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.

⁴¹⁸ For weighting factors, see HVAC variable table in section 3.3.

⁴¹⁹ Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

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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%)⁴²⁰

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

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

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

⁴²⁰ 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.

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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 SAVINGS

There are no expected fossil fuel impacts for this measure.⁴²¹

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-V05-260101

SUNSET DATE: 1/1/2028

⁴²¹ Consider updating measure to include heating and cooling savings in future revisions.

3.3.15. DUCT INSULATION**DESCRIPTION**

Energy and demand savings 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.⁴²²

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

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

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

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

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

Algorithm

CALCULATION OF SAVINGS

Savings should only be claimed for ductwork that exists on the exterior of the building or in unconditioned spaces.

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling and heating 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:

⁴²² 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-ft ²)/Btu] = Actual, must be non-zero.
R_{new}	= Duct heat loss coefficient with improved insulation [(hr-°F-ft ²)/Btu] = Actual
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
$\Delta T_{AVG,cooling}$	= Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature. ⁴²³

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁴²⁴	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	77.8	17.8
Zone 6 (Mason City)	76.0	16.0
Average / Unknown	78.8	18.8

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

If the building is heated with electric heat (ducted resistance or ducted 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. ⁴²⁵

Climate Zone (City Based Upon)	$OA_{AVG,heating}$ [°F] ⁴²⁶	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	40.2	74.8

⁴²³ 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.

⁴²⁴ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded. See 'Ducts – OA_Average_heating and cooling.xlsx' for more details.

⁴²⁵ 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.

⁴²⁶ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded. See 'Ducts – OA_Average_heating and cooling.xlsx' for more details.

Climate Zone (City Based Upon)	OA _{AVG,heating} [°F] ⁴²⁶	ΔT _{AVG,heating} [°F]
Zone 6 (Mason City)	32.3	82.7
Average/Unknown	39.1	75.9

3,142 = Conversion from Btu to kWh.

η_{heating} = Efficiency of heating system

= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%.

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 Mason City with 10.5 SEER central AC, and 1.92 COP heat pump system, and the duct R-value with new insulation is 10.0:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}} \\
 &= ((1/3.5 - 1/10.0) * 100 * 801 * 16.0 / (1,000 * 10.5)) + ((1/3.5 - 1/10.0) * 100 * 1,440 * 82.7 / (3,412 * 1.92)) \\
 &= 22.7 + 337.6 \\
 &= 360.3 \text{ kWh}
 \end{aligned}$$

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta \text{kWh}_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

F_e = Percentage of heating energy consumed by fans, assume 3.14%⁴²⁷

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 Mason City with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\begin{aligned}
 \Delta \text{kWh} &= 27.3 * 0.0314 * 29.3 \\
 &= 25.1 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta \text{kWh}_{\text{cooling}}}{\text{EFLH}_{\text{cooling}}} * CF$$

Where:

$\text{EFLH}_{\text{cooling}}$ = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

⁴²⁷ F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference. Assumed to be consistent with C&I applications.

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

Building Type	CF ⁴²⁸	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁴²⁹	91.5%	N/A

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in Mason City with 10.5 SEER central cooling, and the duct R-value with new insulation is 10.0:

$$\begin{aligned}\Delta kW &= 26.4/801 * 1.00 \\ &= 0.0330 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

R_{existing}	= Duct heat loss coefficient with existing insulation [(hr-°F-ft ²)/Btu]
R_{new}	= Duct heat loss coefficient with new insulation [(hr-°F-ft ²)/Btu]
Area	= Area of the duct surface exposed to the unconditioned space that has been insulated [ft ²].
$\text{EFLH}_{\text{cooling}}$	= Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use
$\Delta T_{\text{AVG,heating}}$	= Average temperature difference [°F] during heating season (see above)
100,000	= Conversion from BTUs to Therms

⁴²⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

⁴²⁹ For weighting factors, see HVAC variable table in section 3.3.

η_{heat} = Efficiency of heating system
= Actual

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in Mason City with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\Delta \text{Therms} = ((1/3.5 - 1/8.0) * 100 * 1,440 * 82.7 / (100,000 * 0.70))$$

$$= 27.3 \text{ Therms}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴³⁰	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴³¹	1.5713%	N/A

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in a small retail building in Mason City with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\Delta \text{PeakTherms} = 27.3 * 0.016064$$

$$= 0.4385 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁴³⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

⁴³¹ For weighting factors, see HVAC variable table in section 3.3.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-DUCT-V05-260101

SUNSET DATE: 1/1/2029

3.3.16. DUCT REPAIR AND SEALING**DESCRIPTION**

Air leaks in ductwork passing through unconditioned 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 professionals⁴³². 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 18 years.⁴³³

DEEMED MEASURE COST

The actual labor and material cost for this measure should be used in screening.

LOADSHAPE

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

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

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

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

Algorithm

⁴³² In order for leakage rates to be considered accurate, performance testing must be carried out by a professional with a high level of experience in the C&I building sector.

⁴³³ DEER 2014 EUL “DEER2014-EUL- 2014-02-05.xlsx”

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

Where:

$$\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to air sealing}$$

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Average duct leakage to exterior at normal operating conditions as estimated by professional testing before air sealing
= Actual⁴³⁴

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.⁴³⁵

Climate Zone (City Based Upon)	$OA_{AVG,cooling}$ [°F] ⁴³⁶	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	77.8	17.8
Zone 6 (Mason City)	76.0	16.0
Average/Unknown	78.8	18.8

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

LM = Latent multiplier to account for latent cooling demand
= dependent on location: ⁴³⁷

Climate Zone (City Based Upon)	LM
Zone 5 (Burlington)	5.0
Zone 6 (Mason City)	5.9

⁴³⁴ 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.

⁴³⁵ 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.

⁴³⁶ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded. See 'Ducts – OA_Average_heating and cooling.xlsx' in 3.3.15 Duct Insulation analysis files for more details.

⁴³⁷ 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
Average/Unknown	5.2

1,000 = 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:⁴³⁸

Climate Zone (City Based Upon)	$OA_{AVG,heating}$ [°F] ⁴³⁹	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	40.2	74.8
Zone 6 (Mason City)	32.3	82.7
Average/Unknown	39.1	75.9

3,142 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating 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 Mason City with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= [((40 - 25) * 60 * 801 * 16.0 * 0.018 * 5.2) / (1,000 * 10.5)] + \\ &\quad [((40 - 25) * 60 * 1,440 * 82.7 * 0.018) / (1.92 * 3,412)] \\ &= 102.8 + 294.5 \\ &= 397 \text{ kWh} \end{aligned}$$

Conservative Deemed Approach

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

⁴³⁸ 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.

⁴³⁹ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded. See 'Ducts – OA_Average_heating and cooling.xlsx' in 3.3.15 Duct Insulation analysis files for more details.

Where:

SavingsPerUnit = Annual savings per linear foot installed airsealing material, dependent on heating / cooling equipment⁴⁴⁰

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 air sealing material applied to exterior ductwork seams, closures or joints.
= Actual

Additional Fan savings

$\Delta kWh_{heating}$ = If gas furnace heat, kWh savings for reduction in fan run time
= $\Delta Therms * F_e * 29.3$

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%⁴⁴¹

29.3 = kWh per Therm

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned}\Delta kWh &= 18.8 * 0.0314 * 29.3 \\ &= 17.3 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$EFLH_{cooling}$ = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

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

Building Type	CF ⁴⁴²	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio

⁴⁴⁰ 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.

⁴⁴¹ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

⁴⁴² This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ⁴⁴²	Model Source
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁴⁴³	91.5%	N/A

For example, an existing small retail building (2,000 Sq Ft) in Mason City with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned}\Delta kW &= 102.8 / 801 * 1.00 \\ &= 0.13 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 100,000)}$$

Where:

$$100,000 = \text{Conversion from BTUs to Therms}$$

Other factors as defined above.

For example, an existing restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned}\Delta Therms &= ((40 - 25) * 60 * 1086 * 74.8 * 0.018) / (0.70 * 100,000) \\ &= 18.8 \text{ therms}\end{aligned}$$

Conservative Deemed Approach

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

Where:

$$SavingsPerUnit = \text{Annual savings per linear foot, dependent on heating / cooling equipment:}^{444}$$

⁴⁴³ For weighting factors, see HVAC variable table in section 3.3.

⁴⁴⁴ 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

End Use	HVAC System	SavingsPerUnit (Therms/ft)
Space Heat Boiler	Gas Boiler*	0.26
Space Heat Furnace	Gas Furnace	0.26

*Note: in instances where boilers supply heat to terminal units or VAV boxes that are already inside conditioned space, savings should not be claimed, as not conditioned air is not passing through exterior ductwork.

L_{Duct} = Linear footage of exterior ductwork sealed

= Actual

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁴⁵	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴⁴⁶	1.5713%	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta PeakTherms &= 18.8 * 0.018843 \\ &= 0.3542 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

⁴⁴⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁴⁶ For weighting factors, see HVAC variable table in section 3.3.

N/A

MEASURE CODE: NR-HVC-DCTS-V05-260101

SUNSET DATE: 1/1/2030

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.⁴⁴⁷

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.⁴⁴⁸ 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

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm**CALCULATION OF 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:

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

⁴⁴⁷ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

⁴⁴⁸ RS Means 2008. Mechanical Cost Data, pages 106 to 119.

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 0.38 ft) = 1.9 ft.

Equivalent Length of Other Components – Elbows and Tees (L_{OC})⁴⁴⁹

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90° 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:⁴⁵⁰

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

⁴⁴⁹ Process Heat Transfer: Principles and Applications, Robert W. Serth, 2014 (Appendix D: Equivalent Lengths of Pipe Fittings)

⁴⁵⁰ 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:

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cooling} \\ &= ((100 + 3.2) * 1,287 * (47.100 - 4.450)) / (1,000 * 12) \\ &= 472.1 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- EFLH_{cooling} = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use
- CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁴⁵¹	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁴⁵²	91.5%	N/A

For example, 3" thick insulation is installed on 100 feet of 2" diameter, bare straight pipe with 5 straight tee components in an industrial building in unknown location with a 12.0 EER cooling system:

$$\begin{aligned}\Delta kW &= 472.1 / 1,287 * 0.439 \\ &= 0.1610 \text{ kW}\end{aligned}$$

⁴⁵¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

⁴⁵² For weighting factors, see HVAC variable table in section 3.3.

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2022*

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

3.3.18. HYDRONIC HEATING PIPE INSULATION

DESCRIPTION

This measure provides rebates for installation of $\geq 1"$ or $\geq 2"$ fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all Nonresidential installations.

Savings estimates are provided for the both exposed indoor or above ground outdoor piping distributing fluid in the following system types (natural gas fired systems only):

- Hydronic heating systems (with or without outdoor reset controls), including:
 - boiler systems that do not circulate water around a central loop and operate upon demand from a thermostat ("non-recirculation")
 - systems that recirculate during heating season only ("Recirculation – heating season only")
 - systems recirculating year round ("Recirculation – year round")
- Low and high-pressure steam systems
 - non-recirculation
 - recirculation - heating season only
 - recirculation - year round

Process piping can also use the algorithms provided but requires custom entry of hours.

Minimum qualifying nominal pipe diameter is 1". Indoor piping must have at least 1" of insulation and outdoor piping must have at least 2" of insulation and include an all-weather protective jacket. New advanced insulating materials may be thinner and savings can be calculated with 3E Plus.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is installing pipe wrap insulation to a length of pipe. Indoor piping must have at least 1" of insulation (or equivalent R-value) and outdoor piping must have at least 2" of insulation (or equivalent R-value) and include an all-weather protective jacket. Minimum qualifying pipe diameter is 1". Insulation must be continuous and contiguous over fittings that directly connect to straight pipe, including elbows and tees.⁴⁵³

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.⁴⁵⁴

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means⁴⁵⁵ pricing reference materials may be used.⁴⁵⁶ The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

⁴⁵³ ASHRAE Handbook—Fundamentals, 23.14; Hart, G., "Saving energy by insulating pipe components on steam and hot water distribution systems", ASHRAE Journal, October 2011

⁴⁵⁴ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

⁴⁵⁵ RS Means 2008. Mechanical Cost Data, pages 106 to 119

⁴⁵⁶ RS Means 2010: "for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting"

Insulation Thickness		
	1 Inch (Indoor)	2 Inches (Outdoor)
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.30.0156	220719.40.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	\$11.26	\$18.07
Jacket Cost per foot	\$5.94	\$6.93
Total Cost per foot	\$17.20	\$25.00

LOADSHAPE

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS 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 0.38 ft) = 1.9ft.

Equivalent Length of Other Components – Elbows and Tees (L_{OC})⁴⁵⁷

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]

⁴⁵⁷ Process Heat Transfer: Principles and Applications, Robert W. Serth, 2014 (Appendix D: Equivalent Lengths of Pipe Fittings)

= Based on system type and location of the piping as shown in the following table:⁴⁵⁸

Pipe Location	System Type	Q _{base} – Q _{eff} (Btu/hr/ft)
Indoor	Hot Water Space Heating - Without Outdoor Reset	90
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	61
	Hot Water Space Heating - With Outdoor Reset, Year-Round	45
	Low Pressure Steam	192
	High Pressure Steam	362
Outdoor	Hot Water Space Heating - Without Outdoor Reset	439
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	347
	Hot Water Space Heating - With Outdoor Reset, Year-Round	293
	Low Pressure Steam	678
	High Pressure Steam	1049

100,000 = Conversion from Btu to Therms

η_{heat} = Efficiency of heating system

= Actual; if unknown, assume the following:

= 84% if boiler installed since January 2021. If boiler is older or date is unknown assume 82% for a hot water boiler or 80% for a steam boiler⁴⁵⁹

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δ therms/ft tables below ⁴⁶⁰

= 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.⁴⁶¹

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

⁴⁵⁸ 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.

⁴⁵⁹ 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.

⁴⁶⁰ 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.

⁴⁶¹ Thermal Regain Factor_4-30-14.docx.

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
Indoor, unheated (no heat transfer to conditioned space)	0%	1.0
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

For example, 1" thick insulation is installed on 100 feet of 1" diameter, bare straight pipe with 5 straight tee components distributing fluid in a low-pressure steam system and located in an indoor space heated with a steam boiler, in an industrial building in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= ((100 + 1.9) * 1,094 * 192 * 0.15) / (100,000 * 0.80) \\ &= 40.1 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁶²	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴⁶³	1.5713%	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:

$$\begin{aligned}\Delta\text{Therms} &= 40.1 * 0.015396 \\ &= 0.6174 \text{ therms}\end{aligned}$$

⁴⁶² Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁶³ 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-V05-250101

SUNSET DATE: 1/1/2028

3.3.19. SHUT OFF DAMPER FOR SPACE HEATING BOILERS OR FURNACES

DESCRIPTION

This measure is for Nonresidential atmospheric boilers or furnaces providing space heating without a shut off damper. When appliances are on standby mode warm room air is drawn through the stack via the draft hood or dilution air inlet at a rate proportional to the stack height, diameter and outdoor temperature. More air is drawn through the vent immediately after the appliance shuts off and the flue is still hot. Installation of a new shut off damper can prevent heat from being drawn up the warm vent and reducing the amount of air that passes through the furnace or boiler heat exchanger. This reduction in air can slightly increase overall operating efficiency by reducing the time needed to achieve steady-state operating conditions.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the space heating boiler or furnace must have a new electrically or thermally activated shut off damper installed on either the exhaust flue or combustion air intake. Barometric dampers do not qualify. The damper actuation shall be interlocked with the firing controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler or furnace incorporates no shut off damper on the combustion air intake or flue exhaust.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the shut off damper is 15 years,⁴⁶⁴ 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.⁴⁶⁵

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

⁴⁶⁴ 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.

⁴⁶⁵ 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.

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

NATURAL GAS SAVINGS

$$\Delta Therms = N_{gi} * SF * EFLH / 100$$

Where:

N_{gi} = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%⁴⁶⁶

Note: The savings factor assumes the boiler or furnace is located in an unconditioned space. The savings factor can be higher for those units located within conditioned space.

EFLH = Default Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁶⁷	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴⁶⁸	1.5713%	N/A

⁴⁶⁶ 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”

“1 - 2%”: Page 2, Sustainable Energy Authority of Ireland “Steam Systems Technical Guide”, see reference file “SEAI Technical Guide – Steam Systems.”

⁴⁶⁷ Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁶⁸ For weighting factors, see HVAC variable table in section 3.3.

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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.⁴⁶⁹

MEASURE CODE: NR-HVC-SODP-V02-200101

SUNSET DATE: 1/1/2024*

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

⁴⁶⁹ CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

3.3.20. ROOM AIR CONDITIONER

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets the ENERGY STAR⁴⁷⁰ minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:⁴⁷¹

Product Class (Btu/H)	Federal Standard CEERbase, with Louvered Sides, without Reverse Cycle ⁴⁷²	Federal Standard CEERbase, without Louvered Sides, without Reverse Cycle	ENERGY STAR CEERee, with Louvered Sides	ENERGY STAR CEERee, without Louvered Sides	ENERGY STAR Most Efficient CEERee, with Louvered Sides	ENERGY STAR Most Efficient CEERee, without Louvered Sides		
<8,000	11.0	10.0	13.7	12.8	14.85	13.5		
8,000 to 10,999	10.9	9.6	14.7	13.0	16.0	14.1		
11,000 to 13,999		9.5		12.8		13.9		
14,000 to 19,999		10.7		9.3		14.4	12.6	13.7
20,000 to 24,999	9.4	9.4	12.7	12.7	13.8	13.8		
25,000-27,999	9.0		12.2		13.2			
≥28,000								

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

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with Louvered Sides	Federal Standard CEERbase, without Louvered Sides ⁴⁷³	ENERGY STAR CEERee, with Louvered Sides ⁴⁷⁴	ENERGY STAR CEERee, without Louvered Sides	ENERGY STAR Most Efficient CEERee, with Louvered Sides ⁴⁷⁵	ENERGY STAR Most Efficient CEERee, without Louvered Sides
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⁴⁷⁰ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁴⁷¹ Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

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

Note these efficiency levels represent ratings without the Connected Allowance.

⁴⁷² Federal standard air conditioner baselines.

⁴⁷³ Federal standard air conditioner baselines.

⁴⁷⁴ ENERGY STAR version 5.0 Room Air Conditioner Program Requirements.

⁴⁷⁵ ENERGY STAR 2024 Most Efficient Recognition Criteria for Room Air Conditioners.

<14,000	N/A	9.3	N/A	10.2	N/A	13.7
≥14,000	N/A	8.7	N/A	9.6	N/A	12.8
<20,000	9.8	N/A	10.8	N/A	14.4	N/A
≥20,000	9.3	N/A	10.2	N/A	13.7	N/A

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.⁴⁷⁶

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$50 for an ENERGY STAR unit⁴⁷⁷ and \$260 for an ENERGY STAR Most Efficient unit.⁴⁷⁸

LOADSHAPE

Loadshapes NREC01-NREC16 dependent on building type.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (\text{FLH}_{\text{RoomAC}} * \text{Btu/H} * (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{ee}}))/1,000$$

Where:

$\text{FLH}_{\text{RoomAC}}$ = Full Load Hours of room air conditioning unit.⁴⁷⁹

Building Type	Zone 5	Zone 6	Average / Unknown
	(Burlington)	(Mason City)	

⁴⁷⁶ Comprehensive TRM Review MA19R17-B-TRM Final Report, submitted by Guidehouse on March 8th, 2021.

⁴⁷⁷ Energy Star Room Air Conditioner Savings Calculator.

⁴⁷⁸ NEEP Mid-Atlantic TRM (version 9.0, October 2019) which uses hedonic models and data pulled from "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, conducted on behalf of the California Public Utility Commission in 2014. For more information, please see "room-ac-analysis-2024.xls", 'ESME Costs' tab.

⁴⁷⁹ 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: . to FLH for Central Cooling for the same location (provided by AHRI) is 31%. This ratio has been applied to the EFLH assumptions from Section 3.3 (modeling).

Convenience	458	350	419
Education	328	221	290
Grocery	612	460	538
Health	362	278	330
Hospital	571	423	519
Industrial	367	265	330
Lodging	466	336	420
Multifamily	466	336	420
Office - Large	380	301	354
Office - Small	339	244	304
Religious	344	247	320
Restaurant	411	296	365
Retail - Large	375	267	334
Retail - Small	365	261	322
Warehouse	296	215	268
Nonresidential Average	337	241	303

Btu/H = Size of unit

= Actual; if unknown assume 8,500 Btu/hr ⁴⁸⁰

CEERbase = Efficiency of baseline unit

= As provided in tables above

CEERee = Efficiency of ENERGY STAR unit

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

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

$$\Delta \text{kWh}_{\text{EnergyStar}} = (433 * 8,500 * (1/10.9 - 1/14.7))/1,000$$

$$= 87.29 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \text{Btu/H} * ((1/(\text{CEERbase} * 1.01) - 1/(\text{CEERee} * 1.01)))/1,000 * \text{CF}$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3⁴⁸¹

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption⁴⁸²)

⁴⁸⁰ Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

⁴⁸¹ 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

⁴⁸² 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

Other variables as defined above.

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

$$\Delta kW_{\text{EnergyStar}} = (8,500 * (1/10.9 * 1.01 - 1/14.7 * 1.01))/1,000 * 0.3$$

$$= 0.0599 \text{ kW}$$

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-RMAC-V03-250101

SUNSET DATE: 1/1/2028

specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See 'ENERGY STAR Version 3.1 Room Air Conditioners Program Requirements'.

3.3.21. ROOM AIR CONDITIONER RECYCLING

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 3.5 years.⁴⁸³

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

$$\Delta kWh = kWh_{exist} - (\%replaced * kWh_{newbase})$$

$$= \frac{Hours * BtuH}{\frac{EER_{exist}}{1.01} * 1000} - (\%replaced * \frac{Hours * BtuH}{CEER_{NewBase} * 1000})$$

Where:

Hours = Full Load Hours of room air conditioning unit⁴⁸⁴

Building Type	Zone 5	Zone 6	
---------------	--------	--------	--

⁴⁸³ One third of assumed measure life for Room AC, which is assumed to be 10.5 years, based on the Department of Energy, Office of Energy Efficiency and Renewable Energy; "Energy Conservation Program, Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners", 10 CFR Part 430 (Docket: EERE-2007-BT-STD-0010, pg. 22514)

⁴⁸⁴ 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.) 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).

	(Burlington)	(Mason City)	Average / Unknown
Convenience	458	350	419
Education	328	221	290
Grocery	612	460	538
Health	362	278	330
Hospital	571	423	519
Industrial	367	265	330
Lodging	466	336	420
Multifamily	466	336	420
Office - Large	380	301	354
Office - Small	339	244	304
Religious	344	247	320
Restaurant	411	296	365
Retail - Large	375	267	334
Retail - Small	365	261	322
Warehouse	296	215	268
Nonresidential Average	337	241	303

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500.⁴⁸⁵

EERexist = Efficiency of recycled unit

= Actual if recorded - If not, assume 9.4.⁴⁸⁶

%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% ⁴⁸⁷

CEERNewbase = Efficiency of baseline unit

= 10.5⁴⁸⁸

⁴⁸⁵ Based on maximum capacity average from the RLW Report; “Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.”

⁴⁸⁶ Federal efficiency standards for Room A/C manufactured between October 1, 2000 and May 31, 2014: 10 CFR 430.32(b) are at 9.8 EER- Weighted by capacity and equipment type based on available products on the EERE - Compliance Certification Database, that are non-ENERGY STAR units, as accessed 05/16/2022.

⁴⁸⁷ 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.

⁴⁸⁸ Federal efficiency standards for Room A/C manufactured after June 1, 2014: 10 CFR 430.32(b) are 10.9 CEER- Weighted by capacity and equipment type based on available products EERE - Compliance Certification Database, that are non-ENERGY STAR units, as accessed 05/16/2022.

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption).⁴⁸⁹

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

$$\begin{aligned}\Delta \text{kWh} &= ((466 * 8500)/(9.8/1.01 * 1,000)) - (0.76 * (466 * 8500)/(10.9 * 1,000)) \\ &= 138.9 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure
= 30%⁴⁹⁰

Other variables as defined above

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

$$\begin{aligned}\Delta kW &= (138.9/466) * 0.3 \\ &= 0.0894 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-APL-RACR-V03-230101

SUNSET DATE: 1/1/2029

⁴⁸⁹ 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'.

⁴⁹⁰ 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.

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 3 years.⁴⁹¹

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) ⁴⁹²
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)

⁴⁹¹Database for Energy-Efficient Resources (DEER) updates for 2020 and revised version 2019, resolution E-4818, Table 8. The Behavioral, Operational and Retro-commissioning (BRO) measure classification was created, where Effective useful lives (EUL) of one to three years are assumed. Resolution E-4818 directed that all measures which utilize a degraded performance baseline and/or are restorative of performance in nature be classified as retro-commissioning.

⁴⁹²Steam 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = LeakRate \times H_{vap} \times Hours_{Heat} \times \%Leak / EFF_{Heat} / 100,000$$

Where:

LeakRate = Average steam loss rate (lb/hr) per leaking trap
 = $24.24 \times (P_{inlet} + 14.7) \times D^2 \times \%Adjust$

Where:

24.24 = Constant from Napier's equation (lb/(hr-psia-in²))

P_{inlet} = Steam trap inlet pressure (psig)
 = Actual

14.7 = Atmospheric pressure (psia)

D = Diameter of steam trap orifice (in)
 = Actual

$\%Adjust$ = Adjustment factor (%) to reduce the maximum theoretical steam flow to the average steam flow
 = 50%⁴⁹³

H_{vap} = Heat of vaporization of steam (Btu/lb)
 = Use values from table below, based on steam trap inlet pressure (psig).⁴⁹⁴

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

⁴⁹³ Enbridge adjustment factor, from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

⁴⁹⁴ Heat of vaporization values from Steam Tables, Power Plant Service, Inc.

P _{Inlet} (psig)	H _{vap} (Btu/lb)
90	886
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 replacement 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 commercial customers and 16% for industrial customers.⁴⁹⁵

EFF_{Heat} = Boiler efficiency (%)

= Actual operating efficiency.

100,000 = Factor to convert Btus to therms

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

$$\Delta \text{Therms} = (24.24 * (30 + 14.7) * 0.125^2 * 0.5) * 929 * 4,500 * 1.0 / (0.75 * 100,000)$$

$$= 471.8 \text{ Therms}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁹⁶	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio

⁴⁹⁵ % Leak values from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

⁴⁹⁶ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁴⁹⁶	Model Source
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁴⁹⁷	1.5713%	N/A

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

$$\begin{aligned}\Delta\text{Therms} &= 471.8 * 0.016064 \\ &= 7.5790 \text{ Peak Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-STRE-V05-260101

SUNSET DATE: 1/1/2029

⁴⁹⁷ 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 or HP 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.⁴⁹⁸

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.

If invoices are unobtainable, assume a measure cost of \$159⁴⁹⁹

LOADSHAPE

⁴⁹⁸ 3 years is given for “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”. DEER2014 EUL Table.

⁴⁹⁹ Average labor and parts paid by Alliant Energy customers who had their electric HVAC systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1,000}$$

Where:

Capacity _{Cool}	= Output capacity of the cooling equipment in Btu per hour (note 1 ton = 12,000Btu/hr) = Actual = If actual capacity is unknown, use 76,649 Btu/hr ⁵⁰⁰
EER _{before}	= Energy Efficiency Ratio of the baseline equipment prior to tune-up = Actual ⁵⁰¹
EER _{after}	= Energy Efficiency Ratio of the baseline equipment after to tune-up = Actual
EFLH	= Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1,000 * EER_{rated}) * EFLH * \%Savings$$

Where:

%Savings	= Deemed percent savings per Tune-Up component. These are additive multiple components are performed (total provided below): ⁵⁰²
----------	---

Tune-Up Component	% savings
Correct Refrigerant Charge	2%
Clean condenser coils	1%
Clean evaporator coils	1%
If full tune up performed	5%

⁵⁰⁰ Average cooling capacity of Alliant Energy customers who had their electric HVAC systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations

⁵⁰¹ 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.

⁵⁰² Savings estimates are determined by applying each maintenance issue (high/low refrigerant charge, dirty condenser coil, dirty evaporator coil and all three combined) to the base maintained Office OpenStudio model and comparing electricity consumption.

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

$$\begin{aligned}\Delta kWh &= (60,000 / (1,000 * 12)) * 1,430 * 5\% \\ &= 358 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

Building Type	CF ⁵⁰³	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁵⁰⁴	91.5%	N/A

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

$$\begin{aligned}\Delta kW &= 358 / 1,430 * 0.997 \\ &= 0.2496 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁵⁰³ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁵⁰⁴ For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-ACTU-V03-260101

SUNSET DATE: 1/1/2028

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

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

For this characterization to apply, the baseline condition is assumed to be a chiller system that does not have a standing maintenance contract or a tune up within the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 3 years.⁵⁰⁵

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.

If invoices are unobtainable, assume a measure cost of \$1,220⁵⁰⁶

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

⁵⁰⁵ 3 years is given for “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”. DEER2014 EUL Table.

⁵⁰⁶ Average labor and parts costs paid by Alliant Energy customers who had their electric chiller systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1000}$$

Where:

Capacity _{Cool}	= output capacity of the chiller in Btu per hour (note 1 ton = 12,000Btu/hr) = Actual, nameplate = If actual capacity is unknown, use 1,350,546 Btu/hr ⁵⁰⁷
EER _{before}	= Energy Efficiency Ratio of the chiller prior to tune-up (note EER = 12 / kW/ton) = Actual, as measured ⁵⁰⁸
EER _{after}	= Energy Efficiency Ratio of the chiller after tune-up = Actual, as measured
EFLH	= Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1000 * EER_{rated}) * EFLH * \%Savings$$

Where:

EER _{rated}	= Nameplate Energy Efficiency Ratio of the chiller
%Savings	= Deemed percent savings per Tune-Up component. ⁵⁰⁹ = 5%

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

$$\begin{aligned}\Delta kWh &= (600,000 / (1,000 * 12)) * 962 * 5\% \\ &= 2,403 kWh\end{aligned}$$

⁵⁰⁷ Average cooling capacity of Alliant Energy customers who had their electric chiller systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

⁵⁰⁸ 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.

⁵⁰⁹ Consistent with deemed approach in 3.3.23 and supported by literature review.

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 ⁵¹⁰	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁵¹¹	91.5%	N/A

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

$$\begin{aligned}\Delta kW &= 2,403 / 962 * 0.768 \\ &= 1.9184 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-CHTU-V03-260101

SUNSET DATE: 1/1/2028

⁵¹⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁵¹¹ 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-fired heat pumps can be separated into two categories, work-activated technologies where a delivered fuel drives a prime mover (e.g., internal combustion engine) which supplies work to a refrigerant compressor, and heat-activated where the primary energy input to the heat pump cycle is thermal energy, often from fuel combustion, driving a sorption-type or other thermally-driven heat pump cycle. Gas heat pumps can typically be direct replacements or substitutes for conventional space heating boilers. Additionally, some are capable of providing cooling and/or service water heating.

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 and SHW in relevant applications, 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,⁵¹² 80% E_T for boilers ≥300,000 Btu/hr and ≤2,500,000 Btu/hr, and 82% E_C for boilers >2,500,000 Btu/hr.⁵¹³ To calculate savings with water heater applications, the baseline equipment is assumed to meet the minimum federal standard efficiencies for water heaters.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁵¹⁴

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is:⁵¹⁵

Replaced Technologies	Installed Cost (\$/ton)	Incremental Cost (\$/ton)
Gas-Fired Heat Pump	\$3,199	N/A
Rooftop Air Source Heat Pump	\$1,720	\$1,479
Ground Source Heat Pump	\$5,366	-\$2,167
Electric Boiler	\$300	\$2,899
Natural Gas Furnace	\$122	\$3,077
Natural Gas Boiler	\$457	\$2,742
Air-cooled Electric Chiller	\$957	\$2,242

⁵¹² Code of Federal Regulations, 10 CFR 430.32(e)(2). Future energy conservation standards are under development.

⁵¹³ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

⁵¹⁴ U.S. Energy Information Administration | Assumptions to the Annual Energy Outlook 2026: Commercial Demand Module.

⁵¹⁵ U.S. Energy Information Administration (EIA), Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, March 2023

Water-cooled Electric Chiller	\$510	\$2,689
Gas-Fired Water Heater	\$409	\$2,790
Electric Resistance Water Heater	\$915	\$2,284

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

For example, for a gas boiler and gas-fired water heater being replaced with a gas heat pump, the incremental cost will be Cost of GHP – (Cost of Natural Gas Boiler + Gas Fired Water Heater)
 = \$3,199 – (\$457 + \$409)
 = \$2,333

LOADSHAPE

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

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Gas-fired heat pumps consume electricity during their operation and therefore result in increased site electric load.

$$\Delta kWh = \frac{-Power * EFLH}{1,000}$$

Where:

Power = Nominal maximum electrical power requirement for the gas-fired heat pump, W
 = Actual. If unknown, assume 0.0052 W per Btu/hr heating input capacity⁵¹⁶
 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 SAVINGS

Space Heating Savings

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

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

⁵¹⁶ Based on average of power requirements for Robur K18 (0.004341794 W/Btu/hr) and GAHP-A (0.005960768 W/Btu/hr)

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

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE ⁵¹⁷
≥300,000 Btu/h and ≤2,500,000 Btu/hr	80% E _T ⁵¹⁸
>2,500,000 Btu/hr	82% E _C ⁵¹⁹

EfficiencyRating(EF) = Efficient equipment efficiency rating

= Actual. If unknown, assume 130%⁵²⁰

100,000 = Conversion of Btu to Therms

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:

$$\Delta kWh = -0.0052 * 150,000 * 1,495/1,000$$

$$= -1,166.10 \text{ kWh}$$

$$\Delta Therms_{SH} = 1,495 * 150,000 * ((1.3/0.84)-1)/100,000$$

$$= 1,228.0 \text{ Therms}$$

Service Hot Water Savings

$$\Delta Therms_{SHW} = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1.0 * (\frac{1}{TE_{base}} - \frac{1}{COP_{EE}})}{100,000}$$

Where:

T_{out} = Tank temperature

= Actual; otherwise assume 140⁵²¹

T_{in} = Incoming water temperature from well or municipal systems

= Actual; otherwise assume 57.8⁵²²

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)

⁵¹⁷ Code of Federal Regulations, 10 CFR 430.32(e)(2).

⁵¹⁸ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

⁵¹⁹ Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87.

⁵²⁰ Based on findings presented Brio and GTI's Gas Heat Pump Roadmap Industry White Paper, November 2019.

⁵²¹ Ideally the actual set point of the water heater should be used. If not, 140°F 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°F. Generally speaking, code limits the temperature to fixtures to 120°F and 140°F for applications like laundry or dishwashing.

⁵²² Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

Where:

Capacity = Usable capacity of hot water storage tank in gallons

= Actual⁵²³

Consumption/Cap = Estimate of consumption per gallon of usable tank capacity, based on building type:⁵²⁴

Building Type ⁵²⁵	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 SHW boiler

= Actual

Consumption/1,000 sq.ft. = Estimate of SHW consumption per 1,000 sq.ft. based on building type:⁵²⁶

⁵²³ If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.

⁵²⁴ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

⁵²⁵ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

⁵²⁶ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

Building Type ⁵²⁷	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

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

= 8.33 lbs/gal

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

100,000 = Converts Btu to Therms

TE_{base} = Rated efficiency of baseline water heater (expressed as Uniform Energy Factor (UEF) or Thermal Efficiency as provided below).

COP_{EE} = Rated efficiency of the commercial gas heat pump as certified expressed as Uniform Energy Factor (UEF) or Coefficient of Performance.

= Actual

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

Equipment Type	Sub-Category	Draw Pattern	Federal Standard – Uniform Energy Factor or Thermal Efficiency	
			Equipment manufactured before October 6, 2026	Equipment manufactured after October 6, 2026
<u>Residential-duty Commercial</u> 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)	UEF = 0.5374 – (0.0009 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5362 – (0.0012 * Rated Storage Volume in Gallons)	UEF = 0.8062 – (0.0012 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6002 – (0.0011 * Rated Storage Volume in Gallons)	UEF = 0.8702 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 0.6597 – (0.0009 * Rated Storage Volume in Gallons)	UEF = 0.9297 – (0.0009 * Rated Storage Volume in Gallons)

⁵²⁷ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

<u>Commercial</u> Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h	>120 gallon tanks	All	80% E _{thermal} , Standby Losses = (Q /800 + 110vRated Storage Volume in Gallons)	95% E _{thermal} , Standby Losses = 0.86 * (Q /800 + 110vRated Storage Volume in Gallons)
<u>Commercial</u> Gas Storage Water Heaters >155,000 Btu/h		All		
<u>Commercial Gas</u> Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% E _{thermal}	96% E _{thermal}
	≥10 gal	All	80% E _{thermal}	96% E _{thermal}

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

Storage Water Heater Draw Pattern ⁵²⁸	
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 ⁵²⁹	
Draw Pattern	Max GPM
Very Small	≥ 0 and < 1.7
Low	≥ 1.7 and < 2.8
Medium	≥ 2.8 and < 4
High	≥ 4

PEAK GAS SAVINGS

$$\Delta PeakTherms = (\Delta Therms_{SH} * GCF) + \left(\frac{\Delta Therms_{SHW}}{365} \right)$$

Where:

$\Delta Therms_{SH}$ = Space Heating Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁵³⁰	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio

⁵²⁸ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table I—Draw Pattern To Be Used Based on First-Hour Rating.

⁵²⁹ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table II—Draw Pattern To Be Used Based on Maximum GPM Rating.

⁵³⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁵³¹	1.5713%	N/A

$\Delta T_{\text{Therms}_{\text{SHW}}}$ = Service Hot Water Therm impact calculated above

365 = Days per year

For example, for a 150,000 Btu/hr, 150 gallon gas-fired heat pump with AFUE 130% at an existing 5,000 sq.ft. large office building in unknown location:

$$\begin{aligned}\Delta \text{Peak Therms} &= (1,228.0 * 0.011592) + (22.1/365) \\ &= 14.2955 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-GFHP-V02-270101

SUNSET DATE: 1/1/2030

⁵³¹ For weighting factors, see HVAC variable table in section 3.3.

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.⁵³²

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 system⁵³³.

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 types: hotel, primary school, secondary school, midrise apartment, and office. Other building types should not use

⁵³²Consistent with measure lifetime assumptions for measure 3.3.4 Heat Pump Systems.

⁵³³ 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.

this characterization for savings estimates but should be noted so that the characterization can be expanded to include them in the future.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = SQFT * (Cool + Heat + Fan)$$

Where:

SQFT = Building square footage

= Actual

Cool, Heat, Fan = Savings factors for cooling, heating and fan energy, respectively. As indicated in the following table and specific to building classification. Established using OpenStudio modeling. Units are kWh/SQFT.

Weather Zone	Building Type	Heat (kWh/SQFT)	Cool (kWh/SQFT)	Fan (kWh/SQFT)
Zone 5 (Burlington)	Hotel - Large	1.16393	0.78482	1.45850
Zone 5 (Burlington)	Hotel - Small	0.68900	0.29869	0.35916
Zone 5 (Burlington)	Primary School	1.07587	0.52884	-0.45726
Zone 5 (Burlington)	Secondary School	1.09193	0.47768	-0.57349
Zone 5 (Burlington)	Midrise Apartment	0.93178	0.22864	0.29093
Zone 5 (Burlington)	Office - Large	0.20981	0.63896	0.44881
Zone 5 (Burlington)	Office - Medium	0.42199	0.22528	-0.72751
Zone 5 (Burlington)	Office - Small	0.43610	0.07685	-0.52305
Zone 6 (Mason City)	Hotel - Large	2.44935	0.51743	1.50572
Zone 6 (Mason City)	Hotel - Small	1.52724	0.23187	0.39258
Zone 6 (Mason City)	Primary School	2.04460	0.41488	-0.36335
Zone 6 (Mason City)	Secondary School	2.18776	0.32268	-0.52077
Zone 6 (Mason City)	Midrise Apartment	2.00461	0.18482	0.28933
Zone 6 (Mason City)	Office - Large	0.41352	0.44891	0.49061
Zone 6 (Mason City)	Office - Medium	0.86435	0.20145	-0.64419
Zone 6 (Mason City)	Office - Small	0.92793	0.07289	-0.43871
Average/unknown	Hotel - Large	1.45822	0.82187	1.50684
Average/unknown	Hotel - Small	0.90767	0.29815	0.38104
Average/unknown	Primary School	1.43780	0.50420	-0.44858
Average/unknown	Secondary School	1.05121	0.50701	-0.59519
Average/unknown	Midrise Apartment	1.20491	0.24142	0.30585
Average/unknown	Office - Large	0.27179	0.64997	0.44639
Average/unknown	Office - Medium	0.54046	0.20073	-0.71958
Average/unknown	Office - Small	0.59469	0.06175	-0.51140

For example, a 50,000 SQFT medium office in Zone 6 installing a VRF system instead of traditional heat pumps saves:

$$\begin{aligned}\Delta kWh &= 50,000 * (0.41352 + 0.44891 + 0.49061) \\ &= 67,652kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{SQFT * Cool}{LH_{cooling}} \right] * CF$$

Where:

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

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

Building Type	CF ⁵³⁴	Model Source
Education	95.8%	OpenStudio
Lodging (use for Hotel)	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	100.0%	OpenStudio

For example, a 50,000 SQFT large office in Zone 6 installing a VRF system instead of traditional heat pumps saves (note: using Cooling Load Hours for Large Office):

$$\begin{aligned} \Delta kW &= ((50,000 * 0.44891)/4,393) * 0.933 \\ &= 4.7670 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-VRFS-V04-270101

SUNSET DATE: 1/1/2030

⁵³⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

3.3.27. DEMAND CONTROLLED VENTILATION**DESCRIPTION**

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO₂) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night-time setbacks are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

Demand controlled ventilation controls can also be added to the exhaust fans to enclosed parking garages. The fans modulate the ventilation airflow based on pollutant concentrations (primarily carbon monoxide) in the space.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new air quality sensors installed on return air systems where no other sensors were previously installed. For heating savings, this measure does not apply to any system with terminal reheat (constant volume or variable air volume). For terminal reheat system a custom savings calculation should be used.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability. The current code minimum for outside air (OA) is 17 CFM per occupant (ASHRAE 62.1 - 2016) which is the value for office space assumed in this measure.

This measure does not apply to packaged single-zone (PSZ) rooftop units with functioning economizers.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 15 years.⁵³⁵

DEEMED MEASURE COST

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost (\$500) and installation (\$1,000 labor) for a total of \$1,500.⁵³⁶

LOADSHAPE

Loadshape NREV01:16 – Nonresidential Ventilation (by Building Type)

COINCIDENCE FACTOR

N/A

Algorithm

⁵³⁵ SWHC006-01, California Technical Forum, 2019.

⁵³⁶ Discussion with vendors. ILSAG, IL TRM v.11, Measure 4.4.19.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas,

$$\Delta \text{kWh} = \text{Condition Space}/1,000 * \text{SF}_{\text{cooling}}$$

For facilities heated by heat pumps,

$$\Delta \text{kWh} = \text{Condition Space}/1,000 * \text{SF}_{\text{cooling}} + \text{Condition Space}/1,000 * \text{SF}_{\text{Heat HP}}$$

For facilities heated by electric resistance,

$$\Delta \text{kWh} = \text{Condition Space}/1,000 * \text{SF}_{\text{cooling}} + \text{Condition Space}/1,000 * \text{SF}_{\text{Heat ER}}$$

Where:

Conditioned Space	= Actual square footage of conditioned space controlled by sensor
$\text{SF}_{\text{cooling}}$	= Cooling Savings Factor
	= Value in table below based on building type and weather zone
$\text{SF}_{\text{Heat HP}}$	= Heating Savings factor for facilities heated by Heat Pump (HP)
	= Value in table below based on building type and weather zone
$\text{SF}_{\text{Heat ER}}$	= Heating Savings factor for facilities heated by Electric Resistance (ER)
	= Value in table below based on building type and weather zone

Saving Factor Tables⁵³⁷

Building Type	SF _{cooling} (kWh/1,000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵³⁸
Office - Low-rise	317	280	432
Office - Mid-rise	248	221	340
Office - High-rise	296	263	405
Religious Building	940	750	1165
Restaurant	608	490	762
Retail - Department Store	435	381	587
Retail - Strip Mall	302	264	406
Convenience Store	390	349	533
Elementary School	435	352	548
High School	425	344	536
College/University	501	393	636
Healthcare Clinic	413	343	529
Lodging	449	400	611
Manufacturing	194	172	264

⁵³⁷ Savings are calculated on an annual basis for each given temperature zone in Illinois and converted using TMYx weather data to Iowa temperature zones via a heating degree day and cooling degree day analysis between respective IL and IA temperature zones.

⁵³⁸ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Building Type	SF _{cooling} (kWh/1,000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵³⁸
Special Assembly Auditorium	708	554	868
Default	444	370	575

Building Type	SF _{Heat HP} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵³⁹
Office - Low-rise	209	292	208
Office - Mid-rise	140	196	140
Office - High-rise	188	263	188
Religious Building	1,361	1,880	1,352
Restaurant	966	1,330	976
Retail - Department Store	3336	459	334
Retail - Strip Mall	225	307	218
Convenience Store	162	224	165
Elementary School	571	819	580
High School	571	799	566
College/University	1,130	1,579	1,130
Healthcare Clinic	401	557	402
Lodging	183	256	187
Manufacturing	117	162	116
Special Assembly Auditorium	1,631	2,210	1,586
Default	547	755	543

Building Type	SF _{Heat ER} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵⁴⁰
Office - Low-rise	625	877	624
Office - Mid-rise	420	587	419
Office - High-rise	564	789	562
Religious Building	4,085	5,639	4,056
Restaurant	2,897	3,990	2,927
Retail - Department Store	1,008	1,375	1,001
Retail - Strip Mall	674	920	655
Convenience Store	488	674	495
Elementary School	1,757	2,458	1,740

⁵³⁹ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁵⁴⁰ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Building Type	SF _{Heat ER} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵⁴⁰
High School	1,712	2,399	1,697
College/University	3,391	4,738	3,389
Healthcare Clinic	1,204	1,672	1,205
Lodging	550	768	559
Manufacturing	350	486	348
Special Assembly Auditorium	4,895	6,632	4,758
Default	1,642	2,268	1,629

For example, for a 7,500 SqFt of low-rise office space in Burlington with gas heat.

$$\begin{aligned}\Delta\text{kWh} &= 7,500 / 1,000 * 317 \\ &= 2,377.5 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta\text{Therms} = \text{Condition Space}/1,000 * \text{SF}_{\text{Heat Gas}}$$

Where:

SF_{Heat Gas} = value in table below based on building type and weather zone⁵⁴¹

Building Type	SF _{Heat Gas} (Therm/1,000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵⁴²
Office - Low-rise	27	37	26
Office - Mid-rise	18	25	18
Office - High-rise	24	33	24
Religious Building	174	241	173
Restaurant	123	171	125
Retail - Department Store	43	58	42
Retail - Strip Mall	29	39	28
Convenience Store	21	29	21
Elementary School	75	105	74
High School	73	102	72

⁵⁴¹ The natural gas energy savings was calculated using TMYx weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in "Demand Control Ventilation 12-30-13.xls".

⁵⁴² Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Building Type	SF _{Heat Gas} (Therm/1,000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines) ⁵⁴²
College/University	144	202	145
Healthcare Clinic	52	71	52
Lodging	23	32	23
Manufacturing	15	21	15
Special Assembly Auditorium	209	283	203
Default	70	97	69

For example, for a 7,500 SqFt of low-rise office space in Burlington.

$$\begin{aligned}\Delta\text{Therms} &= 7,500/1,000 * 27 \\ &= 202.5 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-DCV-V02-260101

SUNSET DATE: 1/1/2030

3.3.28. HVAC ECONOMIZER

DESCRIPTION

Economizers are designed to use unconditioned outside air (OA) instead of mechanical cooling to provide cooling when exterior conditions permit. When the OA temperature is less than the changeover temperature (determined by a static setpoint or a reference return air sensor) up to 100% OA is supplied to help meet the facility's cooling needs, thus reducing mechanical cooling energy and saving energy. This HVAC measure involves the repair and optimization of common economizer problems such as adjusting changeover setpoint, repairing damper motors and linkages, and replacing non-working sensors and/or controllers. These repairs and adjustments result in proper operation which maximizes both occupant comfort and energy savings.

In general, the HVAC Economizer Optimization measure may involve both repair and/or optimization, as detailed below.

Economizer Repair

The economizer repair work is performed to ensure that the existing economizer is working properly. This allows the system to take advantage of free cooling and ensure that the system is not supplying an excess amount of OA during non-economizing periods.

- **Replace Damper Motor** – If the existing damper motor is not operational, the unit will be replaced with a functioning motor to allow proper damper modulation.
- **Repair Damper Linkage** – If the existing linkage is broken or not adjusted properly, the unit will be replaced or adjusted to allow proper damper modulation.
- **Repair Economizer Wiring** – If the existing economizer is not operational due to a wiring issue, the issue will be repaired to allow proper economizer operation.
- **Reduce Over Ventilation** – If the unit is supplying excess OA, the OA damper position will be adjusted to meet minimum ventilation requirements.
- **Replace Economizer Sensor** – If the unit is equipped with a nonadjustable dry bulb (i.e., snapdisk) or malfunctioning analog sensor, the sensor is replaced with a new selectable sensor.
- **Replace Economizer Control** – If the existing economizer controller is not operational, the unit will be replaced or upgraded to allow for proper economizer operation.

Economizer Optimization

The economizer optimization work is performed to ensure that the existing economizer system is set up properly to maximize use of free cooling for units located in a particular climate zone.

- **Economizer Changeover Setpoint Adjustment** – If the unit is equipped with a fully operational economizer, the controller is adjusted to the appropriate changeover setpoint based on ASHRAE 90.1 (Figure 1 - Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers) for the corresponding climate zone.
- **Enable Integrated Operation** – If the unit is equipped with a fully operational economizer and is not set up to allow a minimum of two stages of cooling (1st stage – Economizer Only & 2nd Stage – Economizer & Mechanical Cooling), the unit will be wired to allow two stage cooling.

This measure is only appropriate for single zone packaged rooftop units. Custom calculations are required for savings for multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined as an HVAC economizer that is programmed to meet ASHRAE 90.1 economizer changeover setpoint requirements for the facility's climate zone and changeover control type (Figure 1 – Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers).⁵⁴³

Figure 1 – Baseline ASHRAE High-Limit Shutoff Control Settings

TABLE 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers^b

Control Type	Allowed Only in Climate Zone at Listed Setpoint	Required High-Limit Setpoints (Economizer Off When):	
		Equation	Description
Fixed dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F
	5a, 6a	$T_{OA} > 70^{\circ}\text{F}$	Outdoor air temperature exceeds 70°F
	1a, 2a, 3a, 4a,	$T_{OA} > 65^{\circ}\text{F}$	Outdoor air temperature exceeds 65°F
Differential dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperature	All	$h_{OA} > 28 \text{ Btu/lb}^a$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds 28 Btu/lb ^a of dry air ^a or outdoor air temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperature	All	$h_{OA} > h_{RA}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 75°F

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 75°F and 50% RH. As an example, at approximately 6000 ft elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

b. Devices with selectable rather than adjustable setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is an existing economizer installed on a packaged single zone rooftop HVAC unit. The existing economizer system is currently not operating as designed due to mechanical and/or control problems, and/or is not optimally adjusted.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years.⁵⁴⁴

DEEMED MEASURE COST

The cost for this measure can vary considerably depending upon the existing conditions of the economizer, and the work required to achieve the required efficiency levels. Measure cost should be determined on a site-specific basis.

LOADSHAPE

Loadshape NREC01:16 – Nonresidential Cooling (by Building Type)

COINCIDENCE FACTOR

N/A

Algorithm

⁵⁴³ ASHRAE, Standard 90.1-2013

⁵⁴⁴ DEER 2014 (DEER2014 EUT Table D08 v2.05).

CALCULATION OF SAVINGS

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations.⁵⁴⁵ The equation variables are limited to the ranges listed; if the actual conditions fall outside of these ranges, custom calculations are required.

ELECTRIC ENERGY SAVINGS

$\Delta \text{kWh} = [\text{Baseline Energy Use (kWh/ton)} - \text{Proposed Energy Use (kWh/ton)}] * \text{Cooling Capacity (Tons)}$

The following equations are used to calculate baseline and proposed electric energy use.⁵⁴⁶

Changeover types: Fixed Dry-Bulb (DB), Dual Temperature Dry-Bulb (DTDB), Dual Temperature Enthalpy (DTEth), Fixed Enthalpy (Enth), and Analog ABCD Economizers (ABCD).

Electric Energy Use Equations (kWh/ton):

⁵⁴⁵ IL TRM V12 - ComEd baseline prototype eQuest models which were initially created by the Energy Center of Wisconsin (Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010).

⁵⁴⁶ This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

Building Type	Changeover Type	Equation
Assembly	DB	$cz+CSP*-2.021+EL*-16.362+OAn*1.665+OAx*-3.13$
	DTDB	$cz+EL*-11.5+OAn*1.635+OAx*-2.817$
	DTEnth	$cz+EL*-17.772+OAn*1.853+OAx*-3.044$
	Enth	$cz+CSP*-5.228+EL*-17.475+OAn*1.765+OAx*-3.003$
	HWDB	$cz+CSP*-2.234+EL*-16.394+OAn*1.744+OAx*-3.01$
Convenience Store	DB	$cz+CSP*-3.364+EL*-26.128+OAn*1.986+OAx*-4.21$
	DTDB	$cz+EL*-20.58+OAn*2.114+OAx*-3.592$
	DTEnth	$cz+EL*-29.716+OAn*2.482+OAx*-4.132$
	Enth	$cz+CSP*-7.98+EL*-25.439+OAn*2.058+OAx*-3.678$
	HWDB	$cz+CSP*-3.376+EL*-24.695+OAn*2.052+OAx*-3.71$
Office - Low Rise	DB	$cz+CSP*-0.979+EL*-6.303+OAn*3.1+OAx*-1.172$
	DTDB	$cz+OAn*3.113+OAx*-1.047$
	DTEnth	$cz+EL*-9.416+OAn*3.23+OAx*-1.175$
	Enth	$cz+CSP*-2.831+EL*-7.157+OAn*3.149+OAx*-1.093$
	HWDB	$cz+CSP*-1.253+EL*-6.993+OAn*3.143+OAx*-1.113$
Religious Facility	DB	$cz+CSP*-1.13+OAn*3.548+OAx*-1.014$
	DTDB	$cz+EL*-10.18+OAn*4.057+OAx*-1.28$
	DTEnth	$cz+OAn*3.778+OAx*-1.033$
	Enth	$cz+CSP*-2.13+OAn*3.325+OAx*-0.633$
	HWDB	$cz+CSP*-0.95+OAn*3.32+OAx*-0.651$
Restaurant	DB	$cz+CSP*-1.929+EL*-20.685+OAn*-0.399+OAx*-1.555$
	DTDB	$cz+EL*-14.038+OAx*-1.218$
	DTEnth	$cz+EL*-25.03+OAn*0.292+OAx*-1.548$
	Enth	$cz+CSP*-4.293+EL*-16.491+OAn*-0.48+OAx*-1.162$
	HWDB	$cz+CSP*-1.847+EL*-15.779+OAn*-0.486+OAx*-1.176$
Retail - Department Store	DB	$cz+CSP*-1.012+OAn*3.844+OAx*-0.983$
	DTDB	$cz+OAn*3.745+OAx*-0.717$
	DTEnth	$cz+OAn*4.129+OAx*-1.106$
	Enth	$cz+CSP*-2.579+OAn*3.803+OAx*-0.834$
	HWDB	$cz+CSP*-1.189+OAn*3.787+OAx*-0.855$
Retail - Strip Mall	DB	$cz+CSP*-1.179+EL*-5.574+OAn*3.389+OAx*-1.157$
	DTDB	$cz+OAn*3.386+OAx*-0.937$
	DTEnth	$cz+EL*-9.172+OAn*3.656+OAx*-1.225$
	Enth	$cz+CSP*-2.998+EL*-5.922+OAn*3.362+OAx*-0.991$
	HWDB	$cz+CSP*-1.36+EL*-5.868+OAn*3.349+OAx*-1.014$

Where:

CZ = Climate Zone Coefficient⁵⁴⁷

= Depends on Building Type and Changeover Type (see table below)

⁵⁴⁷ Iowa-specific electric climate zones were developed by applying a cooling degree-day (CDD) factor to climate zones found in the Illinois TRM (Economizer Repair and Optimization). For more details see reference file "Economizer Worksheet".

Building Type	Changeover Type	CZ5 (Burlington)	CZ6 (Mason City)	Unknown (Des Moines)
Assembly	DB	979	710	983
	DTDB	805	584	808
	DTEnth	808	586	812
	Enth	957	694	961
	HWDB	990	718	994
Convenience Store	DB	1995	1446	2003
	DTDB	1646	1193	1653
	DTEnth	1655	1199	1662
	Enth	1900	1377	1908
	HWDB	1950	1413	1958
Office - Low Rise	DB	828	600	832
	DTDB	739	536	742
	DTEnth	744	540	747
	Enth	823	597	827
	HWDB	845	613	849
Religious Facility	DB	770	558	773
	DTDB	677	490	679
	DTEnth	672	487	675
	Enth	734	532	737
	HWDB	751	545	754
Restaurant	DB	1634	1184	1640
	DTDB	1428	1035	1434
	DTEnth	1429	1036	1435
	Enth	1580	1145	1587
	HWDB	1611	1168	1618
Retail - Department Store	DB	877	636	881
	DTDB	790	573	793
	DTEnth	790	573	794
	Enth	865	627	868
	HWDB	889	644	892
Retail - Strip Mall	DB	970	703	974
	DTDB	864	626	867
	DTEnth	869	630	872
	Enth	954	692	958
	HWDB	980	711	984

CSP = Economizer Changeover Setpoint (°F or Btu/lb) (actual in ranges below)

Economizer Control Type		Economizer Changeover Setpoint
Dry-Bulb		60°F – 80°F
Dual Temperature Dry-Bulb		0°F – 5°F delta
Dual Temperature Enthalpy		0 Btu/lb – 5 Btu/lb delta
Enthalpy		18 Btu/lb – 28 Btu/lb
Analog ABCD Economizers	A	73°F
	B	70°F

Economizer Control Type	Economizer Changeover Setpoint
C	67°F
D	63°F
E	55°F

EL = Integrated Economizer Operation (Economizer Lockout)
 = 1 for Economizer w/ Integrated Operation (Two Stage Cooling)
 = 0 for Economizer w/ out Integrated Operation (One Stage Cooling)

OAn = Minimum Outside Air (%OA * 100)⁵⁴⁸

= Actual. %OA must be between 15% and 70%. If unknown, assume:

- Functional Economizer – 30%
- Nonfunctional Economizer (Damper failed closed) – 15%
- Nonfunctional Economizer (Damper failed open) – 30% (assume Minimum Ventilation (Three Fingers))⁵⁴⁹

Note: the actual integer Oan value (e.g., 30) should be used in the regression algorithm, not the percentage (e.g., 0.3).

OAx = Maximum Outside Air (%)

= Actual. must be between 15% and 70%. If unknown, assume:

- Functional Economizer – 70%
- Nonfunctional Economizer (Damper failed closed) – 15%
- Nonfunctional Economizer (Damper failed open) – 30% (assume Minimum Ventilation (Three Fingers))

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - It is assumed that repair or optimization of the economizers will not typically have significant impacts on summer peak demand, due to the temperature ranges that they typically operate.

NATURAL GAS SAVINGS

$\Delta\text{Therms} = [\text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use (Therms/kBtuh)}] * \text{Output Heating Capacity (kBtuh)}$

The following equations are used to calculate baseline and proposed fossil fuel energy use.

Natural Gas Energy Use Equations (therms / kbtu output)

Building Type Changeover Type Equation:

Building Type	Changeover Type	Equation
Assembly	DB	$cz + OAn * 0.0853$
	DTDB	$cz + OAn * 0.0866$
	DTEnth	$cz + OAn * 0.0866$
	Enth	$cz + OAn * 0.0855$
	HWDB	$cz + OAn * 0.0855$

⁵⁴⁸ DNV GL, "HVAC Impact Evaluation Final Report WO32 HVAC – Volume 1: Report," California Public Utilities Commission, Energy Division, HVAC Commercial Quality Maintenance (CQM) (1/28/14).

⁵⁴⁹ Technician rule of thumb taken from CPUC 'HVAC Impact Evaluation Final Report', WO32, 28Jan 2015, p18.

Building Type	Changeover Type	Equation
Convenience Store	DB	$cz+OAn*0.272$
	DTDB	$cz+OAn*0.268$
	DTEnth	$cz+OAn*0.268$
	Enth	$cz+OAn*0.271$
	HWDB	$cz+OAn*0.271$
Office - Low Rise	DB	$cz+OAn*0.34+OA_x*-0.0209$
	DTDB	$cz+OAn*0.33+OA_x*-0.0209$
	DTEnth	$cz+OAn*0.33+OA_x*-0.0209$
	Enth	$cz+OAn*0.338+OA_x*-0.0209$
	HWDB	$cz+OAn*0.338+OA_x*-0.0209$
Religious Facility	DB	$cz+OAn*0.353$
	DTDB	$cz+OAn*0.35$
	DTEnth	$cz+OAn*0.35$
	Enth	$cz+OAn*0.352$
	HWDB	$cz+OAn*0.352$
Restaurant	DB	$cz+OAn*0.0937$
	DTDB	$cz+OAn*0.0978$
	DTEnth	$cz+OAn*0.0978$
	Enth	$cz+OAn*0.0943$
	HWDB	$cz+OAn*0.0943$
Retail - Department Store	DB	$cz+OAn*0.346+OA_x*-0.0146$
	DTDB	$cz+OAn*0.339+OA_x*-0.0146$
	DTEnth	$cz+OAn*0.339+OA_x*-0.0146$
	Enth	$cz+OAn*0.345+OA_x*-0.0146$
	HWDB	$cz+OAn*0.345+OA_x*-0.0146$
Retail - Strip Mall	DB	$cz+OAn*0.231$
	DTDB	$cz+OAn*0.224$
	DTEnth	$cz+OAn*0.224$
	Enth	$cz+OAn*0.23$
	HWDB	$cz+OAn*0.23$

Where:

CZ = Climate Zone Coefficient⁵⁵⁰

⁵⁵⁰ Iowa-specific natural gas climate zones were developed by applying a cooling degree-day (CDD) factor to climate zones found in the Illinois TRM (Economizer Repair and Optimization). For more details see reference file "Economizer Worksheet".

Building Type	Changeover Type	CZ5 (Burlington)	CZ6 (Mason City)	Average (Des Moines)
Assembly	DB	-0.873	-0.633	-0.876
	DTDB	-0.842	-0.610	-0.846
	DTEnth	-0.842	-0.610	-0.846
	Enth	-1.446	-1.048	-1.452
	HWDB	-1.223	-0.886	-1.228
Convenience Store	DB	-1.223	-0.886	-1.228
	DTDB	-1.420	-1.030	-1.426
	DTEnth	-1.420	-1.030	-1.426
	Enth	0.778	0.564	0.781
	HWDB	1.103	0.799	1.107
Office - Low Rise	DB	1.103	0.799	1.107
	DTDB	0.823	0.597	0.827
	DTEnth	0.823	0.597	0.827
	Enth	4.661	3.378	4.680
	HWDB	4.801	3.480	4.821
Religious Facility	DB	4.801	3.480	4.821
	DTDB	4.679	3.391	4.698
	DTEnth	4.679	3.391	4.698
	Enth	5.147	3.731	5.168
	HWDB	5.085	3.686	5.106
Restaurant	DB	5.085	3.686	5.106
	DTDB	5.135	3.722	5.156
	DTEnth	5.135	3.722	5.156
	Enth	3.348	2.426	3.361
	HWDB	3.606	2.614	3.621
Retail - Department Store	DB	3.606	2.614	3.621
	DTDB	3.384	2.453	3.398
	DTEnth	3.384	2.453	3.398
	Enth	1.893	1.372	1.901
	HWDB	2.262	1.639	2.271
Retail - Strip Mall	DB	2.262	1.639	2.271
	DTDB	1.938	1.404	1.946
	DTEnth	1.938	1.404	1.946
	Enth	-0.873	-0.633	-0.876
	HWDB	-0.842	-0.610	-0.846

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-ECON-V02-260101

SUNSET DATE: 1/1/2030

3.3.29. INFRARED HEATERS**DESCRIPTION**

A natural gas-fired radiant infrared heater uses the combustion of natural gas to heat a metal tube or ceramic panel to a very high temperature (typically between 1,200°F and 5,000°F). The high surface temperature causes radiant heat transfer between the heater surface and its surroundings. The surroundings will re-radiate the heat to occupants and release heat through convection to the air, providing a comfortable environment without directly heating air.

Infrared heaters are ideal for space heating applications where there are elevated ceilings with high thermal stratification, spaces with high ventilation or air infiltration rates, or a need for spot heating within an unconditioned or industrial space. Aircraft hangers, warehouses, greenhouses, manufacturing production areas, pools, and loading docks are space types that can be efficiently served by a radiant infrared heater.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a natural gas heater with an electric ignition that uses non-conditioned air for combustion. Gross Radiant Coefficient (GRC) is provided by the manufacturer and defined as the ratio of radiant heat output to the natural gas input energy (in Btu).⁵⁵¹

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard natural gas fired warm air heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁵⁵²

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2.70 per kBtu/hr input capacity.⁵⁵³

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

⁵⁵¹ "AHRI Standard 1330 - 2014 Standard for Performance Rating for Radiant Output of Gas Fired Infrared Heaters". 2014. Air Conditioning, Heating, and Refrigeration Institute. Arlington, VA.

⁵⁵² 2020 Michigan Energy Measures Database (MEMD). Please see file "mi_master_measure_database_2020-011020_681298_7.xlsx"

⁵⁵³ Ibid

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Natural gas savings for this measure are based on the standard practice of HVAC designers to size a gas-fired radiant infrared heater at a lower input capacity than an equivalent warm air unit heater for an identical application.

$$\Delta \text{Therms} = \text{Therms}(\text{base}) - \text{Therms}(\text{IR})$$

$$\text{Therms}(\text{base}) = \text{Capacity} / \text{RSF} * \text{UF} * \text{EFLH} / 100,000$$

$$\text{Therms}(\text{IR}) = \text{Capacity} * \text{UF} * \text{EFLH} / 100,000$$

Where:

Capacity = Input capacity of radiant infrared heater in btu/hr
= Actual

RSF = Radiation Sizing Factor, dependent on Gross Radiant Coefficient⁵⁵⁴ as listed below:^{555,556}
If Gross Radiant Coefficient is unavailable, assume RSF = 0.85.

Gross Radiant Coefficient (GRC)	RSF (Radiation Sizing Factor)
GRC < 0.67	0.85
0.67 ≤ GRC	0.70

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

UF = Utilization Factor
= 100% if installed heater is used for primary heating

= 72.5%,⁵⁵⁷ or custom if installed heater is used for supplementary heating 100,000 = Btu to therm conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-IRHT-V01-260101**SUNSET DATE: 1/1/2029**

⁵⁵⁴ GRC should be provided by the manufacturer.

⁵⁵⁵ Radiation Sizing Factor(RSF) value determined by testing as per 2016 ASHRAE® HANDBOOK: Heating, Ventilating, and Air-Conditioning SYSTEMS AND EQUIPMENT, Inch-Pound Edition, Chapter 16, pg. 16.1, "Energy Conservation," 2016, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Atlanta, GA.

⁵⁵⁶ "Put Your Infra-Red Knowledge to the Test". Contracting Canada, July - August 2002.

⁵⁵⁷ The utilization factor accounts for the fact that unit heaters are typically used for supplementary heating. Value as sourced from the 2020 Wisconsin Focus on Energy Technical Reference Manual, Public Service Commission of Wisconsin, Cadmus – Unit Heaters, ≥ 90% Thermal Efficiency (pg. 234)

3.3.30. CONDENSING UNIT HEATERS**DESCRIPTION**

This measure applies to a gas fired condensing unit heater installed in a commercial application.

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 condensing unit heater up to 300 MBH with a Thermal Efficiency > 90% and the heater must be vented, and condensate drained per manufacturer specifications. The unit must be replacing existing natural gas equipment.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be a non-condensing natural gas unit heater at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁵⁵⁸

DEEMED MEASURE COST

The incremental capital cost for a unit heater is equal to the input capacity in kBtu/h multiplied by \$15.56⁵⁵⁹

Incremental cost = Capacity * \$15.56

Where:

Capacity	= Nominal rating of the input capacity of the new condensing unit heater in kBtu/hr
\$15.56	= Incremental cost per kBtu/h of input capacity of a new condensing unit heater

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

⁵⁵⁸DEER 2008

⁵⁵⁹The incremental capitol cost is based on historic project data from Wisconsin Focus on Energy, spanning 2015 through June 2018. The data is aggregated based on 29 projects that comprised of 100 installed unit heaters. The average installed unit heater cost was \$22.64 / kBtu/h of input unit capacity. The baseline unit heater cost was estimated to be \$7.08 / kBtu/h of input unit capacity, per review of online pricing of Reznor and Modine models on Supply House's website. The incremental cost was sourced from the 2020 Wisconsin Focus on Energy TRM, Public Service Commission of Wisconsin, Cadmus – "Unit Heaters, > 90% Thermal Efficiency (pg. 234)

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = ((\text{Capacity} * \text{EFLH} * \text{UF}) / 100) * (1 / \text{Eff}_{\text{Base}} - 1 / \text{Eff}_{\text{EE}})$$

Where:

Capacity = Nominal rating of the input capacity of the new condensing unit heater in kBtu/hr

= Actual

UF = Utilization Factor

= 72.5%,⁵⁶⁰ or customEff_{Base} = Combustion Efficiency of the baseline unit heater= Default value is 80%⁵⁶¹Eff_{EE} = Combustion Efficiency of the installed unit heater= Actual. Default value is 90%⁵⁶²

100 = conversion from kBtu to therms

EFLH = Equivalent Full Load Hours for Existing Buildings or New Construction are provided in section 3.4 HVAC End Use.

For example, a 150 kBtu condensing unit heater with a combustion efficiency of 90% is installed in a garage in Rockford:

$$\begin{aligned} \Delta \text{therms} &= ((150 * 985 * 0.725) / 100) * (1 / 0.80 - 1 / 0.90) \\ &= 149 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-CUHT- V01-260101**SUNSET DATE: 1/1/2030**

⁵⁶⁰ The utilization factor accounts for the fact that unit heaters are typically over-sized. Value as sourced from the 2020 Wisconsin Focus on Energy Technical Reference Manual, Public Service Commission of Wisconsin, Cadmus – Unit Heaters, ≥ 90% Thermal Efficiency (pg. 234)

⁵⁶¹ Baseline combustion efficiency is sourced from IECC 2012 for all capacity warm-air unit heaters, gas-fired.

⁵⁶² The default efficient equipment efficiency represents the minimum of recommended qualifying equipment and is sourced from the 2025 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 13.0, Volume 2: Commercial and Industrial Measures, Final, September 2024

3.3.31. ENERGY RECOVERY VENTILATOR**DESCRIPTION**

An Energy Recovery Ventilator (ERV) achieves energy savings by recovering thermal energy from the exhaust air stream in a commercial building ventilation system. A heat exchanger (fixed plate or enthalpy wheel) recovers both sensible and latent energy from the exhaust air, which is transferred to the incoming outside air stream. While a *Heat Recovery Ventilator* (HRV) can recover sensible heat, an ERV is capable of transferring both sensible and latent heat energy, thus providing additional benefit especially during the cooling season. This measure can be applied to buildings with or without an economizer, and assumes the ERV is controlled based on indoor versus outdoor air enthalpy.

This measure includes the addition of energy recovery equipment on an existing (retrofit) or new construction (NC) commercial building

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a mechanical ventilation system outfitted with an energy recovery device.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a mechanical ventilation system without energy recovery capabilities

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic energy recovery equipment is 15 years.⁵⁶³

DEEMED MEASURE COST

Energy Recovery Equipment Type	Incremental Cost \$/CFM ⁵⁶⁴
Plate Heat Exchanger	\$3.75
Rotary Wheel	\$3.75

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure, as compared to the O&M costs of a mechanical ventilation system.

LOADSHAPE

Electric Loadshapes:

NREC01 – NREC16 dependent on building type

NREH01 – NREH16 dependent on building type

NREP01 – NREP16 dependent on building type

Natural Gas Loadshapes:

NRGH01-NRGH16 dependent on building type

⁵⁶³ Assumed service life limited by controls - "Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

⁵⁶⁴ "National Cost-Effectiveness of ASHRAE Standard 90.1-2010 Compared to ASHRAE Standard 90.1-2007", PNNL, November 2007 (page 4-16).

NRGB01 – NRGB16 dependent on building type

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan})$$

$\Delta kWh_{cooling}$:

$$\Delta kWh_{cooling} = \frac{4.5 * CFM * \Delta H * Eff_{ERV}}{1000 * SEER} * F_{cool}$$

$\Delta kWh_{heating}$:

$$\Delta kWh_{heating} = \frac{1.08 * CFM * HDD * Eff_{ERV}}{1000 * HSPF} * F_{heat}$$

ΔkWh_{fan} :

$$\Delta kWh_{fan} = \frac{W_{fan_baseline}}{1000} - \frac{W_{fan_{ERV}}}{1000} * Hours$$

Where:

4.5 = Density of air at 70F (0.075 lb/ft³), multiplied by 60 minutes per hour

CFM = Maximum CFM of ERV, in ft³/min

ΔH = The sum of the difference between building return air and outdoor air enthalpy multiplied by the number of hours for each temperature bin. For default values by climate zone, see table below. ⁵⁶⁵

$$\Delta H = \sum (H_{OA} - H_{RA}) * Hrs_{bin}$$

Where:

H_{OA} = Average outdoor air enthalpy (btu/lbm), for each 5-degree temperature increment during the cooling season

H_{RA} = Average Indoor return air enthalpy (btu/lbm) during the cooling season.

= if unknown, assume 25.3 btu/lbm (70F at 50% relative humidity)

Climate Zone	ΔH
Burlington	5,546
Mason City	2,960
Unknown	1,673

⁵⁶⁵ Similar to economizers, commercial ERV systems typically control based on differential enthalpy, therefore periods of time where the indoor air energy content is higher than the outdoor energy content during the cooling season, the ERV is assumed to be inactive. See reference file “Energy Recovery Ventilators non-res.xlsx” for detailed derivation of values. Values based on TMY3 weather data for three IA locations.

Eff_{ERV} = Maximum ERV recovery efficiency, or heat exchanger effectiveness.

= If unknown, assume 0.64 for fixed-plate types, or 0.73 for rotary wheel types⁵⁶⁶

F_{elec_cool} = Cooling factor, equal to 1.0 if central cooling is used, 0 if central cooling not used

SEER = Seasonal Energy Efficiency Ratio of cooling equipment (kbtu/kWh)

= Actual

1000 = conversion factor, 1000 W/kW

1.08 = specific heat of air multiplied by the density of air, at 70F, 1atm

HDD = Heating Degree Days, balance point of 60 degrees Fahrenheit

= If unknown, use default values from table below⁵⁶⁷

Climate Zone	HDD 60
Burlington	4,832
Mason City	6,356
Average (Des Moines)	5,013

F_{elec_heat} = Electric Heating factor, equal to 1.0 if electric heating is used, 0 is electric heating not used

W_{fan_ERV} = Maximum rated watts of ERV fans (W)

Hours = Actual hours per year that system is operating

= 8760 if unknown

HSPF = Heating Seasonal Performance Factor, Defined as the total seasonal heat output (BTU) divided by the seasonal electric consumption (Wh)

= Actual

$W_{fan_baseline}$ = Baseline supply and exhaust fan watts, (W)

= $W_{exhaustfan_base} + W_{supplyfan_base}$

Where:

$W_{exhaustfan_base}$ = Energy demand of existing exhaust fan, in watts (W)

= Actual

$W_{supplyfan_base}$ = Energy demand of existing supply fan, in watts (W)

=Actual

⁵⁶⁶ Minnesota TRM version 5.0, "C/I HVAC – Energy Recovery Ventilator (ERV)", table 4. Analysis of AHRI listed devices available 1/1/2016.

⁵⁶⁷ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 60°F. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

For example, A fixed plate ERV is installed on a small office building with central cooling (SEER 16.0) in Burlington. The building does not use electric heat. The ERV has a max ventilation rate of 2000 CFM, max motor consumption of 1280 watts, and recovery efficiency of 70%. The existing supply and exhaust fans have a combined energy demand of 1400 watts.

$$\begin{aligned}\Delta kWh_{cooling} &= \frac{4.5 * 2000 * 5546 * 70\%}{1000 * 16.0} * 1 \\ &= \mathbf{2,183.7kWh} \\ \Delta kWh_{heating} &= \frac{1.08 * 2000 * 4832 * 70\%}{1000 * 8.3} * 0 \\ &= \mathbf{0kWh} \\ \Delta kWh_{fan} &= \frac{1400}{1000} - \frac{1280}{1000} * 8760 \\ &= \mathbf{1,051.2kWh} \\ \Delta kWh_{Total} &= \mathbf{3,234.9kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling in Existing Buildings or New Construction are provided in section 3.3 HVAC End Use

CF = Summer System Peak Coincidence Factor for Cooling

Building Type	CF ⁵⁶⁸	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁵⁶⁹	91.5%	N/A

⁵⁶⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁵⁶⁹ For weighting factors, see HVAC variable table in section 3.3.

For example, ERV as described in electric energy savings example

$$\begin{aligned}\Delta kW &= \frac{3234.9}{1060} * 99.7 \\ &= 3.043 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Δ Therms:

$$\Delta therms = \frac{1.08 * CFM * HDD * Eff_{ERV}}{100,000 * \eta_{gas_heat}} * F_{gas_heat}$$

Where:

η_{gas_heat} = Natural gas heating system efficiency (%)
= Actual

F_{gas_heat} = Natural gas heating factor, 1.0 if building uses gas heating, 0 if no gas heating is used

100,000 = conversion factor, 100,000 btu/therm

Other factors as defined above.

For example, A fixed plate ERV is installed on a small office building with central heating (AFUE 83%) in Burlington. The ERV has a max ventilation rate of 2000 CFM, max motor consumption of 1280 watts, and recovery efficiency of 70%. The existing supply and exhaust fans have a combined energy demand of 1400 watts.

$$\begin{aligned}\Delta Therms &= \frac{1.08 * 2000 * 4832 * 70\%}{100,000 * 0.83} * 1 \\ &= 88\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta therms * GCF$$

Where:

Δ therms = Natural gas energy savings, as calculated above

GCF = Gas Coincidence Factor for Heating⁵⁷⁰

Building Type	GCF	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio

⁵⁷⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁵⁷¹	1.5713%	N/A

For example,

$$\begin{aligned}\Delta\text{Therms} &= 88 * 1.6211\% \\ &= 1.4266\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR -HVC-ERVR-V01-270101

SUNSET DATE: 1/1/2030

⁵⁷¹ For weighting factors see HVAC variable table in section 3.3.

3.3.32 Stack Economizer for Boilers

DESCRIPTION

Stack economizers are designed to recover heat from hot boiler flue gases. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of HVAC or process boilers with stack economizers. HVAC boilers are defined as those used for space heating applications. Process boilers are defined as those used for industrial, manufacturing, or other non-HVAC applications.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler does not have an economizer installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be the lower of the remaining useful life of the boiler or 15 years.⁵⁷²

DEEMED MEASURE COST

The recommended incremental cost represents the average fully installed cost of a non-condensing stack economizer added to an existing boiler with no prior stack heat recovery. Costs include the economizer heat exchanger and economizer-specific installation labor, ductwork modifications, piping, controls integration, and commissioning. Condensing economizers, condensate management systems, and associated corrosion-control infrastructure are explicitly excluded in this measure.

Boiler Size	Gross Install Costs ⁵⁷³
10 MMBtu/h	\$100,000
15 MMBtu/h	\$150,000
25 MMBtu/h	\$250,000
50 MMBtu/h	\$500,000
100 MMBtu/h	\$1,000,000

DEEMED O&M COST ADJUSTMENTS

The O&M cost for this measure is custom.

LOADSHAPE

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

COINCIDENCE FACTOR

N/A

Algorithm

⁵⁷² PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

⁵⁷³ PG&E Fact Sheet “Stack Gas Economizers”

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL SAVINGS

$$\Delta \text{therms} = SF * MBH_{In} * EFLH * UF / 100$$

Where:

SF = Savings factor
 = calculated custom as $(T_{\text{existing}} - T_{\text{eff}}) / 40^{\circ}\text{F} * \text{TRE}$ or when not possible a default value based on the table below

T _{existing}	= Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack ⁵⁷⁴ = 425°F (water, 81.9% eff) or custom = 480°F (steam, 80.7% eff) or custom
T _{eff}	= Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack = 338°F (conventional economizer – Water Boiler) ⁵⁷⁵ or custom = 365°F (conventional economizer – Steam Boiler) ⁵⁷⁶ or custom = 280°F (condensing economizer – Water Boiler) ⁵⁷⁷ or custom = 308°F (condensing economizer – Steam Boiler) ⁵⁷⁸ or custom
TRE	= % efficiency increase for 40°F of stack temperature reduction = 1%, ⁵⁷⁹ or custom

Based on defaults provided above:

Boiler Type	SF ⁵⁸⁰	
	Conventional Economizer	Condensing Economizer
Hot Water Boiler	2.19% average SF or custom	3.63% average SF or custom
Steam Boiler	2.88% average SF or custom	4.31% average SF or custom

MBH_{In} = Rated boiler input capacity, in MBH (Btu/hr)

= Actual [Sample value 200 MBH]

UF = Boiler utilization factor

= 100% for space heating boilers

= 41.9% for process boilers⁵⁸¹

⁵⁷⁴ Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

⁵⁷⁵ The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, $(425^{\circ}\text{F} + 250^{\circ}\text{F}) / 2 = 338^{\circ}\text{F}$.

⁵⁷⁶ The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, $(480^{\circ}\text{F} + 250^{\circ}\text{F}) / 2 = 365^{\circ}\text{F}$.

⁵⁷⁷ The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, $(425^{\circ}\text{F} + 135^{\circ}\text{F}) / 2 = 280^{\circ}\text{F}$.

⁵⁷⁸ The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, $(480^{\circ}\text{F} + 135^{\circ}\text{F}) / 2 = 308^{\circ}\text{F}$.

⁵⁷⁹ United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998. The Wise Rules indicate savings range of 1-2% per 40°F reduction, so utilizing 1% is a conservative approach.

⁵⁸⁰ These average values should be utilized in absence of actual temperature data. An economizer with a zero temperature change between the existing and the efficient temperatures would not be installed, so these average values are conservative.

⁵⁸¹ Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

EFLH = Default Equivalent Full Load Hours for heating in Existing Buildings or New Construction are provided in section 3 HVAC End Use. For process boilers, use 8,760 hours.

For example,

$$\begin{aligned}\Delta\text{Therms} &= SF * MBH_{In} * EFLH * UF / 100 \\ &= 0.0219 * 200 * 1360 * 100\% / 100 \\ &= 59.6 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Depending on design, stack economizers may require routine maintenance for optimal performance. A custom calculation should be used as necessary.

MEASURE CODE: NR -HVC-STACK-V01-270101

SUNSET DATE: 1/1/2030

3.3.33 Oxygen Trim Controls for Boilers

DESCRIPTION

This measure is for a non-residential boiler providing either space heating or process-specific without oxygen trim combustion controls. Oxygen (O₂) trim controls limit the amount of excess oxygen provided to the burner for combustion. This oxygen level is dependent upon the amount of air provided. Oxygen trim control converts parallel positioning, linkage-less controls, into a closed-loop control configuration with the addition of an exhaust gas analyzer and PID controller. Boilers with oxygen trim controls can maintain a predetermined excess air rate (generally 15% to 30% excess air) over the entire burner firing rate. Boilers without these controls typically have excess air rates around 30% over the entire firing rate. Boiler efficiency drops as the excess air levels are increased.

This measure includes the addition of oxygen trim controls on an existing commercial boiler (RF), NC, or TOS

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify, the boiler burner must have an oxygen control system allowing the combustion air to be adjusted to maintain a predetermined excess oxygen level in the flue exhaust at all firing rates throughout the burner's firing range. This requires an oxygen sensor in the flue exhaust and linkage-less fuel valve and combustion air controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes linkage-less positioning for the burner combustion control. This measure is intended as an incremental upgrade to linkage-less controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the O₂ Trim controls is 20 years.⁵⁸²

DEEMED MEASURE COST

Custom costs should be used when available. The default cost is approximately \$18,290.⁵⁸³

LOADSHAPE

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

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL SAVINGS

$$\Delta \text{Therms} = Ng_i * SF * EFLH * UF / 100$$

Where:

Ng_i = Boiler gas input size (kBtu/hr)
= Custom [Sample Value 1500 kBtu/hr]

UF = Boiler utilization factor
= 100% for space heating boilers
= 41.9% for process boilers⁵⁸⁴

SF = Savings factor

Note: Savings factor is the percentage reduction in gas consumption as a result of the additional O₂ trim controls. Linkage-less controls have an excess air rate of 27% over the entire firing range.⁵⁸⁵ O₂ trim controls have an excess air rate of 15%.⁵⁸⁶ The average difference is 12%. A 15% reduction in excess air is approximately a 1% increase in efficiency.⁵⁸⁷ Therefore, the nominal combustion efficiency increase is 12 /

⁵⁸² Ontario Energy Board, “Final Report: Custom Measure Life”, Michaels Energy, May 10, 2018, burner modification measure life is estimated at 20 years.

⁵⁸³ Washington State University Energy Efficiency Factsheet, “Boiler Combustion Monitoring & Oxygen Trim systems”, 2003. Adjusted for inflation to 2027 dollars.

⁵⁸⁴ Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

⁵⁸⁵ Department of Energy (DOE). 2009. Energy Matters newsletter. Fall 2009- Vol. 1, Iss. 1. Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program.

⁵⁸⁶ Ibid.

⁵⁸⁷ Department of Energy (DOE), January 2012, Steam Tip Sheet #4, Improving Your Boiler’s Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated.

15 * 1% = 0.8%.

= 0.8% for space heating boilers

= 1.1% for process boilers⁵⁸⁸

EFLH = Default Equivalent Full Load Hours for heating in Existing Buildings or New Construction are provided in section 3 HVAC End Use. For process boilers, use 8,760 hours.

100 = convert kBtu to therms

For example,

$$\begin{aligned}\Delta \text{Therms} &= Ngi * SF * EFLH * UF / 100 \\ &= 1500 * 0.008 * 1360 * 100\% / 100 \\ &= 163.2 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed annual Operations and Maintenance cost is \$800.⁵⁸⁹

MEASURE CODE: NR -HVC-OTRIM-V01-270101

SUNSET DATE: 1/1/2030

⁵⁸⁸ Oak Ridge National Laboratory. Steam Survey Guide. ORNL/TM-2001/263. May 2002. United States Environment Protection Agency. Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency. EPA/625/R-99/003. June 2001. Further substantiated by the Focus on Energy Wisconsin 2026 Technical Reference Manual, January 2026 – Boiler Oxygen Trim Controls

⁵⁸⁹ 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.

3.3.34 Advanced Rooftop Controls

DESCRIPTION

The Advanced Rooftop Controls (ARC) measure installs demand-controlled ventilation (DCV) with optional supply-fan speed control via a variable-frequency drive or multi-speed motor to a single-zone, packaged HVAC unit with a functioning integrated economizer already installed. The demand-controlled ventilation modulates the outside air damper based on CO₂ concentration in the conditioned space. The supply fan speed control options consist of setting the fan speed to 40% in ventilation mode and to 90% in heating and cooling modes, or of setting the fan speed to 40% in ventilation mode, to 75% in 1st stage heating and 1st stage cooling modes, and to 90% in 2nd stage heating and 2nd stage cooling modes. The measure results in fan, cooling, and heating savings compared to a baseline scenario of constant-volume, constant-ventilation operation typical of single-zone, packaged HVAC units. There are several off-the-shelf products available for the packaged HVAC unit market that support these control sequences, and the energy savings potential of these strategies has been studied and reported on.⁵⁹⁰

Demand-controlled ventilation modulates the percentage of outside air that is delivered to a space and its occupants by controlling the position of the outside air damper. The outside air damper is set to the minimum position required for the space, and is opened further when CO₂ concentration in the conditioned space increases which indicates an increase in occupancy. The damper also opens to provide 100% outside air cooling (i.e., the unit economizes) when conditions permit. This portion of the measure saves energy by reducing unnecessary heating and cooling of outside air. Demand-controlled ventilation can also be combined with the installation of a variable-frequency drive or a multi-speed motor on the supply fan. This drive is used to reduce the speed of the supply fan when the full design airflow is not required. When the unit is only providing ventilation air (i.e., not heating or cooling), the airflow is reduced substantially, but not below the ASHRAE-required minimum ventilation rate. The flow for heating and cooling can also be reduced a small amount in most cases. Per the fan affinity laws, the reduction in flow correlates to a near cubic reduction in fan power. In these ways, this measure is able to achieve energy savings via reduced cooling, heating, and ventilation.

This measure is intended for commercial buildings served by single-zone, packaged HVAC units. 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 equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that has been retrofitted with demand-controlled ventilation controls with optional supply-fan speed control via a variable-frequency drive.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that lacks demand-controlled ventilation controls and lacks supply-fan speed control via a variable-frequency drive.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years and based on the estimated life of a CO₂ sensor.⁵⁹¹

⁵⁹⁰ Katipamula, S., et al, "Advanced Rooftop Control (ARC) Retrofit: Field-Test Results", Pacific Northwest National Laboratory, July 2013.

⁵⁹¹ During conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors must be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time.

DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used.

Table 1 – Deemed Measure Cost Details

Measure	Material Cost / Unit	Labor/ Unit	Total Cost/Unit
CO2 Sensor and RTU Integration only ⁵⁹²	\$278	\$900	\$1,178
CO2 sensor, RTU integration, and VFD or multi-speed motor ⁵⁹³	\$2,079.10	\$1,367.26	\$3,446.36

LOADSHAPE

Nonresidential Ventilation NREV01 – NREV16

Nonresidential Cooling NREC01 – NREC16

Nonresidential Heating NREH01 – NREH16

Nonresidential Electric Heat Pump NREP01 – NREP16

Nonresidential Gas Heating NREGH01 – NREGH16

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

To determine the savings associated with the Advanced Rooftop Controls (ARC) measure, the IL TRM prototype eQuest models were utilized⁵⁹⁴, which were initially created by the Energy Center of Wisconsin⁵⁹⁵ but modified by VEIC in 2014. For each building type, the most recent versions of the models were used for the baseline models.

Upon examination of the building prototype models it was found that several of the baseline models did not have packaged single zone (PSZ) units. This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, models were chosen that utilized PSZ HVAC systems, and aligned with the small commercial building type applicable to this measure. Once the baseline models were selected, it was determined that several modifications were necessary to the prototype models in order to represent the baseline scenario for this measure:

1. Multistage PSZ HVAC System with Constant Volume Supply Fan
2. Optimized Economizer Controls by Climate Zone
 - a. Economizer Changeover Type – Set to fixed Dry Bulb
 - b. Economizer High-Limit Control Setpoints – Setpoints based on ASHRAE Climate Zones Fixed Dry Bulb Temperature recommendations.

⁵⁹² CO2 Sensor costs - [Business Energy Advisor | Demand-Controlled Ventilation \(bizenergyadvisor.com\)](https://www.bizenergyadvisor.com), 2017. Average sensor cost used from list of eight different vendors and CO2 sensors. RTU integration costs assume high end of estimated range (\$300-\$900) for implementing DCV on a newer DCV-ready RTU with existing economizer.

⁵⁹³ VFD/multi-speed motor costs – RS Means, Q1 2026. Springfield, IL, material and labor cost to install 3hp 460V 3-phase VFD. 3hp is the assumed supply fan motor size on a 10-ton single-zone packaged rooftop unit.

⁵⁹⁴ Illinois TRM V15 C&I measure 4.4.41

⁵⁹⁵ Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010.

- c. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

Additionally, several of the building prototype models were found to have supply fan total static pressure modeled inputs that seemed excessive and atypical for packaged single zone rooftop units. These included convenience stores (5 in. wc), manufacturing facilities (5 in. wc), office low rises (5 in. wc), religious buildings (5 in. wc), and restaurants (5 in. wc). The remaining models had supply fan total static pressure inputs more in line with what would be expected for packaged single zone rooftop units, ranging from 1.3 to 2 in. wc. For each model having a supply fan total static pressure above 2 in. wc, model inputs were adjusted to set these to 2 in. wc. To implement the modifications shown above, changes were made to eQUEST keywords in the prototype models as shown in the following table.

Table 2 – Prototype Modifications to eQuest Keywords

Component Adjusted	eQuest Keyword	Default Value	Modified Prototype Value
System - System Type	SYSTEM:TYPE	PSZ	PVVT
System - Airflow and Temperature Control	SYSTEM:AIR/TEMP-CONTROL	N/A	STAGED-VOLUME
System – Supply Fan Total Static Pressure	SYSTEM:SUPPLY-STATIC	Varies	If >2: 2 Else: IL TR Value
System - Cooling and Heating Capacities	SYSTEM:COOLING-CAPACITY SYSTEM:HEATING-CAPACITY	Auto-sized	Hard-coded (after retrieving auto-sized outputs)
System - Supply Fan Control	SYSTEM:FAN-CONTROL	Varies	CONSTANT-VOLUME
System - Supply Fan Ratios	SYSTEM:MIN-FLOW-RATIO SYSTEM:CMIN-FLOW-RATIO SYSTEM:HMIN-FLOW-RATIO SYSTEM:-MAX-FAN-RATIO	N/A	1
System - Supply Airflow	SYSTEM:SUPPLY-FLOW	Auto-sized	Hard-coded (after retrieving auto-sized outputs)
Economizer - Changeover Type	SYSTEM:OA-CONTROL	Fixed	Single Dry-Bulb
Economizer - Changeover Setpoint	SYSTEM-ECONO-LIMIT-T	Varies	ASHRAE 90.1-2013 – High-Limit Shutoff Control Settings: ASHRAE CLIMATE ZONE – 4A = 65°F ASHRAE CLIMATE ZONE – 5A = 70°F
Economizer - Integrated Operation	SYSTEM:ECONO-LOCKOUT	Yes	No

Further modifications were then made to these baseline models to simulate the following measure scenarios:

1. Demand-controlled ventilation (DCV) controls
2. DCV and supply fan variable frequency drive (VFD) with two fan speed modes
 - a. 40% fan speed for ventilating
 - b. 90% fan speed for heating and cooling
3. DCV and supply fan VFD with three fan speed modes
 - a. 40% fan speed for ventilating
 - b. 75% fan speed for 1st stage heating and cooling
 - c. 90% fan speed for 2nd and higher stage heating and cooling

The eQuest modifications from the baseline models to represent these measure scenarios are shown in the following table.

Table 3 – Baseline and Measure Scenario eQuest Keywords

Component Adjusted	eQuest Keyword	Baseline Value	Measure Scenario Values		
			1	2	3
System - Minimum Outside Air Control	SYSTEM:MIN-OA-METHOD	Fraction of Design Flow	DCV Return Sensor	DCV Return Sensor	DCV Return Sensor
System - Supply Airflow	SYSTEM:SUPPLY-FLOW	Hard-coded	1.0 × Hard-coded value	0.9 × Hard-coded value	0.9 × Hard-coded value
System - Supply Fan Control	SYSTEM:FAN-CONTROL	CONSTANT-VOLUME	CONSTANT-VOLUME	FAN-EIR-FPLR	FAN-EIR-FPLR
System - Supply Fan Ratios	SYSTEM:MIN-FLOW-RATIO	1	1	0.44*	0.44*
	SYSTEM:CMIN-FLOW-RATIO	1	1	1	0.83**
	SYSTEM:HMIN-FLOW-RATIO	1	1	1	0.83**
	SYSTEM:-MAX-FAN-RATIO	1	1	1	1

*Since the total supply flow is limited by 0.9 of the baseline, a value of 0.44 for the minimum flow ratio results in a 40% fan speed: $0.4/0.9=0.44$

** Since the total supply flow is limited by 0.9 of the baseline, a value of 0.83 for the minimum heating/cooling flow ratios results in a 75% fan speed: $0.75/0.9=0.83$

With these modifications in place each scenario was simulated in eQuest for each chosen building type across the three TRM climate zones. Whole building electric and gas savings were determined from the simulation output and are presented in the following sections. Electric savings have been normalized by cooling tons and heating savings by furnace kBtuh output.

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (\text{Capacity}_{\text{Cool}} \times \text{Normalized Electric Cooling Energy Savings}) + (\text{Capacity}_{\text{Heat}} \times \text{Normalized Electric Heating Energy Savings})$$

Where:

$\text{Capacity}_{\text{Cool}}$ = capacity of the cooling equipment in tons (nominal tonnage may be used).
= Actual

Normalized Electric Cooling Energy Savings

= kWh/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Electric Cooling Energy Savings Summary (kWh/ton)

Table 4 – Electric Cooling Energy Savings Summary (kWh/ton)

Building Type	Burlington			Des Moines			Mason City		
Measure Scenario: 1 - DCV 2 - DCV w/ 2-speed control 3 - DCV w/ 3-speed control									
	1	2	3	1	2	3	1	2	3
Grocery	12	281	556	12	283	561	5	274	536
Lodging	39	130	563	42	176	608	17	134	547
Multifamily	31	393	736	30	398	749	21	394	725
Office Low Rise	18	250	500	20	259	511	11	269	511
Restaurant	118	384	623	139	420	647	83	367	602
Retail Large	31	373	661	32	384	675	18	406	725
Retail Small	31	311	579	32	322	601	18	324	609

$Capacity_{Heat}$ = capacity of the heating equipment in tons (nominal tonnage may be used).

= Actual

Normalized Electric Heating Energy Savings

= kWh/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 5 – Electric Energy Heating Savings Summary (kWh/ton)⁵⁹⁶

⁵⁹⁶ Values for electric heat are based on converting the gas therm/kBtuh factors to electric kWh/ton factors factoring in the gas heating efficiencies used in the models and assuming a 2.3 COP heat pump.

Table 5 – Electric Heating Energy Savings Summary (kWh/ton)

Building Type	Burlington			Des Moines			Mason City		
Measure Scenario: 1 - DCV 2 - DCV w/ 2-speed control 3 - DCV w/ 3-speed control									
	1	2	3	1	2	3	1	2	3
Grocery	152	181	190	142	189	194	133	209	202
Lodging	364	461	577	361	506	612	399	631	721
Multifamily	104	174	216	93	191	227	88	236	249
Office Low Rise	93	120	154	85	135	163	80	166	180
Restaurant	734	855	914	702	846	896	630	828	863
Retail Large	185	246	273	170	267	290	159	323	325
Retail Small	1,251	1,158	1,265	1,169	1,100	1,204	1,126	1,081	1,177

For example, a 10-ton rooftop heat pump on an office low rise building in Des Moines installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$$\begin{aligned}
 \Delta \text{kWh} &= (\text{Capacity}_{\text{Cool}} \times \text{Normalized Electric Cooling Energy Savings}) + (\text{Capacity}_{\text{Heat}} \times \text{Normalized Electric Heating Energy Savings}) \\
 &= (10 \text{ tons} \times 259 \text{ kWh/ton}) + (10 \text{ tons} \times 135 \text{ kWh/ton}) \\
 &= 3,940 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL SAVINGS

$$\Delta \text{Therms} = (\text{kBtuh output}) \times \text{Normalized Gas Energy Savings}$$

Where:

kBtuh = heating output of the gas furnace in kBtuh
= Actual

Normalized Gas Energy Savings

= therms/kBtuh output savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 7 – Gas Energy Savings Summary (therms/kBtuh output)

Table 7 – Gas Energy Savings Summary (therms/kBtuh output)

Building Type	Burlington			Des Moines			Mason City		
Measure Scenario:									
1 - DCV									
2 - DCV w/ 2-speed control									
3 - DCV w/ 3-speed control									
	1	2	3	1	2	3	1	2	3
Grocery	0.84	0.79	0.81	0.87	0.83	0.85	0.99	0.94	0.95
Lodging	2.44	2.34	2.53	2.56	2.47	2.66	3.05	2.93	3.08
Multifamily	0.60	0.66	0.84	0.65	0.72	0.87	0.79	0.82	0.95
Office Low Rise	0.59	0.50	0.56	0.61	0.49	0.53	0.67	0.50	0.53
Restaurant	3.48	3.66	3.69	3.63	3.80	3.81	4.41	4.56	4.56
Retail Large	1.19	1.02	1.06	1.23	1.06	1.09	1.39	1.17	1.18
Retail Small	1.26	1.09	1.13	1.32	1.17	1.20	1.53	1.32	1.34

For example, a rooftop unit with a 148 kBtuh output gas furnace on an office low-rise building in Des Moines installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$$\begin{aligned} \Delta \text{Therms} &= (148 \text{ kBtuh}) \times (0.49 \text{ therms/kBtuh output}) \\ &= 72.5 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-ARTC-V01-270101

SUNSET DATE: 1/1/2028

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 ⁵⁹⁷	WHFd ⁵⁹⁸	CF ⁵⁹⁹	WHFh ⁶⁰⁰	IFTherm s Eff = 80%	IFkWh (resistance) COP = 1	IFkWh (heat pump) COP = 2.3	Model Source
General Agricultural Animal Housing and Warehousing	2,920	1.0	1.0	61.8%	0.000	0.000	0.000	0.000	eQuest
Agriculture – Chicken Broilers ⁶⁰¹	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

⁵⁹⁷ 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.

⁵⁹⁸ 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.

⁵⁹⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁶⁰⁰ 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.

⁶⁰¹ 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.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.4 Lighting End Use

Building Type	HOU	WHFe ⁵⁹⁷	WHFd ⁵⁹⁸	CF ⁵⁹⁹	WHFh ⁶⁰⁰	IFTherm s 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	4,630	1.19	1.33	89.5%	0.25	0.011	0.25	0.11	eQuest
Education	1,877	1.19	1.42	66.2%	0.15	0.007	0.15	0.07	OpenStudio
Exterior Lighting	4,676	1.0	1.0	0.0%	0.000	0.000	0.000	0.000	OpenStudio
Grocery	4,663	1.02	1.13	65.6%	0.26	0.011	0.26	0.11	OpenStudio
Health	3,806	1.06	1.56	63.4%	0.06	0.002	0.06	0.02	OpenStudio
Hospital	6,520	1.20	1.20	52.4%	0.07	0.003	0.07	0.03	OpenStudio
Industrial	2,850	1.06	1.04	82.1%	0.26	0.011	0.26	0.11	eQuest
Lodging	3,061	1.24	1.2	48.1%	0.13	0.006	0.13	0.06	OpenStudio
Multifamily	3,061	1.23	1.38	47.0%	0.35	0.015	0.35	0.15	OpenStudio
Office - Large	2,920	1.25	1.36	73.6%	0.05	0.002	0.05	0.02	OpenStudio
Office - Small	2,920	1.16	1.26	73.7%	0.25	0.011	0.25	0.11	OpenStudio
Religious	2,412	1.16	1.34	59.0%	0.32	0.014	0.32	0.14	eQuest
Restaurant	5,443	1.19	1.42	50.7%	0.23	0.010	0.23	0.10	OpenStudio
Retail - Large	4,065	1.06	1.06	67.5%	0.26	0.011	0.26	0.11	OpenStudio
Retail - Small	3,694	1.08	1.01	65.4%	0.32	0.014	0.32	0.14	OpenStudio
Stadium Lighting	300	1.0	1.0	0.00%	0.000	0.000	0.000	0.000	N/A
Warehouse	2,920	1.07	1.00	68.7%	0.37	0.016	0.37	0.16	OpenStudio
Nonresidential Average ⁶⁰²	3,065	1.13	1.19	66.6%	0.29	0.012	0.29	0.13	N/A
Unconditioned building	As above	1.0	1.0	As above	0.000	0.000	0.000	0.000	N/A
Refrigerated Cases ⁶⁰³	As above	1.29	1.29	As above	0.000	0.000	0.000	0.000	N/A
Freezer Cases ⁶⁰⁴	As above	1.50	1.50	As above	0.000	0.000	0.000	0.000	N/A

⁶⁰² For weighting factors, see HVAC variable table in section 3.3.

⁶⁰³ 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.

⁶⁰⁴ 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 (REMOVED 2025)

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 8.0 in which the measure was last active.

3.4.4. LED LAMP SPECIALTY (REMOVED 2025)

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 8.0 in which the measure was last active.

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.

To maximize production efficiency and consolidate inventory many LED fixture manufacturers are providing a number of pre-set lumen output options (and wattage) allowing the contractor to set the appropriate light attributes required at the time of installation. These Field Adjustable Lighting Output (FALO) fixtures contain switches that are not easily accessible once the fixture is installed so it is highly likely the selected setting will endure for the fixtures lifetime. Where possible, the actual setting should be used to evaluate savings, however where not possible assumptions are provided to adjust down the assumed LED wattage to account for participants not always using the maximum wattage setting.

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 STAR⁶⁰⁵ labeled or on the Design Light Consortium qualifying product list.⁶⁰⁶ 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 baseline 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 baseline 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.⁶⁰⁷

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)

⁶⁰⁵ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁶⁰⁶ DesignLights Consortium Qualified Products List.

⁶⁰⁷ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{Watts_{Base} - (Watts_{EE} * (1 - FALO))}{1,000} * Hours * WHFe * ISR$$

Where:

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. For Field Adjustable Lighting Output (FALO) products, use maximum wattage setting. If unknown, use default provided in “LED New and Baseline Assumptions”.

FALO = Adjustment for FALO products to account for settings lower than maximum wattage.
= Dependent on Fixture Type as provided below⁶⁰⁸:

Fixture Type	FALO
LED Linear Replacement Lamps	0.19
LED Troffers	0.18
LED Linear Ambient Fixtures	0.17
LED High Bay Fixtures	0.34
LED Low Bay Fixtures	0.24
LED Exterior Fixtures	0.34

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.⁶⁰⁹

Heating Penalty:

If electrically heated building:

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

Where:

⁶⁰⁸ Values are based on analysis done by Energy Futures Group in 2023; D. Mellinger, Energy Futures Group; “Accounting for Field-adjustable Lighting within Energy Efficiency Programs”, May 09 2023. The values are the average median setting between the maximum and minimum options provided. If programs could collect data on actual settings utilized, this assumption could be improved in the future.

⁶⁰⁹ Negotiated value during Iowa TRM Technical Advisory Committee call, 08/25/2015.

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts;⁶¹⁰ this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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 SAVINGS

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

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts;⁶¹¹ this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

HeatDays = Heat season days per year

= 190⁶¹²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁶¹⁰ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁶¹¹ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁶¹² Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

Reference Tables⁶¹³

LED Category	EE Measure		Baseline			Incremental Cost
	Description	Watt _{SEE}	Description	Watts _{BASE}	Base Cost	
LED Interior Directional	LED Track Lighting	12.2	10% CMH PAR38 & 90% Halogen PAR38	60.4	\$25	\$59
	LED Wall-Wash Fixtures	8.3	40% CFL 42W Pin Base & 60% Halogen PAR38	17.7	\$25	\$59
LED Display Case	LED Display Case Light Fixture	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$10/ft	\$11/ft
	LED Undercabinet Shelf-Mounted Task Light Fixtures	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$10/ft	\$11/ft
	LED Refrigerated Case Light, Horizontal or Vertical	4.0 / ft	5'T8	15.2 / ft	\$10/ft	\$11/ft
	LED Freezer Case Light, Horizontal or Vertical	4.0 / ft	6'T12HO	18.7 / ft	\$10/ft	\$11/ft
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	7.8	F17T8 Standard Lamp - 2 foot	15.0	\$5.00	\$12.75
			Existing less efficient LED (retrofit only)	9.5	N/A	N/A
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	13.9	F32T8 Standard Lamp - 4 foot	28.2	\$3.00	\$15
			Existing less efficient LED (retrofit only)	17.1	N/A	N/A

⁶¹³ Watt, lumen, and costs data assumptions for efficient measures are based upon Design Light Consortium Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. See "LED Lighting Systems TRM Reference Tables 2022 Iowa.xlsx" for more information and specific product links. In v11, a 14% improvement in efficacy was applied to all DLC fixture types to reflect expected outcome of new v6.0 rating (see [Transition to SSL V6.0 and LUNA V2.0 Requirements - DesignLights](#)). At time of update, insufficient product had been rated qualified under the new rating to provide a more fixture type specific update, which is planned to occur for v12. Retrofit only default baseline of an existing less efficient LED is provided for use when actual is not available and is based on assumptions take from DLC presentation "LED-to-LED Replacement", Dan Mellinger, February 5 2026, finding 105.5 lumens per watt efficacy for troffers, 105.4 lumens per watt for high-bay and 84.3 lumens per watt for outdoor fixtures.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline			Incremental Cost
	Description	Watt _{SEE}	Description	Watts _{BASE}	Base Cost	
	T8 LED Replacement Lamp (TLED), 2401-4000 lumens	20.1	F32T8/HO Standard Lamp - 4 foot	41.8	\$11.00	\$13.25
			Existing less efficient LED (retrofit only)	30.3	N/A	N/A
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	22.3	2-Lamp 32w T8 (BF < 0.89)	57.0	\$50	\$53
			Existing less efficient LED (retrofit only)	26.1	N/A	N/A
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	32.2	3-Lamp 32w T8 (BF < 0.88)	84.5	\$55	\$69
			Existing less efficient LED (retrofit only)	40.3	N/A	N/A
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	29.2	2-Lamp 32w T8 (BF < 0.89)	57.0	\$50	\$55
			Existing less efficient LED (retrofit only)	35.5	N/A	N/A
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	39.3	3-Lamp 32w T8 (BF < 0.88)	84.5	\$55	\$76
			Existing less efficient LED (retrofit only)	49.8	N/A	N/A
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50.2	4-Lamp 32w T8 (BF < 0.88)	112.6	\$60	\$104
			Existing less efficient LED (retrofit only)	64.0	N/A	N/A
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	18.8	1-Lamp 32w T8 (BF < 0.91)	29.1	\$50	\$22
			Existing less efficient LED (retrofit only)	21.3	N/A	N/A
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	29.6	2-Lamp 32w T8 (BF < 0.89)	57.0	\$55	\$75
			Existing less efficient LED (retrofit only)	35.5	N/A	N/A

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline			Incremental Cost
	Description	Watt _{SEE}	Description	Watts _{BASE}	Base Cost	
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	38.0	3-Lamp 32w T8 (BF < 0.88)	84.5	\$60	\$83
			Existing less efficient LED (retrofit only)	49.8	N/A	N/A
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	17.1	1-Lamp 32w T8 (BF < 0.91)	29.1	\$50	\$10
			Existing less efficient LED (retrofit only)	23.7	N/A	N/A
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	28.2	2-Lamp 32w T8 (BF < 0.89)	57.0	\$55	\$52
			Existing less efficient LED (retrofit only)	35.5	N/A	N/A
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	38.2	3-Lamp 32w T8 (BF < 0.88)	84.5	\$60	\$78
			Existing less efficient LED (retrofit only)	49.8	N/A	N/A
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	49.4	T5HO 2L-F54T5HO - 4'	120.0	\$65	\$131
			Existing less efficient LED (retrofit only)	64.0	N/A	N/A
	LED Surface & Suspended Linear Fixture, >7500 lumens	72.6	T5HO 3L-F54T5HO - 4'	180.0	\$70	\$173
			Existing less efficient LED (retrofit only)	85.3	N/A	N/A
LED High & Low Bay Fixtures	LED Low-Bay or High-Bay Fixtures, ≤ 10,000 lumens	54.0	3-Lamp T8HO Low-Bay	157.0	\$75	\$44
			Existing less efficient LED	75.9	N/A	N/A

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline				Incremental Cost
	Description	Watt _{SEE}	Description	Watts _{BASE}	Base Cost		
			(retrofit only)				
	LED High-Bay Fixtures, 10,001-15,000 lumens	87.3	4-Lamp T8HO High-Bay	196.0	\$100		\$137
			Existing less efficient LED (retrofit only)	118.6	N/A		N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	123.0	6-Lamp T8HO High-Bay	294.0	\$125		\$202
			Existing less efficient LED (retrofit only)	166.0	N/A		N/A
	LED High-Bay Fixtures, 20,000 – 30,000 lumens	170.0	8-Lamp T8HO High-Bay	392.0	\$150		\$264
			Existing less efficient LED (retrofit only)	237.2	N/A		N/A
	LED High-Bay Fixtures, 30,001-40,000 lumens	219.3	750 Watts Metal Halide	850			\$400
			Existing less efficient LED (retrofit only)	332.1	N/A		N/A
	LED High-Bay Fixtures 40,001-50,000 lumens	258.8	1000 Watts Metal Halide	1080			\$425
			Existing less efficient LED (retrofit only)	426.9	N/A		N/A
	LED High-Bay Fixtures >50,000 lumens	381.6	1500 Watts Metal Halide	1610			\$500
			Existing less efficient LED (retrofit only)	569.3	N/A		N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	11.3	25% 73 Watt EISA Inc, 75% 1L T8	42.0	\$20		\$18
			Existing less efficient LED (retrofit only)	14.2	N/A		N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	25.0	25% 146 Watt EISA Inc, 75% 2L T8	81.0	\$40		\$48
			Existing less	28.4	N/A		N/A

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline				Incremental Cost
	Description	Watt _{SEE}	Description	Watts _{BASE}	Base Cost		
			efficient LED (retrofit only)				
	LED Ag Interior Fixtures, 4,001-6,000 lumens	39.6	25% 217 Watt EISA Inc, 75% 3L T8	121.0	\$60		\$57
			Existing less efficient LED (retrofit only)	47.4	N/A		N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	52.4	25% 292 Watt EISA Inc, 75% 4L T8	159.0	\$80		\$88
			Existing less efficient LED (retrofit only)	66.4	N/A		N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	74.5	200W Pulse Start Metal Halide	227.3	\$120		\$168
			Existing less efficient LED (retrofit only)	94.8	N/A		N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	99.9	320W Pulse Start Metal Halide	363.6	\$160		\$151
			Existing less efficient LED (retrofit only)	132.7	N/A		N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	126.1	350W Pulse Start Metal Halide	397.7	\$200		\$205
			Existing less efficient LED (retrofit only)	170.6	N/A		N/A
	LED Ag Interior Fixtures, > 20,000 lumens	170.0	(2) 320W Pulse Start Metal Halide	727.3	\$240		\$356
			Existing less efficient LED (retrofit only)	237.0	N/A		N/A
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	24.1	100W Metal Halide	113.6	\$60		\$97
			Existing less efficient LED (retrofit only)	47.4	N/A		N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	50.5	175W Pulse Start Metal Halide	198.9	\$90		\$124
			Existing less efficient LED	89.0	N/A		N/A

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline			Incremental Cost
	Description	Watt SEE	Description	Watts _{BASE}	Base Cost	
			(retrofit only)			
	LED Exterior Fixtures, 10,001-15,000 lumens	83.2	250W Pulse Start Metal Halide	284.1	\$120	\$134
			Existing less efficient LED (retrofit only)	148.3	N/A	N/A
	LED Exterior Fixtures, 15,000 – 30,000 lumens	141.5	400W Pulse Start Metal Halide	454.5	\$150	\$196
			Existing less efficient LED (retrofit only)	266.9	N/A	N/A
	LED Exterior Fixtures, 30,001-40,000 lumens	222.7	750 W Metal Halide	850		\$238
			Existing less efficient LED (retrofit only)	415.2	N/A	N/A
	LED Exterior Fixtures, 40,001-50,000 lumens	280.4	1000 W Metal Halide	1,080		\$319
			Existing less efficient LED (retrofit only)	533.8	N/A	N/A
	LED Exterior Fixtures, > 50,000 lumens	513.9	1500 W Metal Halide	1,610		\$1,095
			Existing less efficient LED (retrofit only)	771.1	N/A	N/A
Stadium Lighting	LED Stadium Light Fixtures, 50,001-100,000 lumens	700	1000 W Metal Halide	1,080		Custom
	LED Stadium Light Fixtures, 100,001-150,000 lumens	1,050	1500 W Metal Halide	1,610		Custom
	LED Stadium Light Fixtures, > 150,000 lumens	1,400	2000 W Metal Halide	2,140		Custom

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED 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

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED 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
	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 &	50,000	\$93.22	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	Suspended Linear Fixture, 3001-4500 lumens								
	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 – 30,000 lumens	50,000	\$297.87	70,000	\$62.50	18,000	\$172.00	40,000	\$142.50
	LED High-Bay Fixtures, 20,001 – 30,000 lumens	50,000	\$228.52	70,000	\$62.50	18,000	\$172.00	40,000	\$142.50
	LED High-Bay Fixtures, 30,001-40,000 lumens	50,000	\$294.00	70,000	\$62.50	15,000	\$82.00	40,000	\$143.00
	LED High-Bay Fixtures, 40,001-50,000 lumens	50,000	\$324.00	70,000	\$62.50	15,000	\$88.00	40,000	\$149.00
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 Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	\$124.89	70,000	\$62.50	15,000	\$63.00	40,000	\$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	\$214.95	70,000	\$62.50	15,000	\$68.00	40,000	\$122.50
	LED Exterior Fixtures, 15,000-30,000 lumens	50,000	\$321.06	70,000	\$62.50	15,000	\$73.00	40,000	\$132.50
	LED Exterior Fixtures, 30,001-40,000 lumens	50,000	\$546.00	70,000	\$62.50	15,000	\$82.00	40,000	\$143.00
	LED Exterior Fixtures, 40,001-50,000 lumens	50,000	\$722.00	70,000	\$62.50	15,000	\$88.00	40,000	\$149.00
	LED Exterior Fixtures, > 50,000 lumens	50,000	\$870.00	70,000	\$62.50	15,000	\$96.00	40,000	\$200.00
Stadium Lighting	LED Stadium Light Fixtures, 50,001-100,000 lumens	50,000	\$870.00	70,000	\$62.50	15,000	\$96.00	40,000	\$200.00
	LED Stadium Light Fixtures, 100,001-150,000 lumens	50,000	\$1,300.00	70,000	\$62.50	15,000	\$150.00	40,000	\$225.00
	LED Stadium Light Fixtures, > 150,000 lumens	50,000	\$1,600.00	70,000	\$62.50	15,000	\$200.00	40,000	\$250.00

MEASURE CODE: NR-LTG-LDFX-V10-270101

SUNSET DATE: 1/1/2028

3.4.6. T5 HO FIXTURES AND LAMP/BALLAST SYSTEMS (REMOVED 2025)

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 8.0 in which the measure was last active.

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**DESCRIPTION**

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.⁶¹⁴ 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.⁶¹⁵

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.⁶¹⁶

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 \$32.50.⁶¹⁷

LOADSHAPE

Loadshape E01 – Flat

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS ⁶¹⁸**

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

⁶¹⁴ ENERGY STAR “Save Energy, Money and Prevent Pollution with LED Exit Signs”

⁶¹⁵ 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.

⁶¹⁶ GDA Associates Inc. “Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures”, June 2007.

⁶¹⁷ 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.

⁶¹⁸ 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 ⁶¹⁹	CFL (dual sided)	14W ⁶²⁰
	CFL (single sided)	7W

Watts_{EE} = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W⁶²¹

Hours = Annual operating hours
= 8760

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

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned}\Delta kWh &= ((14 - 4) / 1,000) * 8,760 * 1.13 \\ &= 99.0 kWh\end{aligned}$$

Heating Penalty

If electrically heated building:⁶²²

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

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned}\Delta kWh_{heatpenalty} &= ((14 - 4) / 1,000) * 8,760 * (-0.29) \\ &= -25.4 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

⁶¹⁹ Federal Standards effectively ended the manufacturing of incandescent exit signs in 2006 and therefore in unknown instances it should be assumed existing exit signs use CFL lamps since the lifetime of any remaining incandescent exit signs would to have expired per the 13 year measure assigned to this measure.

⁶²⁰ Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

⁶²¹ Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages.

⁶²¹ Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

⁶²² Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

CF = Summer Peak Coincidence Factor for this measure
= 100%⁶²³

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned}\Delta kW &= ((14 - 4) / 1,000) * 1.19 * 1.00 \\ &= 0.0119 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Heating Penalty if fossil fuel heated building (or if heating is unknown):⁶²⁴

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

$$\begin{aligned}\Delta Therms &= ((14 - 4) / 1,000) * 8,760 * (-0.012) \\ &= -1.0512 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above
 $HeatDays$ = Heat season days per year
= 190⁶²⁵

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

$$\begin{aligned}\Delta PeakTherms &= -1.0519 / 190 \\ &= -0.0055 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁶²³ Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

⁶²⁴ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁶²⁵ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

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	\$13.00 ⁶²⁶	0.57 years ⁶²⁷

MEASURE CODE: NR-LTG-EXIT-V06-250101

SUNSET DATE: 1/1/2030

⁶²⁶ Consistent with assumption as listed by the U.S. Department of Energy, ENERGY STAR Life Cycle Cost Exit-Sign Calculator for estimated labor cost of \$10 (assuming \$40/hour and a task time of 15 minutes). Replacement of a CFL bulb is assumed to be \$3 as noted by regional IA program details (IPL Business Assessment).

⁶²⁷ 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

DESCRIPTION

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.⁶²⁸

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.⁶²⁹

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 characteristics⁶³⁰ 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.⁶³¹

DEEMED MEASURE COST ⁶³²

Actual measure installation cost should be used (including material and labor).⁶³³ Use actual costs of LED unit when know. If unknown use the default values/luminaire provided below:

⁶²⁸ 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

⁶²⁹ 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.

⁶³⁰ See DOE Municipal Solid-State Street Lighting Consortium “Model specifications for LED roadway luminaires v.2.0”

⁶³¹ 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.

⁶³² 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).

⁶³³ Labor should include the removal of the old fixture and installation of the new fixture. IA DOT prevailing wage should be assumed.

Fixture Type	Light Output					
	Low (<50W)		Med (50W-100W)		High (>100W)	
	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 SAVINGS⁶³⁴

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following nominal wattage based on technology.

Metal Halide = 250W⁶³⁵

Mercury Vapor = 175W⁶³⁶

High Pressure Sodium = 170W⁶³⁷

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁶³⁸

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

CF = Summer Peak Coincidence Factor for this measure
=0%

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

⁶³⁴ There is no ISR calculation. Savings are per unit.

⁶³⁵ 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)

⁶³⁶ Based on averaging Mercury Vapor information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (175W)

⁶³⁷ Based on averaging High Pressure Sodium information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (50, 70, 100, 150, 250, 400).

⁶³⁸ 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.⁶³⁹

MEASURE CODE: NR-LTG-STLT-V01-190101

SUNSET DATE: 1/1/2030

⁶³⁹ Based upon NEEPs report and quantitative analysis of LED street light conversions in the Northeast and Mid-Atlantic region. municipal luminaires evaluated by “LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic”, January 2015.

3.4.11. LED TRAFFIC AND PEDESTRIAN SIGNALS (REMOVED 2021)

This measure was archived since the federal code has required LEDs for all traffic and pedestrian modules manufactured since January 2006. No utility is continuing to offering this measure as a retrofit. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 5.0 Volume 3: Nonresidential Measures; Final: July 15, 2020; Effective January 1, 2021 in which the measure was last active.

3.4.12. LIGHTING CONTROLS

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels by turning lights on or off in response to the presence (or absence) of people in a defined area. Associated energy savings depends on the building type, location area covered, type of lighting and activity, and occupancy pattern.

Daylight sensor lighting controls are devices that reduce lumen output levels in response to the amount of daylight available in an area. Such systems save energy by either shutting off lights completely or dimming when there is adequate natural light available.

High end trim refers to the setting of a maximum lumen output for fixtures within a zone to reduce demand below the full rated fixture wattage.

According to the DLC Networked Lighting Control systems are defined "as the combination of sensors, network interfaces, and controllers that effect lighting changes in luminaires, retrofit kits or lamps".⁶⁴⁰ This does not include the luminaires themselves. "Luminaires, retrofit kits and lamps are qualified separately".

Luminaire Level Lighting Controls (LLLCs) have individual sensors and control logic on each fixture allowing further refinement and savings opportunities.

This measure relates to the installation of interior occupancy sensors, daylighting or high-end trim controls on an existing lighting system (not replacement). Lighting control types covered by this measure include switch-mounted, remote-mounted, fixture-mounted, integrated in addition to more sophisticated networked lighting capabilities⁶⁴¹. Daylight sensors covered by this measure include "on or off", stepped dimming systems, such as dual ballast (high/low HID⁶⁴² or inboard/outboard), and continuous dimming systems based on light levels from available daylight.

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

DEFINITION OF EFFICIENT EQUIPMENT

It is assumed that this measure characterization applies to only those lighting controls that regulate a minimum average wattage greater than 45W per control for switch, fixture and remote mounted occupancy sensors, and 20W for integrated sensors. If applicable, it must be accompanied by a daylight harvesting ballast system that meets current CEE specifications at full light output.⁶⁴³ This measure includes both hard-wired and wireless controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with neither occupancy controls nor daylight control sensor. Also, lighting is operated at normal powers levels and controlled with a manual switch.

Note that in new construction or in areas receiving major rehab (additions, alterations renovations, or repairs), occupancy sensors are required by IECC 2012 (section C405.2.2.2) to be installed in the following locations; classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 ft² or less enclosed by floor to ceiling height partitions. Savings should

⁶⁴⁰Design Lights Consortium (DLC) "Networked Lighting Control System Technical Requirements", Version NLC5, updated June 23, 2023, pg. 3.

⁶⁴¹ While the DLC accepts exterior NLC systems, these systems are not addressed comprehensively at present as per NLC5 Technical Requirements.

⁶⁴² 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.

⁶⁴³ Visit Commercial Lighting Qualifying Products List on the CEE Library.

therefore not be claimed for occupancy sensors installed in these instances.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for Luminaire-level lighting controls (LLCs)/Networked Lighting Controls (NLC) is assumed to be 15 years, consistent with the average expected lifetime of the fixture. The expected measure life for all lighting controls is assumed to be 10 years.⁶⁴⁴

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

Lighting Control Type	Cost ⁶⁴⁵
Switch-Mounted (Wall) Occupancy Sensor	\$54
Fixture-Mounted Occupancy Sensor	\$67
Remote-Mounted (Ceiling) Occupancy Sensor	\$105
Fixture-Mounted Daylight Sensor	\$50
Remote-Mounted Daylight Sensor	\$65
Integrated Occupancy Sensor	\$40
Integrated Dual Occupancy & Daylight Sensor	\$50
Fixture-Mounted Dual Occupancy & Daylight Sensor	\$100
Remote-Mounted Dual Occupancy & Daylight Sensor	\$125
Luminaire-Level Lighting Controls	\$56
Interior Networked Lighting Controls <10,000 sqft building	\$0.86 per ft ²
Interior Networked Lighting Controls 10,000-100,000 sqft building	\$0.59 per ft ²
Interior Networked Lighting Controls >100,000 sqft building	\$0.40 per ft ²
High End Trim	\$0.06 per ft ²
Exterior Networked Lighting Controls	Use actual

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS ⁶⁴⁶

⁶⁴⁴ Based on research in Illinois, conducted by Guidehouse, interviewing 46 contractors, reported in 'ComEd Retrofit Add-On EUL Results Memo. January 27, 2020.

⁶⁴⁵ Based on averaging typical prices quoted by online vendors. See 'Lighting Control Analysis_2020.xlsx'; "Cost" Sheet for more information. Cost assumption for Luminaire Level Lighting Controls is based on the average of 'clever' and 'clever-hybrid' LLC incremental costs, including a per fixture contribution to the necessary gateway, servers and installation labor from Kisch et al, "2020 Luminaire Level Lighting Controls Incremental Cost Study", Energy Solutions on behalf of NEEA, January 2021. Cost assumptions for Interior Networked Lighting Controls is based on the average of "office", "warehouse", and "retail" by building size from Schwartz et al., "The Value Proposition for Cost-Effective, Demand Responsive-Enabling Nonresidential Lighting System Retrofits in California Buildings", Lawrence Berkeley National Laboratory and Energy Solutions prepared for California Energy Commission, April 2019. This includes both material and labor cost estimates.

⁶⁴⁶ It is assumed an ISR of 100%.

$$\Delta kWh = kW_{Controlled} * Hours * (ESF_{EE} - ESF_{Base}) * WHFe$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. The total connected load per control should be collected from the customer if possible, particularly for networked lighting controls where variance can be significant. Default values are presented below.

Lighting Control Type	Default kW controlled ⁶⁴⁷	Per
Switch (Wall) Mounted Occupancy Sensor	0.254	Control
Fixture-Mounted Occupancy Sensor	0.264	Fixture
Remote (Ceiling) Mounted Occupancy Sensor	0.413	Control
Fixture-Mounted Daylight Sensor	0.095	Fixture
Remote-Mounted Daylight Sensor	0.239	Control
Integrated Occupancy Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Integrated Occupancy Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Remote-Mounted Dual Occupancy & Daylight Sensor	0.239	Control
Luminaire-Level Lighting Controls < 10,000 Lumens	0.031	Fixture
Luminaire-Level Lighting Controls ≥ 10,000 Lumens	0.118	Fixture
Interior Networked Lighting Controls	0.00061	ft ² space controlled
Exterior Networked Lighting Controls	Custom	Use Actual

Hours = The total annual operating hours of lighting for each type of building before lighting controls. This number should be collected from the customer. If no data is available, the deemed average number of operating hours, by building type, should be used, as provided by Lighting Reference Table in Section 3.4. If building type is unknown, use the Nonresidential Average value.

ESF_{EE} = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis where possible or using a default energy saving factor presented below:

⁶⁴⁷ Occupancy Sensor controlled kw is based on Alliant Data from program years 2018-2019. Removed 2 outlying data points as well as the Agricultural sector. See 'Lighting Control Analysis_2020.xlsx'; "Wattage_Alliant Data" sheet for details on calculations. For the raw data, please see file 'Alliant Data_Occ Sensors and Daylighting Controls 2018-2019.xlsx'. Integrated Dual and Daylight Sensors controlled kw is based on Efficiency Vermont data from program year 2017 for lighting controls. See 'Lighting Control Analysis_2020.xlsx'; "Wattage_EVT Data" sheet for details on calculations.

Lighting Control Type	Energy Savings Factor ⁶⁴⁸
Occupancy Sensor (Switch, Wall, Fixture or Remote Mounted or Integrated in Fixture)	24% 37% with High End Trim
Daylight Sensor (Wall, Fixture or Remote Mounted)	28% 41% with High End Trim
Dual Occupancy & Daylight Sensor without verified daylighting savings (Integrated of Fixture Mounted)	24% 37% with High End Trim
Dual Occupancy & Daylight Sensor with verified daylighting savings (Integrated of Fixture Mounted)	38% 51% with High End Trim ⁶⁴⁹
Interior Networked Luminaire-Level Lighting Controls	61% ⁶⁵⁰
Interior Networked Lighting Controls Only with No LLLCs	35%
Interior Networked Lighting Controls (unknown or mixed LLLCs)	49%
Exterior Networked Lighting Controls	48% ⁶⁵¹

ESF_{Base} = Energy Savings Factor of the lighting controls that existed before the new lighting controls were installed. If no prior lighting controls or unknown, assume 0.

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 3.4.

Heating Penalty:

If electrically heated building:⁶⁵²

$$\Delta kWh_{heatpenalty} = kW_{Controlled} * Hours * (ESF_{EE} - ESF_{Base}) * (-IFkWh)$$

Where:

$IFkWh$ = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the

⁶⁴⁸ Interior controls % savings based except where noted on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. ESF for Vacancy Sensors is based on Papamichael, Konstantions, Bi-Level Switching in Office Spaces, California Lighting Technology Center, February 1,2010. See Figure 8 on page 10 for relevant study results. The study shows a 30% extra savings above a typical occupancy sensor; 24% * 1.3 = 31%.

ESF for Luminaire Level Lighting Controls, Networked Lighting Controls and the 13% High End Trim adder are based upon the weighted average of results from:

- Pacific Northwest National Laboratory, "Evaluation of Advanced Lighting Control Systems in a Working Office Environment", November 2018.
- Schuetter et al., "Cree SmartCast Lighting Retrofit Demonstration: LED Fixtures and Controls for Advanced Holistic Lighting Solutions", September 2020 (expected).
- DesignLights Consortium and NEEA, "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC" Energy Solutions, September 2020. LLLC ESF used in weighted average is the average of all 98 sites with NLCs w/LLLC. NLC ESF is the average of all 194 buildings. High-end trim adder used for other lighting control types is based on the results for the 96 sites w NLCs w/o LLLC and using the "Other Control Strategies" savings where the baseline had influences from high-end trim removed.

⁶⁴⁹ The ESF_{EE} for interior dual occupancy & daylight sensor with high-end trim is estimated to be higher than the interior networked lighting control ESF_{EE} since this measure requires that the sensors be integrated or fixture mounted which has been documented to lead to higher savings than zone or wall sensors. The NLC measure is not specific to fixture, zone, or wall sensors.

⁶⁵⁰ The ESF_{EE} for LLLC is not separated out based on the inclusion of high-end trim since the DesignLights Consortium Technical Requirements Version NLC5 (1/25/21) requires that high-end trim is included for all interior networked lighting controls including LLLC.

⁶⁵¹ Energy Savings Forecast of SolidState Lighting in General Illumination Application, Table F.4 "Energy Savings for each Control Type by Application", Application = Building Exterior, DOE, 2019, pg. 112.

⁶⁵² Negative value because this is an increase in heating consumption due to the efficient lighting.

increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table 3.4.

For example, for a Switch (Wall) Mounted Occupancy Sensor:

$$\begin{aligned}\Delta kWh &= 0.254 * 3,065 * 0.24 * 1.13 \\ &= 211.1 kWh\end{aligned}$$

For a switch (wall) mounted occupancy sensor installed in a building with electric resistance heating, the electric heating penalty is:

$$\begin{aligned}\Delta kWh_{\text{heatpenalty}} &= 0.254 * 3,065 * 0.24 * (-0.29) \\ &= -54.2 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kW_{\text{Controlled}} * WHF_d * (CF_{\text{baseline}} - CF_{LC})$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4

CF_{baseline} = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

CF_{LC} = Summer Peak Coincidence Factor the lighting system with Lighting Controls installed is 15% regardless of building type.⁶⁵³

For controls on exterior fixtures $\Delta kW = 0$

For example, for a Switch (Wall) Mounted Occupancy Sensor:

$$\begin{aligned}\Delta kW &= 0.254 * 1.19 * (0.666 - 0.15) \\ &= 0.156 kW\end{aligned}$$

NATURAL GAS SAVINGS

If gas heated building (or unknown):

$$\Delta Therms = kW_{\text{Controlled}} * Hours * (ESF_{EE} - ESF_{Base}) * -IF_{Therms}$$

Where:

IF_{Therms} = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the Lighting Reference Table in Section 3.4 by building type.

For example, for a Fixture-Mounted Daylight Sensor installed in a gas heated building:

$$\begin{aligned}\Delta Therms &= 0.095 * 3,065 * 0.28 * (-0.012) \\ &= -0.98 Therms\end{aligned}$$

PEAK GAS SAVINGS

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

⁶⁵³ 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.

is therefore assumed to be:

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

Where:

$\Delta Therms$ = Therm impact calculated above

Heatdays = Heat season days per year

= 190⁶⁵⁴

For example, for a Switch (Wall) Mounted Occupancy Sensor installed in a gas heated building:

$\Delta PeakTherms$ = -0.98/190

= -0.00516 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-LICO-V04-250101

SUNSET DATE: 1/1/2027

⁶⁵⁴ Number of days where HDD 55 >0. Calculated from NCDC 15-yr U.S. Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown.

3.4.13. DAYLIGHTING CONTROL (REMOVED 2020)

Measure consolidated with 3.4.12 in version 5.0.

3.4.14. MULTI-LEVEL LIGHTING SWITCH**DESCRIPTION**

Multi-level switching allows some of the electric lighting in a space to be switched off while maintaining a reasonably uniform distribution of light suitable for work. Multi-level switching typically use two or more separate light circuits each of which is controlled by a different switch. These circuits can be arranged in one of three ways:

- 1) Switching alternate lamps in each luminaire
- 2) Switching alternate luminaires
- 3) Switching alternate rows of luminaires

Multi-level switching is used in addition to the usual separation of lighting circuits into different functional areas and saves energy by allowing lamps to remain off when sufficient daylight is present, and by offering occupants the ability to have lower light levels for work. Additional energy can be saved by combining multi-level switching with occupancy sensors or photo-sensor controls.

Multi-level switching is required in the Commercial new construction building energy code (IECC 2012 onward).⁶⁵⁵ 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.⁶⁵⁶

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 \$274.⁶⁵⁷

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS ⁶⁵⁸**

⁶⁵⁵ ASHRAE 90.1-2010, IECC 2012 Lutron “Code Compliance, Commercial Application Guide”. ASHRAE 90.1 2022 further specifies multilevel lighting control guidelines.

⁶⁵⁶ GDS Associates, Measure Life Report “Residential and Commercial/Industrial Lighting and HVAC Measures June, 2007

⁶⁵⁷ 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.

⁶⁵⁸ Assume ISR is 100%.

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$KW_{Controlled}$	= Total lighting load connected to the control in kilowatts. The total connected load should be collected from the customer = Actual.
Hours	= The total annual operating hours of lighting for each type of building before occupancy sensors. This number should be collected from the customer. If no data is available the deemed average number of operating hours by building type should be used as provided in Lighting Reference Table in Section 3.4. If unknown building type, use the Nonresidential Average value.
ESF	= Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Use the default value of 31%. ⁶⁵⁹
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:⁶⁶⁰

$$\Delta kWh_{heatpenalty} = KW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

$IFkWh$	= Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.
---------	--

For example, for multi-level lighting switches controlling a 0.200 kW connected load:

$$\begin{aligned} \Delta kWh &= 0.200 * 3,065 * 0.31 * 1.13 \\ &= 214.7 \text{ kWh} \end{aligned}$$

For multi-level lighting switches controlling a 0.200 kW connected load and installed in a building with electric resistance heating, the electric heating penalty is:

$$\begin{aligned} \Delta kWh_{heatingpenalty} &= 0.200 * 3,065 * 0.31 * (-0.29) \\ &= -55.1 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

Where:

WHF_d	= Waste Heat Factor for Demand to account for cooling savings from efficient lighting in
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⁶⁵⁹ Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Page & Associates Inc. 2011.

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.

⁶⁶⁰Negative value because this is an increase in heating consumption due to the efficient lighting.

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.⁶⁶¹ See Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

For example, for multi-level lighting switches controlling a 0.200 kW connected load:

$$\begin{aligned}\Delta kW &= 0.200 * 0.31 * 1.19 * 0.666 \\ &= 0.049 \text{ kW}\end{aligned}$$

NATURAL GAS 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:

$$\begin{aligned}\Delta Therms &= 0.200 * 3,065 * 0.31 * (-0.012) \\ &= -2.3 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

HeatDays = Heat season days per year

$$= 190^{662}$$

⁶⁶¹ 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.

⁶⁶² Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

For example, for multi-level lighting switches controlling a 0.200 kW connected load and installed in a gas heated building:

$$\begin{aligned}\Delta\text{PeakTherms} &= -2.3/190 \\ &= -0.012 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-MLLS-V04-240101

SUNSET DATE: 1/1/2021*

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

3.5. Miscellaneous

3.5.1. VARIABLE FREQUENCY DRIVES FOR PROCESS

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on fans and centrifugal pump motors in process applications. This characterization does not apply to positive displacement pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a motor 1-100 HP that does not have a VFD. The application must have a variable load, and installation is to include the necessary controls as determined by a qualified engineer. Savings are based on application of VFDs to a range of baseline load conditions including no control, inlet guide vanes, and outlet guide vanes.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. The retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.⁶⁶³

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD fan or centrifugal pump for a process application is 15 years.⁶⁶⁴

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.⁶⁶⁵

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

⁶⁶³ 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".

⁶⁶⁴ "NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013."

⁶⁶⁵ 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
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 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 Factor⁶⁶⁶
= 0.19 kWh/hp for process fans
= 0.26 kWh/hp for process centrifugal pumps

For example, a 50-horsepower VFD operating for 2,386 hours annually driving a process fan would save:

$$\begin{aligned}\Delta kWh &= 50 * 2,386 * 0.19 \\ &= 22,667 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁶⁶⁷

$$\Delta kW = HP * DSF$$

Where:

- HP = Nominal horsepower of controlled motor
- DSF = Summer Coincident Peak Demand Savings Factor⁶⁶⁸
= 0.16 kW/hp for process fans
= 0.26 kW/hp for process centrifugal pumps

⁶⁶⁶ Energy savings factors derived from analysis of 16 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'.

⁶⁶⁷ 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.

⁶⁶⁸ Demand savings factors derived from analysis of 14 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'.

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-V04-250101

SUNSET DATE: 1/1/2030

3.5.2. CLOTHES WASHER

DESCRIPTION

This measure relates to the installation of a commercial grade clothes washer meeting the ENERGY STAR⁶⁶⁹ 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 program⁶⁷⁰.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial grade clothes washer meeting the minimum federal baseline as of January 2018.⁶⁷¹

Efficiency Level		Top Loading	Front Loading
Baseline	Federal Standard	$\geq 1.35 \text{ MEF}_{J2}$, $\leq 8.8 \text{ IWF}$	$\geq 2.00 \text{ MEF}_{J2}$, $\leq 4.1 \text{ IWF}$
Efficient	ENERGY STAR	$\geq 2.2 \text{ MEF}_{J2}$, $\leq 4.0 \text{ IWF}$	

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."*⁶⁷²

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years.⁶⁷³

DEEMED MEASURE COST

The incremental cost is assumed to be \$190.⁶⁷⁴

LOADSHAPE

⁶⁶⁹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁶⁷⁰ Current ENERGY STAR Specification V8.1 active 4/22/21; no changes to efficiency requirements since v8.0. They have just included more product types.

⁶⁷¹ See Federal Standard 10 CFR 431.156.

⁶⁷² Definitions provided on the ENERGY STAR website.

⁶⁷³ Appliance Magazine, January 2011 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

⁶⁷⁴ Based on Industry Data 2015 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

Loadshape RE14 – Residential Clothes Washer⁶⁷⁵

Loadshape G01 – Flat (gas)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Capacity = Clothes Washer capacity (cubic feet)
= Actual, if capacity is unknown, assume 3.7 cubic feet⁶⁷⁶

MEFbase = Modified Energy Factor of baseline unit

Efficiency Level	MEFbase		
	Top Loading	Front Loading	Weighted Average ⁶⁷⁷
Federal Standard	1.35	2.0	1.36

MEFeff = Modified Energy Factor of efficient unit
= Actual, if unknown, assume average values provided below.

Efficiency Level	MEFeff ⁶⁷⁸		
	Top Loading	Front Loading	Weighted Average
ENERGY STAR	2.2		

Ncycles = Number of Cycles per year
= 2,190⁶⁷⁹

%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

⁶⁷⁵ The Residential Clothes Washer loadshape is considered a reasonable proxy for commercial applications – in the absence of any other empirical basis.

⁶⁷⁶ Based on the average clothes washer volume of all units on the ENERGY STAR QPL (accessed March 2025).

⁶⁷⁷ Weighted average MEF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR commercial product in the CCMS database (accessed March 2025).

⁶⁷⁸ ENERGY STAR Program Requirements Product Specifications for Clothes Washers, v8.0, effective February 5, 2018. Modified Energy Factor for commercial clothes washer.

⁶⁷⁹ Based on DOE Technical Support Document, 2009; Chapter 8 Life-Cycle Cost and Payback Period Analysis, pg. 8-15.

efficient unit – see table below)

	Percentage of Total Energy Consumption ⁶⁸⁰		
	%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:⁶⁸¹

Efficiency Level	ΔkWh			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	2,274.9	1,171.6	1,376.8	273.4

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

= 1,643 hours⁶⁸²

CF = Summer Peak Coincidence Factor for measure

= 50%⁶⁸³

⁶⁸⁰ 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).

⁶⁸¹ 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.

⁶⁸² Assuming an average load runs for an estimated 45 minutes.

⁶⁸³ 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	0.6923	0.3565	0.4190	0.0832

NATURAL GAS SAVINGS

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

Where:

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

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

R_{eff} = Recovery efficiency factor

$$= 1.26^{684}$$

$\%Gas_{Dryer}$ = 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	$\Delta Therms$			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	47.4	30.6	78.1

PEAK GAS SAVINGS

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

⁶⁸⁴ To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency. Therefore a factor of 0.98/0.78 (1.26) is applied.

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

Where:

$\Delta Therms$ = Therm impact calculated above

Days = Days per year

= 365

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

Efficiency Level	$\Delta PeakTherms$			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.000	0.130	0.084	0.214

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water (gallons) = Capacity * (IWF_{base} - IWF_{eff}) * N_{cycles}$$

Where:

IWF_{base} = Water Factor of baseline clothes washer

Efficiency Level	IWF_{base}		
	Top loading	Front Loading	Weighted Average ⁶⁸⁵
Federal Standard	8.8	4.1	8.71

IWF_{eff} = Water Factor of efficient clothes washer

= Actual - If unknown assume 4.5

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

Efficiency Level	$\Delta Water$ (gallons per year)
	Weighted Average
ENERGY STAR	34,081

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-CLWA-V03-260101

SUNSET DATE: 1/1/2030

⁶⁸⁵ Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR commercial product in the CCMS (accessed March 2025).

⁶⁸⁶ ENERGY STAR Product Specifications for Clothes Washers, v8.0, effective February 5, 2018.

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.⁶⁸⁷

This measure applies to one-for-one replacement of old failed/near failure 1-350 horsepower⁶⁸⁸ 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.⁶⁸⁹

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:⁶⁹⁰

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

⁶⁸⁷ 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."

⁶⁸⁸ For 1-200 horsepower general purpose motors 1200 rpm, 1800 rpm, 3600 rpm, IESA is equivalent to NEMA Premium®. For 200-350 horsepower general purpose motors 1200 rpm, 1800 rpm, 3600 rpm, federal requirements are equivalent to NEMA Premium specifications. See NEMA MG1-2011 Table 12-12 for more information.

⁶⁸⁹ Goldberg et al, State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Business Programs: Measure Life Study, KEMA, August 25, 2009.

⁶⁹⁰ 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 SAVINGS⁶⁹¹

$$\Delta kWh = (kW_{Base} - kW_{EE}) * Hours$$

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right)$$

$$kW_{EE} = \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right)$$

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%)⁶⁹²

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:⁶⁹³

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

⁶⁹¹ Prevailing energy Savings Methodology for motor measures as highlighted by SEEAAction *Scoping Study to Evaluate Feasibility of national Databases for EM&V Documents and Measure Savings*, June 2011.

⁶⁹² 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.

⁶⁹³ Nominal efficiencies shall be established in accordance with DOE Code of Federal Regulations energy conservation standards 10 CFR 431.25 through 431.26.

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: ⁶⁹⁴

Motor Horsepower/Standard Kilowatt Equivalent	Nominal Full-Load Efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1/.75	85.5	85.5	82.5	82.5	75.5	75.5
1.5/1.1	86.5	86.5	87.5	86.5	78.5	77
2/1.5	86.5	86.5	88.5	87.5	84	86.5
3/2.2	89.5	89.5	89.5	88.5	85.5	87.5
5/3.7	89.5	89.5	89.5	89.5	86.5	88.5
7.5/5.5	91.7	91	91	90.2	86.5	89.5
10/7.5	91.7	91.7	91	91.7	89.5	90.2
15/11	92.4	93	91.7	91.7	89.5	90.2
20/15	93	93	91.7	92.4	90.2	91
25/18.5	93.6	93.6	93	93	90.2	91
30/22	93.6	94.1	93	93.6	91.7	91.7
40/30	94.1	94.1	94.1	94.1	91.7	91.7
50/37	94.5	94.5	94.1	94.1	92.4	92.4
60/45	95	95	94.5	94.5	92.4	93
75/55	95.4	95	94.5	94.5	93.6	94.1
100/75	95.4	95.4	95	95	93.6	94.1
125/90	95.4	95.4	95	95	94.1	94.1
150/110	95.8	95.8	95.8	95.4	94.1	94.1
200/150	96.2	95.8	95.8	95.4	94.5	94.1

$\eta_{E\text{Motor}}$ = Efficient motor nominal/nameplate motor efficiency
= Actual

Hours = Hours for HVAC motors are found in table below:⁶⁹⁵

Building Type	Hot Water Pump Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Convenience*	3,628	2,690	4,630

⁶⁹⁴ Nominal efficiencies shall be established in accordance with DOE Code of Federal Regulations energy conservation standards 10 CFR 431.25 through 431.26.

⁶⁹⁵ 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 Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Education	6,367	2,796	3,544
Grocery	6,499	2,725	8,743
Health	8,720	4,770	3,478
Hospital	8,289	8,760	4,570
Industrial*	3,977	3,080	2,850
Lodging	5,500	7,909	3,909
Multifamily	5,382	5,084	8,760
Office - Large	5,316	4,596	2,662
Office - Small	1,952	2,138	7,667
Religious*	4,763	2,223	2,412
Restaurant	3,027	2,719	7,300
Retail – Large*	4,218	2,405	4,065
Retail - Small	3,029	2,266	7,410
Warehouse*	4,100	1,788	2,920
Nonresidential (Average)	3,659	2,182	4,978

For all non-HVAC applications, hour of use are found below:⁶⁹⁶

Unit HP Range	Mean Annual HOU
1-5	2,745
6-20	3,391
21-50	4,067
51-100	5,329
101-200	5,200
201-350	6,132

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

$$\begin{aligned}\Delta kWh &= 0.746 * 5 * (0.8/0.895 - 0.8/0.905) * 8,760 \\ &= 322.7 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\begin{aligned}\Delta kW &= (kW_{Base} - kW_{EE}) * CF \\ kW_{Base} &= \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right) \\ kW_{EE} &= \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right)\end{aligned}$$

Where:

$$CF = 79.3\%^{697}$$

All other variables provided above.

⁶⁹⁶ United States Industrial Electric Motor Systems Market Opportunities Assessment (p. 66), December 2002.

⁶⁹⁷ Industrial Motor CF in IA_Electric Loadshapes – Working Draft.xls.

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

$$\begin{aligned}\Delta kW &= 0.746 * 5 * (0.8/0.895 - 0.8/0.905) * 0.793 \\ &= 0.029 \text{ kW}\end{aligned}$$

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure.⁶⁹⁸

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: 1/1/2028

⁶⁹⁸ 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 years⁶⁹⁹

DEEMED MEASURE COST

The deemed incremental measure cost is \$400.⁷⁰⁰

LOADSHAPE

Loadshape NRE13 – Indust. 1-shift (8/5)

Loadshape NRE14 – Indust. 2-shift (16/5)

Loadshape NRE15 – Indust. 3-shift (24/5)

Loadshape NRE16 – Indust. 4-shift (24/7)

Algorithm

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (\text{CAP} * \text{DOD}) * \text{CHG} * (\text{CR}_B / \text{PC}_B - \text{CR}_{EE} / \text{PC}_{EE}) * \text{WHFe}$$

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh.⁷⁰¹

DOD = Depth of Discharge

= Use actual depth of discharge, otherwise use a default value of 80%.⁷⁰²

⁶⁹⁹ Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 45.

⁷⁰⁰ Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 42.

⁷⁰¹ 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.

⁷⁰² 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:⁷⁰³

Standard Operations	Number of Charges per Year
1-shift (8 hrs/day – 5 days/week)	520
2-shift (16 hrs/day – 5 days/week)	1,040
3-shift (24 hrs/day – 5 days/week)	1,560
4-shift (24 hrs/day – 7 days/week)	2,184

CR_B = Baseline Charge Return Factor

= 1.2485⁷⁰⁴

PC_B = Baseline Power Conversion Efficiency

= 0.84⁷⁰⁵

CR_{EE} = Efficient Charge Return Factor

= 1.107⁷⁰⁶

PC_{EE} = Efficient Power Conversion Efficiency

= 0.89⁷⁰⁷

WHFe = Waste heat factor for energy to account for cooling energy savings from reduced waste heat from the battery charger

= 1.07 for cooled warehouse, 1.0 for uncooled warehouse and 1.29 for refrigerated buildings⁷⁰⁸

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:

⁷⁰³ 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.

⁷⁰⁴ 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).

⁷⁰⁵ Ibid.

⁷⁰⁶ Ibid.

⁷⁰⁷ Ibid.

⁷⁰⁸ 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:⁷⁰⁹

$$\Delta kWh_{heatpenalty} = (CAP * DOD) * CHG * (CRB / PCB - CREE / PCEE) * (-IFkWh)$$

Where:

IFkWh = Heating Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the battery charger
= 0.44 if resistance heat, 0.19 if heat pump, 0 if unheated.⁷¹⁰

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (PF_B / PC_B - PF_{EE} / PC_{EE}) * Volts_{DC} * Amps_{DC} / 1,000 * WHFd * CF$$

Where:

PF_B = Power factor of baseline charger
= 0.9095⁷¹¹

PF_{EE} = Power factor of high frequency charger
= 0.9370⁷¹²

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.⁷¹³

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.⁷¹⁴

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.⁷¹⁵

CF = Summer Coincident Peak Factor for this measure
= 0.0% (for 1- and 2-shift operation)⁷¹⁶

⁷⁰⁹ Results in a negative value because this is an increase in heating consumption due to the less waste heat.

⁷¹⁰ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁷¹¹ Ibid.

⁷¹² Ibid.

⁷¹³ 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.

⁷¹⁴ 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.

⁷¹⁵ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁷¹⁶ 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)⁷¹⁷

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):⁷¹⁸

$$\Delta Therms = (CAP * DOD) * CHG * (CRB / PCB - CREE / PCEE) * (-IFTherms)$$

Where:

IFTherms = Heating Iteration 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
= 0.016 if gas heated, 0 if unheated⁷¹⁹

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above
HeatDays = Heat season days per year
= 190⁷²⁰

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁷¹⁷ Ibid.

⁷¹⁸ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁷¹⁹ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁷²⁰ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

MEASURE CODE: NR-MSC-BACH-V02-240101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

3.5.5. MODULATING COMMERCIAL GAS CLOTHES DRYER**DESCRIPTION**

This measure applies to the installation of a two-stage modulating gas valve retrofit kit on a standard commercial non-modulating gas dryer. Commercial gas clothes dryers found in coin-operated laundromats, or on-premise laundromats (hospitals, hotels, health clubs, etc.) traditionally have a single firing rate which is sized for the highest heat requirement in initial drying stages, but is oversized for later drying stages requiring less heat. This causes excessive burner cycling to maintain the correct drying temperature, which results in less efficient drying and wasted heat. Replacing the single stage gas valve with a two-stage gas valve allows the firing rate to adjust to the varying heat demand, therefore reducing overall gas consumption. Industrial dryer manufacturers have started to incorporate modulating valves into some larger units, however they have not been widely adopted for units with capacities less than 200 lbs.⁷²¹

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

A 30 to 200 lb capacity commercial gas dryer retrofitted with a two-stage modulating gas valve kit.

DEFINITION OF BASELINE EQUIPMENT

A 30 to 200 lb capacity commercial gas dryer with no modulating capabilities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life for the retrofit kit is 10 years.⁷²²

DEEMED MEASURE COST

The full retrofit cost is assumed to be \$700, including the material cost for the basic modulating gas valve retrofit kit (\$600) and the associated of labor for installation (\$100).⁷²³

LOADSHAPE

Loadshape G03 – Residential Dryer

Coincidence Factor

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

⁷²¹ RMS Energy Consulting. 2021. Retrofit Modulating Gas Dryer Valve for Commercial Dryers. Industry Standard Practice Report. Prepared for Southern California Gas Company

⁷²² Since this is a retrofit measure to an existing piece of equipment the measure life is less than the full life of the dryer. Assumed to be 10 years as cost would be prohibitive for older machines that are nearing the end of their service lives.

⁷²³ Engineering judgement, based on observed costs during Nicor Gas pilot study. "Nicor Gas Emerging Technology Program, 1036: Commercial Dryer Modulation Retrofit Public Project Report." 2014.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

Natural Gas Savings

Note: Accurately estimating dryer energy consumption is complicated and challenging due to a variety of factors that influence cycle times and characteristics and ultimately drying energy requirements. Clothing loads can vary by weight, volume, fiber composition, physical structure, and initial water content, meaning that for any given cycle drying energy requirements can differ. Additionally, dryer settings selected by the user as well as interactions with the site's HVAC systems are known to influence dryer performance. As better information becomes available, this characterization can be modified to allow for a more site-specific estimation of savings.

$$\Delta\text{Therms} = N_{\text{Cycles}} * SF$$

Where:

N_{Cycles} = Number of dryer cycles per year. Refer to the table below if this value is not directly available.

Application	Cycles per Year
Coin- Operated Laundromats ⁷²⁴	1,483
Multi-family Dryers ⁷²⁵	1,074
On-Premise Laundromats ⁷²⁶	3,607

SF = Savings factor
= 0.18 therms/cycle⁷²⁷

If using default cycles the savings are as follows:

Application	ΔTherms
Coin-Operated Laundromats ⁷²⁸	267
Multi-family Dryers ⁷²⁹	193
On-Premise Laundromats ⁷³⁰	649

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

⁷²⁴ From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy, Docket Number EERE-2012-BT-STD-0020.

⁷²⁵ Ibid.

⁷²⁶ Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

⁷²⁷ Based on Illinois weather data, and average dryer performance for laundromat (30 to 45lb) and hotel (75 to 170 lb) dryers. See GTI Analysis.xlsx for complete derivation.

⁷²⁸ From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy.

⁷²⁹ Ibid.

⁷³⁰ Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

N/A

MEASURE CODE: NR-MSC-MODDR-V01-260101

SUNSET DATE: 1/1/2028

3.6. Food Service

3.6.1. DISHWASHER

DESCRIPTION

This measure applies to ENERGY STAR⁷³¹ 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:⁷³²

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

⁷³¹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁷³² Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as "EPA/FSTC research on available models, 2013"

DEEMED MEASURE COST

The incremental capital cost for this measure is:⁷³³

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	\$2,050
	Multi Tank Conveyor	\$970
	Pot, Pan, and Utensil	\$1,710

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.

$$\Delta kWh^{734} = \Delta BuildingEnergy + \Delta BoosterEnergy^{735} + \Delta IdleEnergy$$

Where:

$\Delta BuildingEnergy$ = Change in annual electric energy consumption of building water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)]$$

$\Delta BoosterEnergy$ = Annual electric energy consumption of booster water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)]$$

$\Delta IdleEnergy$ = Annual idle electric energy consumption of dishwasher

$$= [IdleDraw_{Base} * (Hours * Days - Days * RacksWashed * WashTime \div 60)] - [IdleDraw_{ESTAR} * (Hours * Days - Days * RacksWashed * WashTime \div 60)]$$

⁷³³ Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “Difference between a similar ENERGY STAR and non-qualifying model EPA research using AutoQuotes, 2016 (for high/low temp undercounter/single door) and 2012 (all other types)”.

⁷³⁴ Algorithms and assumptions except for inlet water temperature increase for building water heaters derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021.

⁷³⁵ Booster water heater energy only applies to high-temperature dishwashers.

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 days per year
ΔT_{in}	= Inlet water temperature increase (°F) = Custom or if unknown, use 83.5 °F for building water heaters ⁷³⁶ 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

⁷³⁶ Inlet water temperature increase for building water heaters based on 140 °F building water heater set point and 56.5 °F inlet water temperature to the DHW system.

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

$$\Delta \text{kWh} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy} + \Delta \text{IdleEnergy}$$

Where:

$$\begin{aligned} \Delta \text{BuildingEnergy} &= [(1.09 * 75 * 365) * (83.5 * 1.0 * 8.2 / 0.98 / 3,412)] - [(0.86 * 75 * 365) * (83.5 * 1.0 * 8.2 / 0.98 / 3,412)] \\ &= 1,289.3 \text{ kWh} \\ \Delta \text{BoosterEnergy} &= [(1.09 * 75 * 365) * (40 * 1.0 * 8.2 / 0.98 / 3,412)] - [(0.86 * 75 * 365) * (40 * 1.0 * 8.2 / 0.98 / 3,412)] \\ &= 617.6 \text{ kWh} \\ \Delta \text{IdleEnergy} &= [0.76 * (18 * 365 - 365 * 75 * 2.0 / 60)] - [0.30 * (18 * 365 - 365 * 75 * 2.0 / 60)] \\ &= 2602.5 \text{ kWh} \\ \Delta \text{kWh} &= 1,289.3 + 617.6 + 2,602.5 \\ &= 4,509.3 \text{ kWh} \end{aligned}$$

Default values for WaterUse, RacksWashed, kW_{Idle}, and WashTime are presented in the table below.

	RacksWashed	WashTime	WaterUse		IdleDraw	
Low Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.73	1.19	0.50	0.25
Stationary Single Tank Door	280	1.5	2.10	1.18	0.60	0.30
Single Tank Conveyor	400	0.3	1.31	0.79	1.60	0.85
Multi Tank Conveyor	600	0.3	1.04	0.54	2.00	1.00
High Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.09	0.86	0.76	0.30
Stationary Single Tank Door	280	1.0	1.29	0.89	0.87	0.55
Single Tank Conveyor	400	0.3	0.87	0.70	1.93	1.20
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	1.85
Pot, Pan, and Utensil	280	3.0	0.70	0.58	1.20	0.90

Savings for all water heating combinations are presented in the tables below.

Electric building and electric booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	12,536.5	8,092.0	4,444.5
	Stationary Single Tank Door	46,402.5	25,924.6	20,477.8
	Single Tank Conveyor	48,549.1	28,606.8	19,942.3
	Multi Tank Conveyor	57,637.0	29,716.3	27,920.7
High Temp	Under Counter	13,346.2	8,834.8	4,511.3
	Stationary Single Tank Door	44,204.5	30,253.2	13,951.3

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
	Single Tank Conveyor	49,781.0	37,992.9	11,788.1
	Multi Tank Conveyor	79,529.8	46,657.9	32,871.9
	Pot, Pan, and Utensil	23,441.4	19,285.2	4,156.2

Electric building and natural gas booster water heating

Dishwasher Type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	12,536.5	8,092.0	4,444.5
	Stationary Single Tank Door	46,402.5	25,924.6	20,477.8
	Single Tank Conveyor	48,549.1	28,606.8	19,942.3
	Multi Tank Conveyor	57,637.0	29,716.3	27,920.7
High Temp	Under Counter	10,416.1	6,523.1	3,893.1
	Stationary Single Tank Door	31,258.6	21,321.5	9,937.0
	Single Tank Conveyor	37,308.2	27,957.3	9,350.9
	Multi Tank Conveyor	58,670.2	35,045.3	23,624.9
	Pot, Pan, and Utensil	16,416.5	13,464.6	2,951.9

Natural gas building and electric booster water heating

Dishwasher Type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,828.8	1,414.4	1,414.4
	Stationary Single Tank Door	2,409.0	1,204.5	1,204.5
	Single Tank Conveyor	9,344.0	4,964.0	4,380.0
	Multi Tank Conveyor	10,950.0	5,475.0	5,475.0
High Temp	Under Counter	7,229.7	4,009.0	3,220.7
	Stationary Single Tank Door	17,179.9	11,608.3	5,571.6
	Single Tank Conveyor	23,744.0	17,043.6	6,700.4
	Multi Tank Conveyor	35,985.3	22,416.6	13,568.7
	Pot, Pan, and Utensil	8,776.9	7,134.6	1,642.3

Natural gas building and natural gas booster water heating

Dishwasher Type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,828.8	1,414.4	1,414.4
	Stationary Single Tank Door	2,409.0	1,204.5	1,204.5
	Single Tank Conveyor	9,344.0	4,964.0	4,380.0
	Multi Tank Conveyor	10,950.0	5,475.0	5,475.0
High Temp	Under Counter	4,299.7	1,697.3	2,602.5
	Stationary Single Tank Door	4,234.0	2,676.7	1,557.3
	Single Tank Conveyor	11,271.2	7,008.0	4,263.2
	Multi Tank Conveyor	15,125.6	10,804.0	4,321.6
	Pot, Pan, and Utensil	1,752.0	1,314.0	438.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

$$= 90\%^{737}$$

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

$$\begin{aligned}\Delta kW &= 4514 / (18 * 365) * 0.9 \\ &= 0.618 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta Therms^{738} = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

$\Delta BuildingEnergy$ = Change in annual natural gas consumption of building water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)]$$

$\Delta BoosterEnergy$ = Change in annual natural gas consumption of booster water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)]$$

Where:

Eff_{Heater} = Efficiency of water heater

= Custom or 78% for gas building⁷³⁹ and 80% for gas booster water heaters

100,000 = Therms to Btu conversion factor

Other variables as defined above.

⁷³⁷ PG&E Work Paper PGECOFST126 Revision 0, Table 10, pg. 18.

⁷³⁸ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, except for inlet water temperature increase for building water heaters and efficiency of gas building water heater

⁷³⁹ 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%.

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\Delta\text{Therms} = \Delta\text{BuildingEnergy} + \Delta\text{BoosterEnergy}$$

Where:

$$\begin{aligned}\Delta\text{BuildingEnergy} &= [(1.09 * 75 * 365) * (83.5 * 1.0 * 8.2 \div 0.78 \div 100,000)] - [(0.86 * 75 * 365) * (83.5 * 1.0 * 8.2 \div 0.78 \div 100,000)] \\ &= 55.3 \text{ therms} \\ \Delta\text{BoosterEnergy} &= [(1.09 * 75 * 365) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] - [(0.86 * 75 * 365) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] \\ &= 25.8 \text{ therms} \\ \Delta\text{Therms} &= 55.3 + 25.8 \\ &= 81.1 \text{ Therms}\end{aligned}$$

Savings for all water heating combinations are presented in the tables below.

Electric building and natural gas booster water heating

Dishwasher Type		Therms _{Base}	Therms _{SESTAR}	ΔTherms
Low Temp	Under Counter	NA	NA	NA
	Stationary Single Tank Door	NA	NA	NA
	Single Tank Conveyor	NA	NA	NA
	Multi Tank Conveyor	NA	NA	NA
High Temp	Under Counter	122.5	96.6	25.8
	Stationary Single Tank Door	541.1	373.3	167.8
	Single Tank Conveyor	521.3	419.5	101.9
	Multi Tank Conveyor	871.9	485.4	386.5
	Pot, Pan, and Utensil	293.6	243.3	50.3

Natural gas building and natural gas booster water heating

Dishwasher Type		Therms _{Base}	Therms _{SESTAR}	ΔTherms
Low Temp	Under Counter	405.8	279.1	126.7
	Stationary Single Tank Door	1,838.8	1,033.2	808.6
	Single Tank Conveyor	1,638.7	988.2	650.5
	Multi Tank Conveyor	1,951.4	1,013.2	938.2
High Temp	Under Counter	378.1	298.3	79.8
	Stationary Single Tank Door	1,670.6	1,152.6	518.0
	Single Tank Conveyor	1,609.6	1,295.1	314.5
	Multi Tank Conveyor	2,691.9	1,498.6	1,193.3
	Pot, Pan, and Utensil	906.6	751.1	155.4

Natural gas building and electric booster water heating

Dishwasher Type		Therms _{Base}	Therms _{SESTAR}	ΔTherms
Low Temp	Under Counter	405.8	279.1	126.7
	Stationary Single Tank Door	1,838.8	1,033.2	805.6
	Single Tank Conveyor	1,638.7	988.2	650.5
	Multi Tank Conveyor	1,951.4	1,013.2	938.2
High	Under Counter	255.6	201.7	53.9

Dishwasher Type		Therms _{Base}	Therms _{ESTAR}	ΔTherms
Temp	Stationary Single Tank Door	1,129.5	779.3	350.2
	Single Tank Conveyor	1,088.3	875.6	212.6
	Multi Tank Conveyor	1,820.0	1,013.2	806.8
	Pot, Pan, and Utensil	612.9	507.9	105.1

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\begin{aligned} \Delta PeakTherms &= 81.2 / 365 \\ &= 0.2225 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$$

Where:

WaterUse_{Base} = Water use per rack (gal) of baseline dishwasher

= Use value from table within the electric energy savings characterization as determined by machine type and sanitation method

WaterUse_{ESTAR} = Water use per rack (gal) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

Other variables as defined above.

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\begin{aligned} \Delta Water &= (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days) \\ \Delta Water &= (1.73 * 75 * 365) - (1.19 * 75 * 365) \\ &= 14,782.5 \text{ gallons} \end{aligned}$$

Savings for all dishwasher types are presented in the table below.

	Annual Water Consumption (gallons)		
	Baseline	ENERGY STAR	Savings
Low Temperature			
Under Counter	47,358.8	32,576.3	14,782.5

	Annual Water Consumption (gallons)		
	Baseline	ENERGY STAR	Savings
Stationary Single Tank Door	214,620.0	120,596.0	94,024.0
Single Tank Conveyor	191,260.0	115,340.0	75,920.0
Multi Tank Conveyor	227,760.0	118,260.0	109,500.0
High Temperature			
Under Counter	29,838.8	23,542.5	6,296.3
Stationary Single Tank Door	131,838.0	90,958.0	40,880.0
Single Tank Conveyor	127,020.0	102,200.0	24,820.0
Multi Tank Conveyor	212,430.0	118,260.0	94,170.0
Pot, Pan, and Utensil	71,540.0	59,276.0	12,264.0

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-DISH-V04-250101

SUNSET DATE: 1/1/2028

3.6.2. COMMERCIAL SOLID AND GLASS DOOR REFRIGERATORS & FREEZERS

DESCRIPTION

This measure applies to ENERGY STAR⁷⁴⁰ vertical closed and horizontal closed refrigerators or freezers installed in a commercial kitchen. ENERGY STAR commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new ENERGY STAR certified vertical closed or horizontal closed, solid or glass door refrigerator or freezer, chef base or service over the counter meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V) or Total Display Area (sq ft).

ENERGY STAR Requirements (Version 5.0, Effective December 22, 2022)

Volume (ft ³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.0267V+0.8	≤ 0.21V+0.90
15 ≤ V < 30	≤ 0.05V+0.45	≤ 0.12V+2.248
30 ≤ V < 50		≤ 0.2578V-1.8864
V ≥ 50	≤ 0.025V+1.6991	≤ 0.14V+4.0
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
Chef Bases		
Doors or Drawers		
All Volumes	≤ 0.05V+2.1	≤ 0.22V+6.0
Service Over Counter		
Total Display Area (in sq ft)		
0 < TDA < 20	≤ 0.32TDA+0.6	N/A
20 ≤ V < 40	≤ 0.65TDA-6.0	
40 ≤ V	≤ 0.4667TDA+1.3333	

⁷⁴⁰ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new vertical closed or horizontal closed, solid or glass door refrigerator or freezer, chef base or service over the counter refrigerator that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁷⁴¹

DEEMED MEASURE COST

The incremental capital per cubic foot cost for this measure can be found below.⁷⁴²

Description and Volume (cu. ft.)	Refrigerator	Freezer
	Incremental Unit Cost per Foot	
Solid Door		
0 ≤ V < 15	\$6.15	\$3.32
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
Glass Door		
0 ≤ V < 15	\$5.78	\$2.74
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
Chest		
Solid/Glass	\$10.95	\$6.62
Chef Bases		
All Volumes	\$14.60	\$7.74
Service Over the Counter		
All Areas	\$ 4.34	N/A

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm**CALCULATION OF SAVINGS**

⁷⁴¹Measure life from Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which is sourced from the California Public Utilities Commission (CPUC), Energy Division. DEER, 2014.

⁷⁴²Based on ENERGY STAR V5.0 Commercial Refrigeration and Freezer Data Package Costs applied over volumes of models by type on the ENERGY STAR Qualified Products List. See Commercial Solid and Glass Door Refrigerators & Freezers Analysis 2025 for details.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

ELECTRIC ENERGY SAVINGS

Custom calculation below.⁷⁴³

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

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}^{744}
Solid Door Refrigerator	$0.05V + 1.36$
Glass Door Refrigerator	$0.1V + 0.86$
Solid Door Freezer	$0.22V + 1.38$
Glass Door Freezer	$0.29V + 2.95$
Solid Door Chest Refrigerator	$0.05V + 0.91$
Glass Door Chest Refrigerator	$0.06V + 0.37$
Solid Door Chest Freezer	$0.06V + 1.12$
Glass Door Chest Freezer	$0.08V + 1.23$

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR refrigerator or freezer
 = Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V):⁷⁴⁵

⁷⁴³ Algorithms and assumptions from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021 and ENERGY STAR V5.0 Commercial Refrigerator and Freezer Data Package (2022).

⁷⁴⁴ United States Department of Energy, 10 CFR Part 431, “Energy Conservation Standards for Commercial Refrigeration Equipment”, March, 2017.

⁷⁴⁵ ENERGY STAR, “ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers”, v5.0, Effective December 22, 2022.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

Volume (ft³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.0267V+0.8	≤ 0.21V+0.90
15 ≤ V < 30	≤ 0.05V+0.45	≤ 0.12V+2.248
30 ≤ V < 50		≤ 0.2578V-1.8864
V ≥ 50	≤ 0.025V+1.6991	≤ 0.14V+4.0
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
Chef Bases		
Doors or Drawers		
All Volumes	≤ 0.05V+2.1	≤ 0.22V+6.0
Service Over Counter		
Total Display Area (in sq ft)		
0 < TDA < 20	≤ 0.32TDA+0.6	N/A
20 ≤ V < 40	≤ 0.65TDA-6.0	
40 ≤ V	≤ 0.4667TDA+1.3333	

V = Refrigerated volume (ft³) calculated in accordance with the Department of Energy test procedure in 10 CFR §431.64

= Actual installed

Days = Days of refrigerator or freezer operation per year

= 365 days per year

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

$$\begin{aligned} \Delta kWh &= [(0.05 * 35 + 1.36) - (0.05 * 35 + 0.45)] * 365 \\ &= 332.2 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / HOURS) * CF$$

Where:

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

ΔkWh	= Electric energy savings, calculated above
HOURS	= Hours of refrigerator or freezer operation per year = 8760 ⁷⁴⁶
CF	= Summer peak coincidence factor = 96.4%

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\begin{aligned}\Delta kW &= (332.2/8760) * 0.964 \\ &= 0.0366kW\end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CSGD-V03-260101

SUNSET DATE: 1/1/2029

⁷⁴⁶ Equipment is assumed to operate continuously, 24 hour per day, 365 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 wastewater (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new pre-rinse spray valve with a maximum flow rate that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment flow rate depends on program type. For TOS, the baseline equipment is a new pre-rinse spray valve with a maximum flow rate of 1.20 gpm or less.⁷⁴⁷ For DI, the baseline equipment is an existing pre-rinse spray valve with a flow rate of 1.6 gpm or less.⁷⁴⁸

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years.⁷⁴⁹

DEEMED MEASURE COST

For TOS programs, the incremental cost of this measure is assumed to be \$0.⁷⁵⁰ For DI programs, the total installed cost is assumed to be \$53.⁷⁵¹

LOADSHAPE

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

⁷⁴⁷ Baseline for TOS programs is calculated using the maximum flow rate for each product class in 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment weighted by estimated 2019 shipments for each product class from Table 3.6.1: U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022.

⁷⁴⁸ 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.

⁷⁴⁹ Measure life from U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022, page 8-12.

⁷⁵⁰ Incremental measure cost based on U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022, page 8-1.

⁷⁵¹ Total installed cost is the manufacturer selling price (\$34.99) from Table 8.2.1 multiplied by the retailer markup (1.52) from Table 8.2.2: U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022. It is assumed that programs typically install spray valves only when other kitchen equipment is also being installed, and therefore, there are no additional labor costs associated with spray valve installations.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 1,167.0 kWh for TOS and 3,112.0 kWh for DI.⁷⁵²

$$\Delta kWh = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 3,412 * \Delta WaterUse$$

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. ⁷⁵³
T _{in}	= Inlet Water Temperature to the DHW system = Actual, otherwise assume 57.8. ⁷⁵⁴
1.0	= Specific heat of water (Btu/lb/°F)
8.33	= Specific weight capacity of water (lb/gal)
Eff _{Heater}	= Efficiency of water heater = Custom or if unknown, use 98% for electric water heaters
3,412	= kWh to Btu conversion factor
ΔWaterUse	= Change in annual water consumption = Custom calculation in Water Impact Descriptions and Calculation section of this measure, otherwise use 5,610.2 gal/yr for TOS and 14,960.6 gal/yr for DI

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above, would save:

$$\begin{aligned} \Delta kWh &= 1.00 * (140 - 57.8) * 1.0 * 8.33 / 0.98 / 3,412 * 5,610.2 \\ &= 1,148.8 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / ((Minutes/60) * Days) * CF$$

⁷⁵² 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.

⁷⁵³ 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.

⁷⁵⁴ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20; water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

Where:

ΔkWh	= Electric energy savings, calculated above
Minutes	= Average daily minutes of spray valve operation
	= Custom or if unknown, use 64 minutes per day. ⁷⁵⁵
60	= Minutes to hours conversion factor
Days	= Annual days of operation
	= Custom or if unknown, use 365 days per year
CF	= Summer peak coincidence factor
	= 1.14% for a fast-food restaurant and 2.50% for a sit-down restaurant. ⁷⁵⁶

For example, an efficient pre-rinse spray valve installed in a sit-down restaurant under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned}\Delta kW &= 1,148.8 / ((64/60) * 365) * 0.0250 \\ &= 0.07377 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Custom calculation below, otherwise use deemed value of 49.2 therms/yr for TOS and 131.3 therms/yr for DI.⁷⁵⁷

$$\Delta Therms = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 100,000 * \Delta WaterUse$$

Where:

Eff_{Heater}	= Efficiency of water heater
	= Custom or if unknown, use 78% ⁷⁵⁸ for gas water heaters
100,000	= Btu to therms conversion factor
Other variables as defined above.	

⁷⁵⁵ ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

⁷⁵⁶ 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.

⁷⁵⁷ 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

⁷⁵⁸ 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%.

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned}\Delta\text{Therms} &= 1.00 * (140 - 57.8) * 1.0 * 8.2 / 0.78 / 100,000 * 5,610.2 \\ &= 48.5 \\ &\text{therms/yr}\end{aligned}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned}\Delta\text{PeakTherms} &= 48.5 / 365 \\ &= 0.1329 \text{ therms/day}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 5,844.0 gal/yr for TOS and 14,493.1 gal/yr for DI.⁷⁵⁹

$$\Delta\text{WaterUse} = (\text{Flow}_{\text{Base}} - \text{Flow}_{\text{EE}}) * \text{Minutes} * \text{Days}$$

Where:

$\text{Flow}_{\text{Base}}$ = Flow rate (gal/min) of baseline pre-rinse spray valve
= Custom or if unknown, use 1.20 gpm for TOS⁷⁶⁰ and 1.6 gpm for DI⁷⁶¹

Flow_{EE} = Flow rate (gal/min) of efficient pre-rinse spray valve
= Custom or if unknown, use 0.96 gal/min⁷⁶²

Other variables as defined above.

For example, an efficient pre-rinse spray valve, installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned}\Delta\text{WaterUse} &= (1.20 - 0.96) * 64 * 365 \\ &= 5,606.4 \text{ gal/yr}\end{aligned}$$

⁷⁵⁹ 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.

⁷⁶⁰ 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.

⁷⁶¹ 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.

⁷⁶² A new pre-rinse spray valve is assumed to be 20% more efficient than the federal standard.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-SPRY-V05-240101

SUNSET DATE: 1/1/2028

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.⁷⁶³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$5,900.⁷⁶⁴

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 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)

⁷⁶³Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁷⁶⁴Incremental 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 ⁷⁶⁵
InputRate _{EE}	= Rated energy input rate of infrared upright broiler (Btu/hr)
	= Custom or if unknown, use 82,333 Btu/hr ⁷⁶⁶
Duty	= Duty cycle of upright broiler (%)
	= Custom or if unknown, use 70% ⁷⁶⁷
Hours	= Typical operating hours of upright broiler
	= Custom or if unknown, use 2,496 hours ⁷⁶⁸
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared upright broiler with default values from the algorithm above would save:

$$\Delta \text{Therms} = [(95,000 - 82,333) * (0.70 * 2,496) / 100,000] / (82,333 / 1,000)$$

$$= 2.7 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation
	= Custom or if unknown, use 312 days per year ⁷⁶⁹

For example, an infrared upright broiler with default values from the calculation above would save:

$$\Delta \text{PeakTherms} = 2.7 / 312$$

$$= 0.0087 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRUB-V01-170101

⁷⁶⁵ Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3

⁷⁶⁶ 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%

⁷⁶⁷ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁷⁶⁸ 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

⁷⁶⁹ 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.⁷⁷⁰

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,000.⁷⁷¹

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Custom calculation below, otherwise use deemed value of 9.7 therms / MBtu/hr input.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

Where:

$InputRate_{Base}$ = Rated energy input rate of baseline salamander broiler (Btu/hr)

⁷⁷⁰Measure life from Nicor Gas Energy Efficiency Plan 2022-2025. Revised Plan Filed March, 2021.

⁷⁷¹Incremental cost from Nicor Gas Energy Efficiency Plan 2022-2025. Revised Plan Filed March, 2021.

	= 38,500 Btu/hr ⁷⁷²
InputRate _{EE}	= Rated energy input rate of infrared salamander broiler (Btu/hr)
	= Custom or if unknown, use 24,750 Btu/hr ⁷⁷³
Duty	= Duty cycle of salamander broiler (%)
	= Custom or if unknown, use 70% ⁷⁷⁴
Hours	= Typical operating hours of salamander broiler
	= Custom or if unknown, use 2,496 hours ⁷⁷⁵
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared salamander broiler with default values from the algorithm above would save:

$$\Delta\text{Therms} = [(38,500 - 24,750) * (0.70 * 2,496) / 100,000] / (24,750 / 1,000)$$

$$= 9.7 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation
	= Custom or if unknown, use 312 days per year ⁷⁷⁶

For example, an infrared salamander broiler with default values from the calculation above would save:

$$\Delta\text{PeakTherms} = 9.7 / 312$$

$$= 0.0311 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRBL-V02-240101

⁷⁷² Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3

⁷⁷³ 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%

⁷⁷⁴ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁷⁷⁵ 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

⁷⁷⁶ 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: 1/1/2030

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.⁷⁷⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,200.⁷⁷⁸

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Custom calculation below, otherwise use deemed value of 8.4 therms / MBtu/hr input.⁷⁷⁹

$$\Delta Therms = [(\Delta PreheatEnergy + \Delta CookingEnergy) * Days / 100,000] / \left(\frac{InputRate_{EE}}{1,000} \right)$$

Where:

$$\Delta PreheatEnergy = (PreheatRate_{Base} * Preheats * PreheatTime / 60) - (PreheatRate_{EE} * Preheats * PreheatTime / 60)$$

⁷⁷⁷Measure life from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator.

⁷⁷⁸Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562

⁷⁷⁹ Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

$$\text{PreheatTime} / 60)$$

$$\Delta\text{CookingEnergy} = (\text{InputRate}_{\text{Base}} - \text{InputRate}_{\text{EE}}) * \text{Hours}$$

Where:

Days	= Annual days of operation
	= Custom or if unknown, use 312 days per year ⁷⁸⁰
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 ⁷⁸¹
60	= Minutes to hours conversion factor
InputRate _{Base}	= Input energy rate of baseline charbroiler
	= 128,000 Btu/hr
InputRate _{EE}	= Input energy rate of infrared charbroiler
	= Custom or if unknown, use 96,000 Btu/hr
Hours	= Average daily hours of operation
	= Custom or if unknown, use 8 hours per day

For example, an infrared charbroiler with default values from the calculation above would save:

$$\Delta\text{Therms} = [(\Delta\text{PreheatEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000] / (\text{InputRate}_{\text{EE}} / 1,000)$$

Where:

$$\begin{aligned} \Delta\text{PreheatEnergy} &= (64,000 * 1 * 15 / 60) - (54,000 * 1 * 15 / 60) \\ &= 2,500 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (128,000 - 96,000) * 8 \\ &= 256,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= [(2,500 + 256,000) * 312 / 100,000] / (96,000 / 1,000) \\ &= 8.4 \text{ therms/ MBtu/hr input} \end{aligned}$$

PEAK GAS SAVINGS

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

⁷⁸⁰Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3

⁷⁸¹Typical 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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 8.4 / 312 \\ &= 0.0269 \text{ therms/MBtu/hr input/day}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRCB-V01-170101

SUNSET DATE: 1/1/2022*

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

3.6.7. CONVECTION OVEN

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR⁷⁸² convection ovens installed in a commercial kitchen. Convection ovens are general purpose ovens that use fans to circulate hot, dry air over the food surface. ENERGY STAR certified convection ovens are approximately 20% more efficient than standard ovens.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified convection oven meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by both fuel type and oven capacity (full size versus half size).

ENERGY STAR Requirements (Version 3.0, Effective January 1, 2023)

Oven Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate (kW)	Cooking Efficiency %	Idle Energy Rate (Btu/h)	Cooking Efficiency %
Full Size - All # pans	N/A	N/A	≤ 9,500	≥ 49
Half-Size	≤ 1.00	≥ 71	N/A	N/A
Full-Size ≥ 5 Pans	≤ 1.40	≥ 76	N/A	N/A
Full-Size < 5 Pans	≤ 1.00		N/A	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas convection oven that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁷⁸³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$400.⁷⁸⁴

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

⁷⁸² In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁷⁸³ Lifetime from ENERGY STAR V3.0 Commercial Ovens Data Package (2022), which is sourced from the CA TRM and CA Energy Wise.

⁷⁸⁴ Measure cost from 2014-2023 Iowa Statewide Assessment of Energy Efficiency Potential

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric convection oven below, otherwise use deemed value of an average of 3,777 kWh for full-size ovens (2,982 kWh for models with at least 5 pans, 4,573 kWh for models with less than 5 pans) and 192.1 kWh for half-size ovens.⁷⁸⁵

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

Hours = Average daily hours of operation

= Custom or if unknown, use 12 hours per day

Days = Annual days of operation

= Custom or if unknown, use 365 days per year

1,000 = Wh to kWh conversion factor

FoodCooked = Food cooked per day

= Custom or if unknown, use 100 pounds

Production_{Base} = Production capacity of baseline electric convection oven

= 90 lb/hr for full-size ovens and 45 lb/hr for half-size ovens

Production_{ESTAR} = Production capacity of ENERGY STAR electric convection oven

= Custom or if unknown, use 90 lb/hr for full-size ovens and 50 lb/hr for half-size ovens

IdleRate_{Base} = Idle energy rate of baseline electric convection oven

= 2,000 W for full-size ovens and 1,030 W for half-size ovens

IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR electric convection oven

= Custom or if unknown, use 1,400 for full-size ovens, greater than or equal to 5 pans, and 1,000 for half-size ovens and full-size ovens, less than 5 pans.

E_{FOOD} = ASTM energy to food

= 73.2 Wh/lb

Eff_{Base} = Cooking efficiency of baseline electric convection oven

= 65% for full-size ovens and 68% for half-size ovens

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric convection oven

= Custom or if unknown, use 71% for half-size ovens and 76% for full-size ovens

⁷⁸⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated July 15, 2021, as well as the ENERGY STAR v3.0 Commercial Ovens Data Packet (2022).

For example, an ENERGY STAR full-size electric convection oven, with greater than 5 pans, with default values from the algorithm above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (2,000 * (12 - 100 / 90)) - (1,400 * (12 - 100 / 90)) \\ &= 6,533 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 73.2 / 0.65) - (100 * 73.2 / 0.76) \\ &= 1,630 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (6,533 + 1,630) * 365 / 1,000 \\ &= 2,979.5 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 78.7%

Other variables as defined above.

For example, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta kW &= 2,979.5 / (12 * 365) * 0.787 \\ &= 0.5354 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 240.5 therms/yr. ⁷⁸⁶

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

FoodCooked = Food cooked per day
= Custom or if unknown, use 100 pounds

Production_{Base} = Production capacity of baseline gas convection oven
= 83 lb/hr

⁷⁸⁶ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated July 15, 2021, as well as the ENERGY STAR v3.0 Commercial Ovens Data Packet (2022).

$Production_{ESTAR}$ = Production capacity of ENERGY STAR gas convection oven
 = Custom or if unknown, use 86 lb/hr

$IdleRate_{Base}$ = Idle energy rate of baseline gas convection oven
 = 15,100 Btu/hr

$IdleRate_{ESTAR}$ = Idle energy rate of ENERGY STAR gas convection oven
 = Custom or if unknown, use 9,500 Btu/hr

E_{FOOD} = ASTM energy to food
 = 250 Btu/lb

Eff_{Base} = Cooking efficiency of baseline gas convection oven
 = 44%

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR gas convection oven
 = Custom or if unknown, use 49%

Other variables as defined above.

For example, an ENERGY STAR gas convection oven with default values from the algorithm above would save:

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (15,100 * (12 - 100 / 83)) - (9,500 * (12 - 100 / 86)) \\ &= 60,054 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 250 / 0.44) - (100 * 250 / 0.49) \\ &= 5,798 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta Therms &= (60,054 + 5,798) * 365 / 100,000 \\ &= 240.4 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

$\Delta Therms$ = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR gas convection with default values from the algorithm above would save:

$$\begin{aligned} \Delta PeakTherms &= 240.4 / 365 \\ &= 0.6585 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESCV-V02-230101

SUNSET DATE: 1/1/2030

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.⁷⁸⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2230.⁷⁸⁸

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 SAVINGS

⁷⁸⁷PG&E Workpaper PGECOFST117 Commercial Conveyor Oven – Gas Revision #6, published April 1, 2016.

⁷⁸⁸PG&E Workpaper PGECOFST117 Commercial Conveyor Oven – Gas Revision #6, published April 1, 2016.

Custom calculation below, otherwise use deemed value of 633.9 therms/yr.⁷⁸⁹

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta PreheatEnergy = (PreheatEnergy_{Base} * Preheats) - (PreheatEnergy_{EE} * Preheats)$$

$$\Delta IdleEnergy = IdleRate_{Base} * (Hours - (FoodCooked / Production_{Base}) - (Preheats * PreheatTime / 60)) - IdleRate_{EE} * (Hours - (FoodCooked / Production_{EE}) - (Preheats * PreheatTime / 60))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{EE})$$

Where:

Days = Annual days of operation
= Custom or if unknown, use 312 days per year⁷⁹⁰

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 day⁷⁹¹

FoodCooked = Number of pizzas cooked per day
= Custom or if unknown, use 250 pizzas per day

Production_{Base} = Production capacity of baseline oven
= 150 pizzas per hour

Production_{EE} = Production capacity of efficient oven
= Custom or if unknown, use 220 pizzas per hour

⁷⁸⁹ Unless otherwise noted, the assumptions are derived from the PG&E Workpaper PGECOFST117 Commercial Conveyor Oven – Gas Revision #6, published April 1, 2016.

⁷⁹⁰ Assumptions are derived from the FSTC Oven Technology Assessment.

⁷⁹¹ Ibid.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.8 Conveyor Oven

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:

$$\Delta \text{Therms} = (\Delta \text{PreheatEnergy} + \Delta \text{IdleEnergy} + \Delta \text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta \text{PreheatEnergy} &= (35,000 * 1) - (18,000 * 1) \\ &= 17,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{IdleEnergy} &= 70,000 * (10 - (250 / 150) - (1 * 15 / 60)) - 57,000 * (10 - (250 / 220) - (1 * 15 / 60)) \\ &= 74,856 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{CookingEnergy} &= (250 * 190 / 0.20) - (250 * 190 / 0.42) \\ &= 124,405 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{Therms} &= (17,000 + 74,856 + 124,405) * 312 / 100,000 \\ &= 674.7 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Natural gas energy savings, calculated above

Days = Annual days of operation

= Custom or if unknown, use 312 days per year

For example, an efficient conveyor oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta \text{PeakTherms} &= 674.7 / 312 \\ &= 2.163 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CVOV-V06-250101

SUNSET DATE: 1/1/2028

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.⁷⁹²

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,700.⁷⁹³

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 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:

⁷⁹²Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁷⁹³Incremental 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 ⁷⁹⁴
InputRate _{EE}	= Energy input rate of infrared rotisserie oven (Btu/hr) = Custom or if unknown, use 40,323 Btu/hr ⁷⁹⁵
Duty	= Duty cycle of rotisserie oven (%) = Custom or if unknown, use 60% ⁷⁹⁶
Hours	= Typical operating hours of rotisserie oven = Custom or if unknown, use 2,496 hours ⁷⁹⁷
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared rotisserie oven with default values from the algorithm above would save:

$$\Delta \text{Therms} = [(50,000 - 40,323) * (0.60 * 2,496) / 100,000] / (40,323 / 1,000)$$

$$= 3.6 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation = Custom or if unknown, use 312 days per year ⁷⁹⁸

For example, an infrared rotisserie oven with default values from the calculation above would save:

$$\Delta \text{PeakTherms} = 3.6 / 312$$

$$= 0.0115 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁷⁹⁴ Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7-2 .

⁷⁹⁵ 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%

⁷⁹⁶ Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7-2.

⁷⁹⁷ 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.

⁷⁹⁸ 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.

MEASURE CODE: NR-FSE-IROV-V02-220101

SUNSET DATE: 1/1/2025*

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

3.6.10. COMMERCIAL STEAM COOKER**DESCRIPTION**

This measure applies to electric or natural gas fired ENERGY STAR⁷⁹⁹ steam cookers installed in a commercial kitchen. Commercial steam cookers contain compartments where steam energy is transferred to food by direct contact. ENERGY STAR certified steam cookers have shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficiency steam delivery.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified steam cooker meeting idle energy rate (kW or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and pan capacity.

ENERGY STAR Requirements (Version 1.2, Effective August 1, 2003)

Pan Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
3-pan	≤ 400 W	≥ 50%	≤ 6,250 Btu/hr	≥ 38% N/A
4-pan	≤ 530 W		≤ 8,350 Btu/hr	
5-pan	≤ 670 W		≤ 10,400 Btu/hr	
6-pan and larger	≤ 800 W		≤ 12,500 Btu/hr	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas steam cooker that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸⁰⁰

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,758 for electric steam cookers and \$2,059 for gas steam cookers.⁸⁰¹

LOADSHAPE

Loadshape NRE02 – Nonresidential Electric Cooking – Restaurant

Loadshape NRG01 – Nonresidential Gas Cooking – Restaurant

⁷⁹⁹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸⁰⁰ Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁸⁰¹ Incremental costs from California Technical Forum. (2024, November 14). Steamer, Commercial (Measure SWFS005-05). California Electronic Technical Reference Manual (eTRM). SWFS005-03_Steamers_2022_Price_Updated.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric steam cooker below, otherwise use deemed value from the table that follows.⁸⁰²

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [((1 - \text{SteamMode}) * \text{IdleRate}_{\text{Base}} + \text{SteamMode} * \text{Production}_{\text{Base}} * \text{Pans} \\ &\quad * \text{EFOOD}/\text{Eff}_{\text{Base}}) * (\text{Hours} - \text{FoodCooked}/(\text{Production}_{\text{Base}} * \text{Pans}))] - [((1 - \text{SteamMode}) \\ &\quad * \text{IdleRate}_{\text{ESTAR}} + \text{SteamMode} * \text{Production}_{\text{ESTAR}} * \text{Pans} * \text{EFOOD}/\text{Eff}_{\text{ESTAR}}) * (\text{Hours} - \\ &\quad \text{FoodCooked}/(\text{Production}_{\text{ESTAR}} * \text{Pans}))] \end{aligned}$$

$$\Delta \text{cookingEnergy} = (\text{FoodCooked} * \text{EFOOD}/\text{Eff}_{\text{Base}}) - (\text{FoodCooked} * \text{EFOOD}/\text{Eff}_{\text{ESTAR}})$$

Where:

Days = Annual days of operation

= Custom or if unknown, use 365 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 capacity⁸⁰³

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

⁸⁰² Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁸⁰³ 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
E _{FOOD}	= ASTM energy to food
	= 30.8 Wh/lb
Eff _{Base}	= Cooking efficiency (%) of baseline electric steam cooker ⁸⁰⁴
	= 30%
Eff _{ESTAR}	= Cooking efficiency (%) of ENERGY STAR electric steam cooker
	= Custom or if unknown, use 50%
Hours	= Average daily hours of operation
	= Custom or if unknown, use 9hours per day
FoodCooked	= Food cooked per day (lbs)
	= Custom or if unknown, use 100 pounds

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [((1 - 0.40) * 1,100 + 0.40 * 23.3 * 6 * 30.8 / 0.30) * (9 - 100 / (23.3 * 6))] - [((1 - 0.40) * 800 + 0.40 * 16.7 * 6 * 30.8 / 0.50) * (9 - 100 / (16.7 * 6))]$$

$$= 29,434 \text{ Wh}$$

$$\Delta CookingEnergy = (100 * 30.8 / 0.30) - (100 * 30.8 / 0.50)$$

$$= 4,106.7 \text{ Wh}$$

$$\Delta kWh = (29,434 + 4,106.7) * 365 / 1,000$$

$$= 12,242.4 \text{ kWh}$$

Savings for all pan capacities are presented in the table below.

Pan Capacity	Savings (kWh)
3	6,875.0
4	8,666.5
5	10,458.5
6	12,250.7
10	19,420.7
Average	11,534.3

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

$$\Delta kWh = \text{Electric energy savings, calculated above}$$

$$CF = \text{Summer peak coincidence factor}$$

$$= 78.7\%$$

Other variables as defined above

⁸⁰⁴ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

$$\begin{aligned}\Delta kW &= 12,242.4 / (9 * 365) * 0.787 \\ &= 2.9330 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Custom calculation for a natural gas steam cooker below, otherwise use deemed value from the table that follows.⁸⁰⁵

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\begin{aligned}\Delta IdleEnergy &= [((1 - SteamMode) * IdleRate_{Base} + SteamMode * Production_{Base} * Pans * E_{FOOD} / Eff_{Base}) * \\ & \quad (Hours - FoodCooked / (Production_{Base} * Pans))] - [((1 - SteamMode) * IdleRate_{ESTAR} + \\ & \quad SteamMode * Production_{ESTAR} * Pans * E_{FOOD} / Eff_{ESTAR}) * (Hours - \\ & \quad FoodCooked / (Production_{ESTAR} * Pans))]\end{aligned}$$

$$\Delta cookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

IdleRate_{Base} = Idle energy rate (Btu/hr) of baseline gas steam cooker

= Use value from table below as determined by pan capacity⁸⁰⁶

IdleRate_{ESTAR} = Idle energy rate (Btu/hr) of ENERGY STAR gas steam cooker

= Custom or if unknown, use value from table below as determined by pan capacity

Idle Energy Rates of Gas Steam Cooker		
Pan Capacity	IdleRate _{Base}	IdleRate _{ESTAR}
3	16,500	6,250
5		10,400
6		12,500
10		12,500

Production_{Base} = Production capacity (lb/hr) per pan of baseline gas steam cooker

= 23.3 lb/hr

Production_{ESTAR} = Production capacity (lb/hr) per pan of ENERGY STAR gas steam cooker

= Custom or if unknown, use 20 lb/hr

E_{FOOD} = ASTM energy to food

= 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker⁸⁰⁷

⁸⁰⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁸⁰⁶ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR for steam generator and boiler-based cookers

⁸⁰⁷ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

= 18%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR gas steam cooker
= Custom or if unknown, use 38%

Other variables as defined above.

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [((1 - 0.40) * 16,500 + 0.40 * 23.3 * 6 * 105 / 0.18) * (9 - 100 / (23.3 * 6))] - [((1 - 0.40) * 12,500 + 0.40 * 20 * 6 * 105 / 0.38) * (9 - 100 / (20 * 6))] \\ &= 182,699.3 \text{ Btu} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 105 / 0.18) - (100 * 105 / 0.38) \\ &= 30,701.8 \text{ Btu} \end{aligned}$$

$$\begin{aligned} \Delta Therms &= (182,699.3 + 30,701.8) * 365 / 100,000 \\ &= 778.9 \text{ therms} \end{aligned}$$

Savings for all pan capacities are presented in the table below.

Pan Capacity	Savings (Therms)
3	458.3
5	672.8
6	779.4
10	1,204.9
Average	778.8

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

$\Delta therms$ = 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:

$$\begin{aligned} \Delta PeakTherms &= 778.9 / 365 \\ &= 2.1340 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below.⁸⁰⁸ Savings are the same for 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

⁸⁰⁸ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

= 40 gal/hr

$\text{WaterUse}_{\text{ESTAR}}$ = Water use (gal/hr) of ENERGY STAR steam cooker

= Actual or if unknown, source from the following table:

Steam Cooker Type	Water Use (gallons/hour)
Steam Generator	15
Boiler Based	10
Boilerless	3
Unknown	9.3 ⁸⁰⁹

Other variables as defined above

For example, a steam cooker with defaults from the calculation above would save

$$\begin{aligned}\Delta \text{WaterUse} &= (40 - 9.315) * 9 * 365 \\ &= 100,849.582,181 \text{ gal/year}\end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-STMC-V05-270101

SUNSET DATE: 1/1/2031

⁸⁰⁹ Water use for unknown ENERGY STAR steam cookers is the average of water use values provided by ENERGY STAR for steam generator, boiler-based, and boilerless cookers

3.6.11. FRYER**DESCRIPTION**

This measure applies to electric or natural gas fired ENERGY STAR⁸¹⁰ 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.⁸¹¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,500 for standard electric, \$500 for large vat electric, \$1,000 for standard gas, and \$2,000 for large vat gas fryers.⁸¹²

LOADSHAPE

Loadshape NRE02 – Nonresidential Electric Cooking – Restaurant

Loadshape NRG01 – Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric fryer below, otherwise use deemed value of 3,128.2 kWh for standard fryers and

⁸¹⁰ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸¹¹ Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “FSTC research on available models, 2009”

⁸¹² Measure costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “EPA research on available models using AutoQuotes, October 2020”.

2,537.9 kWh for large vat fryers.⁸¹³

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

Hours	= Average daily hours of operation
	= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer
Days	= Annual days of operation
	= Custom or if unknown, use 365 days per year
1,000	= Wh to kWh conversion factor
FoodCooked	= Food cooked per day
	= Custom or if unknown, use 150 pounds
Production _{Base}	= Production capacity of baseline electric fryer
	= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers
Production _{ESTAR}	= Production capacity of ENERGY STAR electric fryer
	= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers
IdleRate _{Base}	= Idle energy rate of baseline electric fryer
	= 1,200 W for standard fryers and 1,350 W for large vat fryers
IdleRate _{ESTAR}	= Idle energy rate of ENERGY STAR electric fryer
	= Custom or if unknown, use 800 W for standard fryers and 1,100 for large vat fryers
E _{FOOD}	= ASTM energy to food
	= 167 Wh/lb
Eff _{Base}	= Cooking efficiency of baseline electric fryer
	= 75% for standard fryers and 70% for large vat fryers
Eff _{ESTAR}	= Cooking efficiency of ENERGY STAR electric fryer
	= Custom or if unknown, use 83% for standard fryers and 80% for large vat fryers

⁸¹³ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (1200 * (16 - 150 / 65)) - (800 * (16 - 150 / 70)) \\ &= 5,345 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (150 * 167 / 0.75) - (150 * 167 / 0.83) \\ &= 3,219 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (5,345 + 3,219) * 365 / 1,000 \\ &= 3,125.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 78.7%

Other variables as defined above.

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

$$\begin{aligned} \Delta kW &= 3,125.9 / (16 * 365) * 0.787 \\ &= 0.4212 \text{ kW} \end{aligned}$$

NATURAL GAS 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.⁸¹⁴

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta cookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

Production_{Base} = Production capacity of baseline gas fryer
= 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers

Production_{ESTAR} = Production capacity of ENERGY STAR gas fryer

⁸¹⁴ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

	= Custom or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers
IdleRate _{Base}	= Idle energy rate of baseline gas fryer
	= 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers
IdleRate _{ESTAR}	= Idle energy rate of ENERGY STAR gas fryer
	= Custom or if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers
E _{FOOD}	= ASTM energy to food
	= 570 Btu/lb
Eff _{Base}	= Cooking efficiency of baseline gas fryer
	= 35% for both standard and large vat fryers
Eff _{ESTAR}	= Cooking efficiency of ENERGY STAR gas fryer
	= Custom or if unknown, use 50% for both standard and large vat fryers
Other variables as defined above.	

For example, an ENERGY STAR standard-sized gas fryer, using default values from above, would save:

$$\Delta \text{Therms} = (\Delta \text{IdleEnergy} + \Delta \text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta \text{IdleEnergy} &= (14,000 * (16 - 150 / 60)) - (9,000 * (16 - 150 / 65)) \\ &= 65,769 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{CookingEnergy} &= (150 * 570 / 0.35) - (150 * 570 / 0.50) \\ &= 73,286 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{Therms} &= (65,769 + 73,286) * 365 / 100,000 \\ &= 507.9 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

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:

$$\begin{aligned} \Delta \text{PeakTherms} &= 507.9 / 365 \\ &= 1.3915 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESFR-V04-240101

SUNSET DATE: 1/1/2028

3.6.12. GRIDDLE

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR⁸¹⁵ certified griddles installed in a commercial kitchen. ENERGY STAR commercial griddles achieve approximately 10% higher efficiency than standard griddles with strategies such as highly conductive or reflective plate materials and improved thermostatic controls.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR electric or natural gas fired griddle meeting idle energy rate limits as determined by fuel type.

ENERGY STAR Requirements (Version 1.2, Effective May 8, 2009 for natural gas and January 1, 2011 for electric griddles)

Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
$\leq 320 \text{ W/ft}^2$ $\leq 1.00 \text{ kW}$	Reported	$\leq 2,650 \text{ Btu/hr/ft}^2$ N/A	Reported

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fired griddle that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸¹⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is \$850 for an electric griddle and \$1,250 for a gas griddle.⁸¹⁷

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 2,641 kWh for single-sided electric

⁸¹⁵ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸¹⁶ Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “FSTC research on available models, 2009”

⁸¹⁷ Measure cost from Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, July 2016”

griddle and 3,1813 kWh for double-sided electric griddle.⁸¹⁸

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [(IdleRate_{Base} * Width * Length) * (Hours - FoodCooked/Production_{Base})] - [(IdleRate_{ESTAR} * Width * Length) * (Hours - FoodCooked/Production_{ESTAR})]$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

$$\Delta PreHeatEnergy = PreheatEnergy_{Base} - PreheatEnergy_{ESTAR}$$

Where:

Hours	= Average daily hours of operation = Custom or if unknown, use 12 hours per day
Days	= Annual days of operation = Custom or if unknown, use 365 days per year
1,000	= Wh to kWh conversion factor
Width	= Griddle width = Custom or if unknown, use 3 feet
Depth	= Griddle depth = Custom or if unknown, use 2 feet
FoodCooked	= Food cooked per day = Custom or if unknown, use 100 pounds
Production _{Base}	= Production capacity of baseline electric griddle = 35 lb/hr for single-sided electric griddle = 70 lb/hr for double-sided electric griddle
Production _{ESTAR}	= Production capacity of ENERGY STAR electric griddle = Custom or if unknown, use: = 40 lb/hr for single-sided electric griddle or, = 83.5 lb/hr for double-sided electric griddle
IdleRate _{Base}	= Idle energy rate of baseline electric griddle = 400 W/ft ²
IdleRate _{ESTAR}	= Idle energy rate of ENERGY STAR electric griddle = Custom or if unknown, use 320 W/ft ²
E _{FOOD}	= ASTM energy to food = 139 Wh/lb
Eff _{Base}	= Cooking efficiency of baseline electric griddle = 65%

⁸¹⁸ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric griddle
 = Custom or if unknown, use;
 = 70% for single-sided electric griddle or,
 = 72% for double-sided electric griddle

$PreHeatEnergy_{BASE}$ = Wh used for 1, 15 minute preheat per day of baseline electric griddle
 = 4,000 Wh

$PreHeatEnergy_{ESTAR}$ = Wh used for 1, 15 minute preheat per day of ENERGY STAR electric griddle
 = Custom or if unknown, use:
 = 2,000 Wh

For example, an ENERGY STAR single-sided electric griddle with defaults from the calculation above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [400 * (3 * 2) * (12 - 100 / 35)] - [320 * (3 * 2) * (12 - 100 / 40)] \\ &= 3,702.9 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 139 / 0.65) - (100 * 139 / 0.70) \\ &= 1,527.5 \end{aligned}$$

$$\begin{aligned} Wh \Delta PreHeatEnergy &= (4,000 - 2,000) \\ &= 2,000 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (3,702.9 + 1,527.5 + 2,000) * 365 / 1,000 \\ &= 2,639.1 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
 = 78.7%

Other variables as defined above.

For example, a single-sided ENERGY STAR electric griddle with defaults from the calculation above would save:

$$\begin{aligned} \Delta kW &= 2,639.1 / (12 * 365) * 0.787 \\ &= 0.4742 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

Custom calculation for a natural gas griddle below, otherwise use deemed value of 153.3 therms for single-sided gas griddles and 221.6 therms for double-sided gas griddles.⁸¹⁹

⁸¹⁹ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = [IdleRate_{Base} * (Width * Length) * (Hours - FoodCooked / Production_{Base})] - [IdleRate_{ESTAR} * (Width * Length) * (Hours - FoodCooked / Production_{ESTAR})]$$

$$\Delta cookingEnergy = (FoodCooked * EFOOD / Eff_{Base}) - (FoodCooked * EFOOD / Eff_{ESTAR})$$

$$\Delta preHeatEnergy = (PreHeatEnergy_{Base} - PreHeatEnergy_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

Production_{Base} = Production capacity of baseline gas griddle

= 25 lb/hr for single-sided gas griddle

= 50 lb/hr for double-sided gas griddle

Production_{ESTAR} = Production capacity of ENERGY STAR gas griddle

= Custom or if unknown, use;

= 45 lb/hr for single-sided gas griddle

= 69.9 lb/hr for double-sided gas griddle

IdleRate_{Base} = Idle energy rate of baseline gas griddle

= 3,500 Btu/hr/ft²

IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR gas griddle

= Custom or if unknown, use 2,650 Btu/hr/ft²

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% for single-sided gas griddle

= 35% for double-sided gas griddle

PreHeatEnergy_{Base} = Btu used for 1, 15 min preheat per day of baseline gas griddle

= 21,000 Btu

PreHeatEnergy_{ESTAR} = Btu used for 1, 15 min preheat per day of ENERGY STAR gas griddle

= Custom or if unknown, use:

= 15,000 Btu

Other variables as defined above.

For example, a single-sided ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\Delta \text{Therms} = (\Delta \text{IdleEnergy} + \Delta \text{CookingEnergy} + \Delta \text{PreHeatEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta \text{IdleEnergy} &= [3,500 * (3 * 2) * (12 - 100 / 25)] - [2,650 * (3 * 2) * (12 - 100 / 45)] \\ &= 12,533.3 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{CookingEnergy} &= (100 * 475 / 0.32) - (100 * 475 / 0.38) \\ &= 23,437.5 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{PreHeatEnergy} &= (21,000 - 15,000) \\ &= 6,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta \text{Therms} &= (12,533.3 + 23,437.5 + 6,000) * 365 / 100,000 \\ &= 153.2 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

Δtherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, a single-sided ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\begin{aligned} \Delta \text{PeakTherms} &= 153.2 / 365 \\ &= 0.4197 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESGR-V03-240101

SUNSET DATE: 1/1/2028

3.6.13. PASTA COOKER**DESCRIPTION**

This measure applies to natural gas fired dedicated pasta cookers as determined by the manufacturer and installed in a commercial kitchen. This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas fired pasta cooker.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas fired stove where pasta is cooked in a pan.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸²⁰

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,400.⁸²¹

LOADSHAPE

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

The annual natural gas energy savings from this measure is a deemed value equaling 1381 Therms.⁸²²

PEAK GAS SAVINGS

The annual peak gas energy savings from this measure is a deemed value equaling 3.781 Therms/day.⁸²³

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁸²⁰ See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

⁸²¹ Ibid

⁸²² See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

⁸²³ Calculated using the formula $\Delta\text{PeakTherms} = \Delta\text{Therms} / \text{days}$. Using deemed values $\Delta\text{PeakTherms} = 1380 \text{ Therms} / 365 \text{ days}$.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-PCKR-V01-250101

SUNSET DATE: 1/1/2028

3.6.14. RACK OVEN – DOUBLE OVEN**DESCRIPTION**

This measure applies to natural gas fired high efficiency rack oven – double oven installed in a commercial kitchen. This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas rack oven – double oven with a baking efficiency $\geq 56\%$.⁸²⁴

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas rack oven – double oven with a baking efficiency $<51\%$.⁸²⁵

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸²⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is \$3,000.⁸²⁷

LOADSHAPE

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Custom calculation below, otherwise use deemed value of 585 therms based on default values.⁸²⁸

$$\Delta Therms = (\Delta DailyPreheatEnergy + \Delta DailyIdleEnergy + \Delta DailyCookingEnergy) \times Days / 100,000$$

$$\Delta DailyPreheatEnergy = DailyPreheats \times (PreheatEnergyBase - PreheatEnergyEE)$$

⁸²⁴ Based on average test data per ASTM F2093 used in California Foodservice Rack Oven Memo 09202019 Attachment supporting the CAeTRM.

⁸²⁵ Ibid

⁸²⁶ Lifecycle determined from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment.

⁸²⁷ See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

⁸²⁸ Assumptions derived from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator, FSTC Oven Technology Assessment, Section 7: Ovens, and from FSTC Gas Double Rack Oven Test Reports.

$$\Delta \text{DailyIdleEnergy} = (\text{IdleRateBase} \times (\text{Hours} - \frac{\text{LB}}{\text{PCBase}} - \frac{\text{DailyPreheats} \times \text{PreheatTime}}{60})) - (\text{IdleRateEE} \times (\text{Hours} - \frac{\text{LB}}{\text{PCEE}} - \frac{\text{DailyPreheats} \times \text{PreheatTime}}{60}))$$

$$\Delta \text{DailyCookingEnergy} = (\frac{\text{LB} \times \text{EFOOD}}{\text{EffBase}}) - (\frac{\text{LB} \times \text{EFOOD}}{\text{EffEE}})$$

Where⁸²⁹:

DailyPreheats	= Number of preheats per day = Custom; or if unknown, 1
PreheatEnergyEE	= Preheat energy of energy efficient rack oven – double oven = Custom; or if unknown 65,758 Btu
PreheatEnergyBase	= Preheat energy of baseline rack oven – double oven = Custom; or if unknown 90,009 Btu
IdleRateEE	=Idle rate of energy efficient rack oven – double oven =Custom; or if unknown, 24,600 Btu/hr
IdleRateBase	=Idle rate of baseline rack oven – double oven =Custom; or if unknown, 36,909 Btu/hr
LB	= Pounds of food cooked per day = Custom; or if unknown, 1,200 lb/day
PCEE	= Production capacity of energy efficient rack oven – double oven = Custom; or if unknown, 279 lbs/hour
PCBase	= Production capacity of baseline rack oven – double oven = Custom; or if unknown, 272 lbs/hour
PreheatTime	= Length of a single preheat = Custom; or if unknown, 20 minutes
60	= Conversion of minutes to hour
EFOOD	= ASTM energy to food ratio, the energy absorbed by food during cooking = 235 Btu/lb
EffEE	= Cooking efficiency of energy efficient rack oven – double oven = Custom; or if unknown, use 56%
EffBase	= Cooking efficiency of baseline rack oven – double oven = Custom; or if unknown, 51%
Hours	= Average daily hours of operation = Custom; or if unknown, use 12 hours ⁸³⁰

⁸²⁹ Unless noted otherwise, assumptions consistent with Southern California Gas Company (SCG). 2019. “Reformulated baseline efficiencies and eligibility requirements for Commercial Rack Oven workpaper SWFS014-01.” Memorandum submitted to Peter Biermayer (Energy Division) and Sue Haselhorst (Ex Ante Review Team). September 18, 2019.

⁸³⁰ Typical operating hours based on oven operating schedule of 12 hours per day, 6 days per week, 52 weeks per year, provided in FSTC Gas Double Rack Oven Test Reports on various double rack ovens.

Days = Annual days of operation
 = Custom or if unknown, use 365 days per year
 100,000 = Btu to therms conversion factor

PEAK GAS SAVINGS

Custom calculation below, otherwise use deemed value of 1.602 therms/day based on default values.⁸³¹

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

Δ therms = Natural gas energy savings, calculated above

For example, a rack oven double oven with defaults from the calculation above would save:

$$\begin{aligned} \Delta PeakTherms &= 585 / 365 \\ &= 1.603 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-RKOV-V01-250101

SUNSET DATE: 1/1/2028

⁸³¹ Assumptions derived from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator, FSTC Oven Technology Assessment, Section 7: Ovens, and from FSTC Gas Double Rack Oven Test Reports.

3.6.15. ENERGY STAR HOT FOOD HOLDING CABINET**DESCRIPTION**

This measure applies to electric ENERGY STAR⁸³² hot food holding cabinets (HFHC) installed in a commercial 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 an ENERGY STAR certified HFHC.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an electric HFHC that's not ENERGY STAR certified and at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸³³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,000.⁸³⁴

LOADSHAPE

Loadshape NRE02 – Non-Residential Electric Cooking – Restaurant

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type:⁸³⁵

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.39
Average/Unknown	0.41

Algorithm

CALCULATION OF SAVINGS

⁸³² In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸³³ Lifetime from ENERGY STAR Commercial Kitchen Equipment Calculator, Hot Food Holding Cabinet Calculations, which cites reference as "FSTC research on available models, 2009".

⁸³⁴ Measure cost from ENERGY STAR Commercial Kitchen Equipment Calculator, published 2021, which cites reference as "EPA research using AutoQuotes, 2020".

⁸³⁵ Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values of 546 kWh.⁸³⁶

$$\Delta kWh = (IdleEnergyRateBase - IdleEnergyRateES) * HOURSday * Days/1000$$

Where:

IdleEnergyRateBase = Custom, otherwise
= 30 * V

V = Volume of HFHC (cubic feet)
= Custom, otherwise assume 15 cu ft

HOURSday = Average Daily Operation
= custom or if unknown, use 9 hours

Days = Annual days of operation
= custom or if unknown, use 365 days a year

IdleEnergyRateES = Custom, otherwise assume maximum ENERGY STAR Idle Energy Rate presented below. If volume is unknown assume 15 cu ft, resulting in 284W:

Cabinet Volume (cu ft)	Power (W)
$V < 13$	$21.5 * V$
$13 \leq V < 28$	$2 * V + 254$
$28 \leq V$	$3.8 * V + 203.5$

For example, if a full size HFHC, with a volume of 15 cubic ft, is installed the measure would save:

$$\begin{aligned} \Delta kWh &= ((15 * 30) - (2 * V + 254)) * 9 * 365 / 1,000 \\ &= (450 - 284) * 9 * 365 / 1,000 \\ &= 545.3 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$$\text{Hours} = HOURSday * Days$$

For example, if a full size HFHC, with a volume of 15 cubic feet, is installed in a cafeteria the measure would save:

$$\begin{aligned} &= 545.3 / (9 * 365) * 0.39 \\ &= 0.0647 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

⁸³⁶ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, published 2021.

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-HFHC-V01-250101

SUNSET DATE: 1/1/2028

3.6.16. COMBINATION OVEN**DESCRIPTION**

This measure applies to both natural gas fired and electric high efficiency combination convection and steam ovens installed in a commercial 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 new natural gas or electric combination oven meeting the ENERGY STAR⁸³⁷ idle rate and cooking efficiency requirements as specified below.⁸³⁸

ENERGY STAR Requirements (Version 3.0, Effective January 12, 2023)

Fuel Type	Operation	Idle Rate (Btu/h for Gas, kW for Electric)	Cooking-Energy Efficiency, (%)
Natural Gas (5-40 Pan Capacity)	Steam Mode Convection Mode	$\leq 200P+6,511$ $\leq 140P+3,800$	≥ 41 ≥ 57
Electric (5-40 Pan Capacity)	Steam Mode Convection Mode	$\leq 0.133P+0.6400$ $\leq 0.083P+0.35$	≥ 55 ≥ 78
Electric (3-4 Pan Capacity)	Steam Mode Convection Mode	$\leq 0.60P$ $\leq 0.05P+0.55$	≥ 51 ≥ 70

Note: P = Pan capacity as defined in Section 1.Y, of the Commercial Ovens Program Requirements Version 3.0⁸³⁹

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a natural gas or electric combination oven that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸⁴⁰

DEEMED MEASURE COST

The costs vary based on the efficiency and make of the equipment. Actual costs should be used when available, deemed costs are available in the below table when actual costs are unknown⁸⁴¹:

Oven Type & Capacity	Baseline Cost	Efficient Cost	Incremental Measure Cost
Electric < 15 Pan Capacity	\$13,919	\$16,189	\$2,269
Electric 15 – 30 Pan Capacity	\$18,966	\$21,247	\$2,281
Electric > 30 Pan Capacity	\$30,827	\$34,625	\$3,798
Gas < 15 Pan Capacity	\$15,406	\$19,338	\$3,932
Gas 15 – 30 Pan Capacity	\$20,292	\$24,509	\$4,217

⁸³⁷ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸³⁸ ENERGY STAR Commercial Ovens Key Product Criteria, version 3.0, effective January 12, 2023

⁸³⁹ Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.

⁸⁴⁰ The measure life is sourced from the Food Service Technology Center's energy savings calculator for combination ovens.

⁸⁴¹ Costs are sourced from Food Service Technology Center 2016 'Combi_2016_Prices_Updated' which is also used in the ENERGY STAR Commercial Foodservice Savings Calculator, published March, 2021.

Iowa Statewide Technical Reference Manual –3.6.16 Combination Oven

Gas > 30 Pan Capacity	\$32,508	\$38,337	\$5,829
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LOADSHAPE

Loadshape NRE02 – Non-Residential Electric Cooking – Restaurant

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type:⁸⁴²

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.39
Average/Unknown	0.41

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁸⁴³

$$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec} + \Delta PreHeatEnergy_{Elec}) * Days / 1,000$$

Where:

$\Delta CookingEnergy_{ConvElec}$ = Change in total daily cooking energy consumed by electric oven in convection mode

$$= LB_{Elec} * (E_{FOOD_{ConvElec}} / ElecEFF_{ConvBase} - E_{FOOD_{ConvElec}} / ElecEFF_{ConvEE}) * \%Conv$$

$\Delta CookingEnergy_{SteamElec}$ = Change in total daily cooking energy consumed by electric oven in steam mode

$$= LB_{Elec} * (E_{FOOD_{SteamElec}} / ElecEFF_{SteamBase} - E_{FOOD_{SteamElec}} / ElecEFF_{SteamEE}) * \%Steam$$

$\Delta IdleEnergy_{ConvElec}$ = Change in total daily idle energy consumed by electric oven in convection mode

$$= [(ElecIDLE_{ConvBase} * ((HOURS - LB_{Elec} / ElecPC_{ConvBase}) * \%Conv)) - (ElecIDLE_{ConvEE} * ((HOURS - LB_{Elec} / ElecPC_{ConvEE}) * \%Conv))]$$

$\Delta IdleEnergy_{SteamElec}$ = Change in total daily idle energy consumed by electric oven in steam mode

$$= [(ElecIDLE_{SteamBase} * ((HOURS - LB_{Elec} / ElecPC_{SteamBase}) * \%Steam)) - (ElecIDLE_{SteamEE} * ((HOURS - LB_{Elec} / ElecPC_{SteamEE}) * \%Steam))]$$

⁸⁴²Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

⁸⁴³ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated March 2021.

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$$* ((\text{HOURS} - \text{LB}_{\text{Elec}} / \text{ElecPC}_{\text{SteamEE}}) * \%_{\text{Steam}}))]$$

$\Delta \text{PreHeatEnergy}_{\text{Elec}}$ = Change in total daily energy consumed by electric oven to preheat
= $\text{Preheat}_{\text{BaseElec}} - \text{Preheat}_{\text{EEElec}}$

Where:

LB_{Elec} = Estimated mass of food cooked per day for electric oven (lbs/day)
= Custom, or if unknown, use 200 lbs (If $P < 15$) or 250 lbs (If $P \geq 15$)

$\text{EFOOD}_{\text{ConvElec}}$ = Energy absorbed by food product for electric oven in convection mode
= Custom or if unknown, use 73.2 Wh/lb

ElecEFF = Cooking energy efficiency of electric oven
= Custom or if unknown, use values from table below

	Base	EE
$\text{ElecEFF}_{\text{Conv}}$	72%	78%
$\text{ElecEFF}_{\text{Steam}}$	52%	55%

$\%_{\text{Conv}}$ = Percentage of time in convection mode
= Custom or if unknown, use 50%

$\text{EFOOD}_{\text{SteamElec}}$ = Energy absorbed by food product for electric oven in steam mode
= Custom or if unknown, use 30.8 Wh/lb

$\%_{\text{steam}}$ = Percentage of time in steam mode
= $1 - \%_{\text{conv}}$

$\text{ElecIDLE}_{\text{Base}}$ = Idle energy rate (W) of baseline electric oven
= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($\text{ElecIDLE}_{\text{ConvBase}}$)	Steam Mode ($\text{ElecIDLE}_{\text{SteamBase}}$)
< 15	1,754	5,260
> = 15 to <30	2,966	8,866
>= 30	4,418	11,875

HOURS = Average daily hours of operation
= Custom or if unknown, use 12 hours

$\text{ElecPC}_{\text{Base}}$ = Production capacity (lbs/hr) of baseline electric oven
= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($\text{ElecPC}_{\text{ConvBase}}$)	Steam Mode ($\text{ElecPC}_{\text{SteamBase}}$)
< 15	79	126
> = 15	166	295

$\text{ElecIDLE}_{\text{ConvEE}}$ = Idle energy rate of ENERGY STAR electric oven in convection mode
= Custom or if unknown, use default below:

$$= (0.083 * P + 0.350) * 1000 \text{ for 5-40 Pan Capacity}$$

$$= (0.05 * P + 0.55) * 1000 \text{ for 3-4 Pan Capacity}$$
ElecPC_{EE} = Production capacity (lbs/hr) of ENERGY STAR electric oven
 = Custom of if unknown, use values from table below

Pan Capacity	Convection Mode (ElecPC _{ConvEE})	Steam Mode (ElecPC _{SteamEE})
< 15	119	177
> = 15	201	349

ElecIDLE_{SteamEE} = Idle energy rate of ENERGY STAR electric oven in steam mode
 = Custom or if unknown, use default below:

$$= (0.133 * P + 0.64) * 1000 \text{ for 5-40 Pan Capacity}$$

$$= (0.60 * P) * 1000 \text{ for 3-4 Pan Capacity}$$

Preheat_{BaseElec} = Total preheat energy consumption per day of baseline electric unit (Wh)
 = Custom or if unknown, use default below:

Pan Capacity	Preheat _{BaseElec}
< 15	1,635
> = 15	3,146

Preheat_{EEElec} = Total preheat energy consumption per day of ENERGY STAR electric unit (Wh)

Pan Capacity	Preheat _{EEElec}
< 15	997
> = 15	1,633

Days = Days of operation per year
 = Custom or if unknown, use 365 days per year

1,000 = Wh to kWh conversion factor

For example, a 10-pan capacity ENERGY STAR electric combination oven in place of a baseline electric oven would save:

$$\begin{aligned}\Delta \text{kWh} &= (\Delta \text{CookingEnergy}_{\text{ConvElec}} + \Delta \text{CookingEnergy}_{\text{SteamElec}} + \Delta \text{IdleEnergy}_{\text{ConvElec}} + \Delta \text{IdleEnergy}_{\text{SteamElec}} + \\ &\quad \Delta \text{PreHeatEnergy}_{\text{Elec}}) * \text{Days} / 1,000 \\ \Delta \text{CookingEnergy}_{\text{ConvElec}} &= 200 * (73.2 / 0.72 - 73.2 / 0.78) * 0.50 \\ &= 782 \text{ Wh} \\ \Delta \text{CookingEnergy}_{\text{SteamElec}} &= 200 * (30.8 / 0.52 - 30.8 / 0.55) * (1 - 0.50) \\ &= 323 \text{ Wh} \\ \Delta \text{IdleEnergy}_{\text{ConvElec}} &= [(1,754 * ((12 - 200/79) * 0.50)) - (1,180 * ((12 - 200/119) * 0.50))] \\ &= 2215 \text{ Wh} \\ \Delta \text{IdleEnergy}_{\text{SteamElec}} &= [(5,260 * ((12 - 200/126) * (1 - 0.50))) - (1,970 * ((12 - 200/177) * (1 - 0.50)))] \\ &= 16,678 \text{ Wh} \\ \Delta \text{PreHeatEnergy}_{\text{Elec}} &= 1,635 - 997 \\ &= 638 \text{ Wh} \\ \Delta \text{kWh} &= (782 + 323 + 2215 + 16,678 + 638) * 365 / 1,000 \\ &= 7,532 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\Delta \text{CookingEnergy}_{\text{ConvElec}} + \Delta \text{CookingEnergy}_{\text{SteamElec}} + \Delta \text{IdleEnergy}_{\text{ConvElec}} + \Delta \text{IdleEnergy}_{\text{SteamElec}} + \Delta \text{PreHeatEnergy}_{\text{Elec}}) / (1,000 * \text{HOURS}) * \text{CF}$$

Where:

CF = Summer peak coincidence factor is dependent on building type:⁸⁴⁴

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.39
Average/Unknown	0.41

All other variables as defined above.

⁸⁴⁴Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

For example, a 10-pan capacity electric combination oven in a Full Service Limited Menu restaurant would save:

$$\begin{aligned}\Delta kW &= \Delta kWh / (1000 * HOURS) * CF \\ &= (782 + 323 + 2215 + 16,678 + 638) / (1000 * 12) * 0.51 \\ &= 0.88 kW\end{aligned}$$

NATURAL GAS SAVINGS⁸⁴⁵

$$\Delta Therms = (\Delta CookingEnergy_{ConvGas} + \Delta CookingEnergy_{SteamGas} + \Delta IdleEnergy_{ConvGas} + \Delta IdleEnergy_{SteamGas} + \Delta PreHeatEnergy_{Gas}) * Days / 100,000$$

Where:

$$\begin{aligned}\Delta CookingEnergy_{ConvGas} &= \text{Change in total daily cooking energy consumed by gas oven in convection mode} \\ &= LB_{Gas} * (E_{FOOD_{ConvGas}} / GasEFF_{ConvBase} - E_{FOOD_{ConvGas}} / GasEFF_{ConvEE}) * \%_{Conv}\end{aligned}$$

$$\begin{aligned}\Delta CookingEnergy_{SteamGas} &= \text{Change in total daily cooking energy consumed by gas oven in steam mode} \\ &= LB_{Gas} * (E_{FOOD_{SteamGas}} / GasEFF_{SteamBase} - E_{FOOD_{SteamGas}} / GasEFF_{SteamEE}) * \%_{Steam}\end{aligned}$$

$$\begin{aligned}\Delta IdleEnergy_{ConvGas} &= \text{Change in total daily idle energy consumed by gas oven in convection mode} \\ &= [(GasIDLE_{ConvBase} * ((HOURS - LB_{Gas}/GasPC_{ConvBase}) * \%_{Conv})) - (GasIDLE_{ConvEE} * ((HOURS - LB_{Gas}/GasPC_{ConvEE}) * \%_{Conv}))]\end{aligned}$$

$$\begin{aligned}\Delta IdleEnergy_{SteamGas} &= \text{Change in total daily idle energy consumed by gas oven in steam mode} \\ &= [(GasIDLE_{SteamBase} * ((HOURS - LB_{Gas}/GasPC_{SteamBase}) * \%_{Steam})) - (GasIDLE_{SteamEE} * ((HOURS - LB_{Gas}/GasPC_{SteamEE}) * \%_{Steam}))]\end{aligned}$$

$$\begin{aligned}\Delta PreHeatEnergy_{Gas} &= \text{Change in total daily energy consumed by gas oven to preheat} \\ &= Preheat_{BaseGas} - Preheat_{EEGas}\end{aligned}$$

Where:

$$LB_{Gas} = \text{Estimated mass of food cooked per day for gas oven (lbs/day)}$$

= Custom, or if unknown, use 200 lbs (If P <15), 250 lbs (If 15 ≤ P < 30), or 400 lbs (If P ≥ 30)

$$E_{FOOD_{ConvGas}} = \text{Energy absorbed by food product for gas oven in convection mode}$$

= Custom or if unknown, use 250 Btu/lb

$$GasEFF = \text{Cooking energy efficiency of gas oven}$$

= Custom or if unknown, use values from table below

	Base	EE
GasEFF _{Conv}	49%	57%
GasEFF _{Steam}	37%	41%

⁸⁴⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated March 2021.

$E_{FOOD_{SteamGas}}$ = Energy absorbed by food product for gas oven in steam mode

= Custom or if unknown, use 105 Btu/lb

$GasIDLE_{Base}$ = Idle energy rate (Btu/hr) of baseline gas oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($GasIDLE_{ConvBase}$)	Steam Mode ($GasIDLE_{SteamBase}$)
< 15	9,840	24,003
15-30	11,734	27,795
>30	15,376	27,957

$GasPC_{Base}$ = Production capacity (lbs/hr) of baseline gas oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($GasPC_{ConvBase}$)	Steam Mode ($GasPC_{SteamBase}$)
< 15	125	195
15-30	176	211
>30	392	579

$GasIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR gas oven in convection mode

= Custom or if unknown, use default below:

= $140 * P + 3,800$

$GasPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR gas oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($GasPC_{ConvEE}$)	Steam Mode ($GasPC_{SteamEE}$)
< 15	124	172
15-30	210	277
>30	394	640

$GasIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR gas oven in steam mode

= Custom or if unknown, use default below:

= $200 * P + 6511$

$Preheat_{BaseGas}$ = Total preheat energy consumption per day of baseline gas unit (BTU)

= Custom or if unknown, use default below:

Pan Capacity	$Preheat_{BaseGas}$
< 15	10,964
> = 15	15,844

$Preheat_{EEGas}$ = Total preheat energy consumption per day of ENERGY STAR gas unit (BTU)

= Custom or if unknown, use default below:

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Pan Capacity	Preheat _{EEGas}
< 15	4,467
> = 15	10,638

100,000 = Conversion factor from Btu to therms
 3.412 = Conversion factor from Wh to Btu
 Days = Days of operation per year
 = Custom or if unknown, use 365 days per year
 1,000,000 = Conversion factor from Btu to MMBtu

For example, a 10-pan capacity ENERGY STAR natural gas combination oven in place of a baseline natural gas oven would save:

$$\Delta \text{Therms} = (\Delta \text{CookingEnergy}_{\text{ConvGas}} + \Delta \text{CookingEnergy}_{\text{SteamGas}} + \Delta \text{IdleEnergy}_{\text{ConvGas}} + \Delta \text{IdleEnergy}_{\text{SteamGas}} + \Delta \text{PreHeatEnergy}_{\text{Gas}}) * \text{Days} / 100,000$$

$$\Delta \text{CookingEnergy}_{\text{ConvGas}} = 200 * (250 / 49\% - 250 / 57\%) * 50\%$$

$$= 7,160.8 \text{ Btu}$$

$$\Delta \text{CookingEnergy}_{\text{SteamGas}} = 200 * (105 / 37\% - 105 / 41\%) * 50\%$$

$$= 2,768.6 \text{ Btu}$$

$$\Delta \text{IdleEnergy}_{\text{ConvGas}} = ((9,840 * ((12 - 200 / 125) * 50\%)) - ((5,200 * ((12 - 200 / 124) * 50\%))))$$

$$= 24,161.5 \text{ Btu}$$

$$\Delta \text{IdleEnergy}_{\text{SteamGas}} = ((24,003 * ((12 - 200 / 195) * 50\%)) - (8,511 * ((12 - 200 / 172) * 50\%)))$$

$$= 85,591.0 \text{ Btu}$$

$$\Delta \text{PreHeatEnergy}_{\text{Gas}} = 10,964 - 4,467$$

$$= 6,497 \text{ Btu}$$

$$\Delta \text{Therms} = (7,160.8 + 2,768.6 + 24,161.5 + 85,591.0 + 6,497.0) * 365 / 100,000$$

$$= 460.6 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-COMBO-V01-250101

SUNSET DATE: 1/1/2028

3.7. Shell Measures

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.⁸⁴⁶ 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.⁸⁴⁷

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

⁸⁴⁶ Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.

⁸⁴⁷ 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 types⁸⁴⁸:

$$\Delta kWh = \Delta CFM_{50} * (Cool + Fan + Pump + \frac{Heat * 10,000}{(\eta_{heating} * 3,412)})$$

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:

⁸⁴⁸ 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

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{DD,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Infiltration at natural conditions as estimated by blower door testing before air sealing
= Actual⁸⁴⁹

CFM_{Post} = Infiltration at natural conditions as estimated by blower door testing after air sealing
= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{DD,cooling}$ = Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁵⁰	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

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

LM = Latent multiplier to account for latent cooling demand
= dependent on location:⁸⁵¹

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 (SEER) of cooling system (Btu/Wh)

⁸⁴⁹ 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.

⁸⁵⁰ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁵¹ 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, SEER may be calculated from other commonly listed efficiency ratings (kW/ton or SCOP):

$$\text{SEER} = 12 / \text{IPLV or NPLV (kW/ton)}$$

$$\text{SEER} = \text{SCOP} \times 3.412$$

$\Delta \text{kWh}_{\text{heating}}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{(\text{CFM}_{\text{Pre}} - \text{CFM}_{\text{Post}}) * 60 * \text{EFLH}_{\text{heating}} * \Delta T_{\text{DD,heating}} * 0.018}{(\eta_{\text{heating}} * 3,412)}$$

$\text{EFLH}_{\text{heating}}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{\text{DD,heating}}$ = Design Day temperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	$\text{OA}_{\text{DD,heating}}$ [°F] ⁸⁵²	$\Delta T_{\text{DD,heating}}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

3,142 = Conversion from Btu to kWh.

η_{heating} = Efficiency of heating system, expressed as COP

= Actual. For equipment with HSPF ratings, use the following conversion to COP:

$$\text{COP} = \text{HSPF} / 3.413$$

For example, a small retail building (2,000 SqFt) in Mason City with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}} \\ &= [((340 - 225) * 60 * 801 * 13.0 * 0.018 * 4.2) / (1000 * 10.5)] + \\ &\quad [((340 - 225) * 60 * 1,440 * 77.9 * 0.018) / (1.92 * 3,412)] \\ &= 517.3 + 2126.7 \\ &= 2,644 \text{ kWh} \end{aligned}$$

Conservative Deemed Approach

$$\Delta \text{kWh} = \text{SavingsPerUnit} * \text{SqFt}$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁸⁵³

⁸⁵² National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁵³ The values in the table represent estimates of savings from a 10-15% improvement in air leakage. The values are half those

End Use	HVAC System	SavingsPerUnit (kWh/ft ²)
Cooling Chillers	Chiller	0.027
Cooling DX	Air Conditioning	0.041
Space Heat	Electric Resistance/Furnace	0.2915
Heat Pump – Cooling	Heat Pump	0.041
Heat Pump – Heating	Heat Pump	0.1885

SqFt = Building square footage

= Actual

Additional Fan savings

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time

= $\Delta \text{therms} * F_e * 29.3$

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%⁸⁵⁴

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 = $83 * 0.0314 * 29.3$

= 76 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Note: for Multifamily, or mixed use retail plus Multifamily building types,

$$\Delta kWh_{cooling} = \Delta CFM_{50} * Cool$$

Where:

$EFLH_{cooling}$ = Equivalent Full Load hours of air conditioning are provided in Section 3.3, HVAC 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 ⁸⁵⁵	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio

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.

⁸⁵⁴ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

⁸⁵⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ⁸⁵⁵	Model Source
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁸⁵⁶	91.5%	N/A

For example, a small retail building (2,000 Sq) Ft in Mason City with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned}\Delta kW &= 517.3 / 801 * 1.00 \\ &= 0.6458 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

For Multifamily, or mixed use retail plus Multifamily building types:

$$\Delta Therms = \Delta CFM_{50} * \frac{Heat}{\eta_{heating}}$$

For all other building types:

$$\Delta Therms = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{DD,heating} * 0.018}{(\eta_{heating} * 100,000)}$$

Where:

$$100,000 = \text{Conversion from BTUs to Therms}$$

Other factors as defined above

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned}\Delta Therms &= ((340 - 225) * 60 * 1086 * 77.9 * 0.018) / (0.70 * 100,000) \\ &= 150 \text{ therms}\end{aligned}$$

Conservative Deemed Approach

⁸⁵⁶ For weighting factors, see HVAC variable table in section 3.3.

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁸⁵⁷

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:

Δ therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁵⁸	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁸⁵⁹	1.5713%	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned}\Delta PeakTherms &= 150 * 0.018843 \\ &= 2.826 \text{ therms}\end{aligned}$$

⁸⁵⁷ 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.

⁸⁵⁸ Calculated as the percentage of total savings in the maximum saving day, from models.

⁸⁵⁹ 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-SHL-AIRS-V07-270101

SUNSET DATE: 1/1/2029

3.7.2. 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 SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building:

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

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

Where:

$R_{existing}$	= Complete roof assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu] ⁸⁶⁰
R_{new}	= Complete roof assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
Area	= Area of the insulated roof surface in square feet, as measured from within the conditioned space (area of overhangs or eaves should be excluded, for example).
$EFLH_{cooling}$	= Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVACend use
$\Delta T_{DD,cooling}$	= Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁶¹	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

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

⁸⁶⁰ 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.

⁸⁶¹ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See ‘IA_Design-Day.xlsx’ in 3.7.3 Roof Insulation analysis files for more details.

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:

$$\Delta \text{kWh}_{\text{heating}} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{DD,heating}}}{(3,412 * \eta_{\text{heating}})}$$

Where:

- EFLH_{heating} = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use
- $\Delta T_{\text{DD,heating}}$ = Design Day temperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	OA _{DD,heating} [°F] ⁸⁶²	$\Delta T_{\text{DD,heating}}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

- 3,142 = Conversion from Btu to kWh.
- H_{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 an unknown location with 1,500 ft² of R-20 roof insulated to R-35, 10.5 SEER central AC, and 1.92 COP heat pump system:

$$\begin{aligned} \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}} \\ &= ((1/20 - 1/35) * 1,500 * 1.0 * 924 * 16.9 / (1,000 * 10.5)) + ((1/20 - 1/35) * 1,500 * 1.0 * 1,240 * 70.9 / (3,412 * 1.92)) \\ &= 47.8 + 431.4 \\ &= 479 \text{ kWh} \end{aligned}$$

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta \text{kWh}_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

- ΔTherms = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁶³

⁸⁶² National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁶³ 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.

29.3 = Conversion from therms to kWh

For example, for a small retail building with insulation entirely above deck in an unknown location with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned}\Delta kWh &= 32.9 * 0.0314 * 29.3 \\ &= 30.3 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

EFLH_{cooling} = Equivalent Full Load hours of air conditioning are provided in Section 3.3, HVAC end use

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

Building Type	CF ⁸⁶⁴	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁸⁶⁵	91.5%	N/A

For example, for a small retail building with insulation entirely above deck in an unknown location with 1,500 ft² of R-20 roof insulated to R-35, and 10.5 SEER central AC:

$$\begin{aligned}\Delta kW &= 47.8/924 * 1.00 \\ &= 0.0517 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

⁸⁶⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models..

⁸⁶⁵ For weighting factors, see HVAC variable table in section 3.3.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{DD,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

R_{existing}	= Complete roof heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
R_{new}	= Complete roof heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
Area	= Area of the insulated roof surface in square feet. Assume 1000 sq ft for planning.
$\text{EFLH}_{\text{heating}}$	= Equivalent Full Load Hours for Heating are provided in Section 3.3, HVAC end use
$\Delta T_{\text{DD,heating}}$	= Design Day temperature difference [°F] during heating season (see above)
100,000	= Conversion from BTUs to Therms
η_{heat}	= Efficiency of heating system
	= Actual

For example, for a small retail building with insulation entirely above deck in an unknown location with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta \text{Therms} &= ((1/20 - 1/35) * 1,500 * 1.0 * 1,240 * 70.9 / (100,000 * 0.70)) \\ &= 40.4 \text{ therms} \end{aligned}$$

Peak Gas Savings

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

Where:

Δtherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁶⁶	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁸⁶⁷	1.5713%	N/A

⁸⁶⁶ Calculated as the percentage of total savings in the maximum saving day, from models.

⁸⁶⁷ For weighting factors, see HVAC variable table in section 3.3.

For example, for a small retail building with insulation entirely above deck in an unknown location with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 40.4 * 0.016064 \\ &= 0.648 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-XINS-V08-270101

SUNSET DATE: 1/1/2028

3.7.3. FOUNDATION WALL INSULATION

DESCRIPTION

Energy and demand savings are realized through reductions in the building cooling and heating loads. Insulation is added to foundation sidewalls. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post assembly R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

For retrofit projects, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly. If existing condition is unknown, assume IECC 2006.

For new construction projects, baseline is building code, IECC 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

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

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

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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} * EFLH_{cooling} * \Delta T_{DD,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

$R_{existingAG}$	= Above grade wall heat loss coefficient, with existing insulation, for the complete structural assembly [(hr-°F-ft²)/Btu] ⁸⁶⁸
R_{newAG}	= Above grade wall heat loss coefficient, with new insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]
$Area_{AG}$	= Area of the above grade wall surface in square feet
$EFLH_{cooling}$	= Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVACend use
$\Delta T_{DD,cooling}$	= Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁶⁹	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

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

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} \right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}} \right) * Area_{BG} \right) * EFLH_{heating} * \Delta T_{DD,heating}}{(3,412 * \eta_{heating})}$$

Where:

$R_{existingBG}$	= Below grade wall assembly heat loss coefficient with existing insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]
------------------	--

⁸⁶⁸ 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.

⁸⁶⁹ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. See ‘IA_Design-Day.xlsx’ in 3.7.3 Roof Insulation analysis files for more details.

= Actual R-value of wall assembly plus “Average Earth R-value” by depth in table below⁸⁷⁰
For example, for an area that extends 5 feet below grade, an R-value of 7.46 would be selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft ² -h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft ² -h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69

R_{newBG} = Below grade wall assembly heat loss coefficient with new insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]

Area_{BG} = Area of the below grade wall surface in square feet.

$\text{EFLH}_{\text{heating}}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{\text{DD,heating}}$ = Design Daytemperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	$\text{OA}_{\text{DD,heating}}$ [°F] ⁸⁷¹	$\Delta T_{\text{DD,heating}}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

3,412 = Conversion from Btu to kWh.

H_{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.

$$\Delta \text{kWh}_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁷²

⁸⁷⁰ 6 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

⁸⁷¹ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See ‘IA_Design-Day.xlsx’ in 3.7.3 Roof Insulation analysis files for more details.

⁸⁷² F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300-record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh_{cooling} / EFLH_{cooling}) * CF$$

Where:

EFLH_{cooling} = Equivalent Full Load hours of air conditioning are provided in Section 3.3, HVACend use

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

Building Type	CF ⁸⁷³	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁸⁷⁴	91.5%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

Δ Therms

$$= \frac{\left(\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} \right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}} \right) * Area_{BG} \right) \right) * EFLH_{heating} * \Delta T_{DD,heating}}{(100,000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other terms as defined above.

Peak Gas Savings

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

⁸⁷³ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁸⁷⁴ For weighting factors, see HVAC variable table in section 3.3.

Where:

Δ therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁷⁵	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁸⁷⁶	1.5713%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-FINS-V07-270101

SUNSET DATE: 1/1/2028

⁸⁷⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

⁸⁷⁶ 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 SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is:

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

Where:

$R_{existing}$	= Complete wall assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu] ⁸⁷⁷
R_{new}	= Complete wall assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
Area	= Area of the wall surface in square feet.
$EFLH_{cooling}$	= Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use
$\Delta T_{DD,cooling}$	= Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁷⁸	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

⁸⁷⁷ 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.

⁸⁷⁸ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. See ‘IA_Design-Day.xlsx’ in 3.7.3 Roof Insulation analysis files for more details.

- 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:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * EFLH_{heating} * \Delta T_{DD,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use
- $\Delta T_{DD,heating}$ = Design Day temperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	$OA_{DD,heating}$ [°F] ⁸⁷⁹	$\Delta T_{DD,heating}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

- 3,412 = Conversion from Btu to kWh.
- $H_{heating}$ = Efficiency of heating system
- = Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * F_e * 29.3$$

Where:

- $\Delta Therms$ = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁸⁰
- 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

⁸⁷⁹ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁸⁰ F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference. Assumed to be consistent with C&I applications.

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 ⁸⁸¹	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁸⁸²	91.5%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * \text{Area} * EFLH_{heating} * \Delta T_{DD,heating}}{(100,000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Complete wall heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]

R_{new} = Complete wall heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]

Area = Area of the wall surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating are provided in Section 3.3, HVAC end use

$\Delta T_{DD,heating}$ = Design Day temperature difference [°F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Peak Gas Savings

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

Where:

⁸⁸¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁸⁸² For weighting factors, see HVAC variable table in section 3.3.

Δ therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁸³	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁸⁸⁴	1.5713%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WINS-V06-270101

SUNSET DATE: 1/1/2028

⁸⁸³ Calculated as the percentage of total savings in the maximum saving day, from models.

⁸⁸⁴ 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.⁸⁸⁵

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$1.50 per square foot of window area.⁸⁸⁶

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

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

⁸⁸⁵ Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.

⁸⁸⁶ Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{(U_{code} - U_{eff}) * A_{window} * EFLH_{cooling} * \Delta T_{DD,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)
 = Dependent on climate zone and window type. If unknown, assume the most conservative value, 0.36. See table below for IECC2012 requirements:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft².°F.h)
 = Actual.

A_{window} = Area of insulated window (including visible frame and glass) (ft²)

$EFLH_{cooling}$ Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{DD,cooling}$ = Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁸⁷	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
 = Actual. If not directly specified, SEER may be calculated from other commonly listed efficiency ratings (kW/ton or SCOP):
 $SEER = 12 / NPLV \text{ or } IPLV \text{ (kW/ton)}$
 $SEER = SCOP \times 3.412$
 = if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{(U_{code} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{DD,heating}}{(3,412 * \eta_{heating})}$$

Where:

⁸⁸⁷ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

EFLH_{heating} = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{DD,heating}$ = Design Day temperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	OA _{DD,heating} [°F] ⁸⁸⁸	$\Delta T_{DD,heating}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

3,142 = Conversion from Btu to kWh.

H_{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 an unknown location installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system and a 1.92 COP Heat Pump system:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= (((0.43 - 0.25) * 8 * 1,418 * 16.9) / (1000 * 12.0)) + (((0.43 - 0.25) * 8 * 1,096 * 70.9) / (3,412 * 1.92)) * 15 \\ &= (2.88 + 17.08) * 15 \\ &= 299.4 \text{ kWh} \end{aligned}$$

Other factors as defined above.

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁸⁹

29.3 = Conversion from therms to kWh

⁸⁸⁸ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁸⁹ F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference. Assumed to be consistent with C&I applications.

For example, for a restaurant in an unknown location installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned}\Delta kWh &= 40.9 * 0.0314 * 29.3 \\ &= 37.6 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$EFLH_{cooling}$ = Equivalent Full Load hours of air conditioning are provided in Section 3.3, HVAC end use

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

Building Type	CF ⁸⁹⁰	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁸⁹¹	91.5%	N/A

For example, for a restaurant in an unknown location installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system:

$$\begin{aligned}\Delta kW &= (1.39 * 15) / 3,038 * 0.997 \\ &= 0.0068 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{(U_{code} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{DD,heating}}{(100,000 * \eta_{heat})}$$

Where:

⁸⁹⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

⁸⁹¹ For weighting factors, see HVAC variable table in section 3.3.

U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)
 = Dependent on climate zone and window type. See table below:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft².°F.h)
 = Actual.

A_{window} = Net area of insulated window (ft²)

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating are provided in Section 3.3, HVAC end use

$\Delta T_{DD,heating}$ = Design Day temperature difference [°F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

= if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

For example, a restaurant in an unknown location installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

$$\Delta \text{Therms} = (((0.43 - 0.25) * 21 * 3,174 * 15.9) / (100,000 * 0.70)) * 15$$

$$= 40.9$$

Peak Gas Savings

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

Where:

Δtherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁹²	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest

⁸⁹² Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁸⁹²	Model Source
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁸⁹³	1.5713%	N/A

For example, a restaurant in an unknown location 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%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 40.9 * 0.018843 \\ &= 0.77\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WIND-V06-270101

SUNSET DATE: 1/1/2024*

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

⁸⁹³ For weighting factors, see HVAC variable table in section 3.3.

3.7.6. INSULATED DOORS

DESCRIPTION

Energy and demand savings are realized through reductions in the building cooling and heating loads.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an **exterior door** with insulation levels that exceed current 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.⁸⁹⁴

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 SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings are calculated as the sum of energy saved when cooling and 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

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

Where:

⁸⁹⁴ FannieMae Estimated useful life tables for multifamily properties, judged to be applicable to C&I facilities as well.

$R_{existing}$	= Existing door heat loss coefficient [(hr-°F-ft ²)/Btu]. If unknown, assume 1.43 for swinging doors, 0.69 for roll-up or sliding doors in zone 5, and 2.0 for roll-up or sliding doors in zone 6. ⁸⁹⁵
R_{new}	= New door heat loss coefficient [(hr-°F-ft ²)/Btu]
Area	= Area of the door surface in square feet.
$EFLH_{cooling}$	= Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use
$\Delta T_{DD,cooling}$	= Design Day temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{DD,cooling}$ [°F] ⁸⁹⁶	$\Delta T_{DD,cooling}$ [°F]
Zone 5 (Burlington)	93.9	18.9
Zone 6 (Mason City)	88.0	13.0
Average/unknown (Des Moines)	91.9	16.9

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:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * EFLH_{heating} * \Delta T_{DD,heating}}{(3,412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$	= Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use
$\Delta T_{DD,heating}$	= Design Day temperature difference [°F] during heating season between outdoor air temperature and assumed 68°F heating indoor temperature

Climate Zone (City based upon)	$OA_{DD,heating}$ [°F] ⁸⁹⁷	$\Delta T_{DD,heating}$ [°F]
Zone 5 (Burlington)	1.9	66.1
Zone 6 (Mason City)	-9.9	77.9
Average/ unknown (Des Moines)	-2.9	70.9

3,412	= Conversion from Btu to kWh.
$H_{heating}$	= Efficiency of heating system

⁸⁹⁵ IECC 2006 code requirement

⁸⁹⁶ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

⁸⁹⁷ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X Climate.OneBuilding.Org. . In alignment with ASHRAE handbook, design day temperatures represent 99.6 and 0.04 percentiles of hourly temperatures by location. . See 'IA_Design-Day.xlsx' in 3.7.3 Roof Insulation analysis files for more details.

= 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.

$$\Delta \text{kWh}_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.
 F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁹⁸
 29.3 = Conversion from therms to kWh

For example, for a restaurant in an unknown location installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta \text{kWh} &= 9.21 * 0.0314 * 29.3 \\ &= 8.47 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = (\Delta \text{kWh}_{\text{cooling}} / \text{LH}_{\text{cooling}}) * \text{CF}$$

Where:

$\text{EFLH}_{\text{cooling}}$ = Equivalent Full Load hours of air conditioning are provided in Section 3.3, HVAC end use
 CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁸⁹⁹	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office – Large	93.3%	OpenStudio
Office – Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail – Large	86.3%	eQuest
Retail – Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁹⁰⁰	91.5%	N/A

⁸⁹⁸ F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

⁸⁹⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁹⁰⁰ For weighting factors, see HVAC variable table in section 3.3.

For example, for a restaurant in an unknown location installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a 10.5 SEER central AC system:

$$\begin{aligned}\Delta kW &= 0.5 / 3,038 * 0.997 \\ &= 0.00016 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{DD,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = Existing door heat loss [(hr-°F-ft²)/Btu]
- R_{new} = New door heat loss coefficient [(hr-°F-ft²)/Btu]
- Area = Area of the door surface in square feet.
- $\text{EFLH}_{\text{heating}}$ = Equivalent Full Load Hours for Heating are provided in Section 3.3, HVAC end use
- $\Delta T_{\text{DD,heating}}$ = Design Day 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 an unknown location installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned}\Delta \text{Therms} &= ((1/1.43 - 1/11) * 21 * 3,174 * 15.9) / (100,000 * 0.70) \\ &= 9.21\end{aligned}$$

Peak Gas Savings

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

Where:

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

Building Type	GCF ⁹⁰¹	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio

⁹⁰¹ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁹⁰¹	Model Source
Multifamily	1.2864%	OpenStudio
Office – Large	1.1592%	OpenStudio
Office – Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio
Retail – Large	1.4303%	eQuest
Retail – Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ⁹⁰²	1.5713%	N/A

For example, for a restaurant in an unknown location installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 9.21 * 0.018843 \\ &= 0.174 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-DOOR-V08-260101

SUNSET DATE: 1/1/2029

⁹⁰² 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.⁹⁰³

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.⁹⁰⁴

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.

$$\Delta kWh = kW_{Controlled} * (Hours * \%Controlled) * (1 + (0.80/COP))$$

⁹⁰³2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

⁹⁰⁴ 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 ⁹⁰⁵
Hours	= Annual case lighting hours of use = Actual or if unknown, assume 6,575 hours ⁹⁰⁶
%Controlled	= Percentage savings due to the occupancy sensor = Actual or if unknown, assume 40% ⁹⁰⁷
0.80	= Percentage of heat from LED lighting assumed to be transferred to the refrigeration system
COP	= Coefficient of performance of cooler or freezer = Actual or if unknown, use 3.5 for coolers, 2.0 for freezers, or 2.5 for unknown cooler type ⁹⁰⁸

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned}\Delta kWh &= kW_{Controlled} * (Hours * \%Controlled) * (1 + (0.80 / COP)) \\ \Delta kWh &= 0.090 * (6,575 * 0.40) * (1 + (0.80 / 3.5)) \\ &= 290.8 kWh \text{ per control}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / Hours) * CF$$

Where:

ΔkWh	= Electric energy savings, calculated above
CF	= Summer peak coincidence factor = 100% for all building types
Other variables as defined above	

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (290.8 / 6,575) * 1.00 \\ &= 0.044 kW\end{aligned}$$

NATURAL GAS SAVINGS

⁹⁰⁵ Controlled lighting load from Efficiency Vermont No. 2018 TRM, based on LED Refrig Lighting ERCO_Talking_Points v3, PG&E

⁹⁰⁶ Assumption for a business operating 18 hours per day

⁹⁰⁷ Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls.

⁹⁰⁸ COP values from Efficiency Vermont No. 2015-90 TRM, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F (freezers) and 20°F (coolers), and a condensing temperature of 90°F. Unknown cooler type COP value is sourced from Oak Ridge National Laboratory, "Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report", 2019, Section 4.3.2.2

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-CLOS-V02-240101

SUNSET DATE: 1/1/2028

3.8.2. DOOR HEATER CONTROLS FOR COOLER OR FREEZER

DESCRIPTION

This measure applies to door heater controls installed on commercial coolers or freezers. There are two main categories of commercially available control strategies that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates door heaters when the relative humidity in a store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint. Savings result from a reduction in electric energy use due to heaters not running continuously and from reduced cooling loads when heaters are off. The assumptions included within this measure assume that door heater controls which are properly designed and commissioned will achieve approximately equivalent savings, regardless of control strategy.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a door heater control installed on a commercial glass door cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a door heater without controls, installed on a commercial glass door cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁹⁰⁹

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.⁹¹⁰

LOADSHAPE

Loadshape NRE01 – Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Doors * kW_{Base} * Hours * ESF * BF$$

Where:

$$kW_{Base} = \text{Per door electric energy consumption of door heater}$$

⁹⁰⁹ Commercial Refrigeration Anti-Sweat Heater Controls, California Technical Forum, Workpaper SWCR001-01, May 2019

⁹¹⁰ 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 ⁹¹¹
Doors	= Number of doors controlled by sensor
	= Actual
Hours	= Annual hours of cooler or freezer operation
	= Assume 8,760 hours per year
ESF	= Energy Savings Factor; percentage of hours annually that the door heater element is powered off due to controls
	= 45.1% for coolers and freezers ⁹¹²
BF	= Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional heat generated by the door heaters.
	= 1.4 for coolers, 1.8 for freezers, or 1.4 for unknown cooler type ⁹¹³

For example, a 3-door reach-in cooler with a door heater control would save:

$$\begin{aligned}\Delta kWh &= \text{Doors} * kW_{\text{Base}} * \text{Hours} * \text{ESF} * \text{BF} \\ \Delta kWh &= 3 * 0.066 * 8,760 * 0.451 * 1.4 \\ &1,095 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh	= Electric energy savings, calculated above
CF	= Summer peak coincidence factor
	= 96.4%

Other variables as defined above.

For example, a 3-door reach-in cooler with a door heater control would save:

$$\begin{aligned}\Delta kW &= (1095/8760) * 0.964 \\ &= 0.1205 \text{ kW}\end{aligned}$$

⁹¹¹ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁹¹² 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.

⁹¹³ Cooler and freezer bonus factors are from NEEP Refrigeration Loadshape Report. The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015 (pg. 78)

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-DHCT-V05-260101

SUNSET DATE: 1/1/2029

3.8.3. EFFICIENT MOTORS FOR WALK-IN AND DISPLAY CASE COOLERS / FREEZERS

DESCRIPTION

This measure applies to the replacement of an existing permanent split capacitor (PSC) evaporator fan motor with an electrically commutated motor (ECM) or Q-Sync motor on commercial walk-in or display case coolers or freezers. Savings result from a reduction in electric energy use from a more efficient fan motor and from a reduced cooling load due to less heat gain from a more efficient fan motor in the air stream.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ECM or Q-Sync installed on a commercial walk-in or display case cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard-efficiency PSC fan motor installed on a commercial walk-in or display case cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁹¹⁴

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. In actual costs are unknown, the full installed cost for a brushless DC fan or Q-Sync type motor is \$305 (\$231 for the motor, \$74 for installation labor including travel time).⁹¹⁵

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

⁹¹⁴ DEER 2014 Work Paper PGE3PREF126, as referenced in 2023 IL TRM version 11, Measure 4.6.4

⁹¹⁵ Full incremental cost of motor and labor sourced from DEER 2014 Work Paper PGE3PREF126 (cost of the controller (\$70) and controller install labor (\$92) excluded). Q-Sync and ECM motors combined into single category based on AESC, "ENERGY SAVINGS OF PERMANENT MAGNET SYNCHRONOUS FAN MOTOR ASSEMBLY REFRIGERATED CASE EVAPORATORS", May 2016, pg 26: "new PMSM fan (sync) is estimated to have same cost as a similar ECM model".

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.3 Efficient Motors for Walk-in and Display Case Coolers / Freezers

	= Actual; or if unknown, use 14.95 W for display cases ⁹¹⁶ or 42 W for walk-ins ⁹¹⁷
EFF _{Base}	= Efficiency of baseline motor
	= Actual or if unknown, use 29% ⁹¹⁸
EFF _{EE}	= Efficiency of efficient motor
	= Actual or if unknown, use 66% for ECM or 75% for Q-Sync ⁷⁵²
1,000	= Conversion factor from watts to kilowatts
Hours	= Annual hours of cooler or freezer operation
	= Assume 8,760 hours
LF	= Load factor of fan motor
	= Actual or if unknown, assume 0.90 ⁹¹⁹
DC	= Duty cycle of fan motor
	= Custom or if unknown, assume 100% ⁹²⁰
COP	= Coefficient of performance of cooler or freezer
	= Actual or if unknown, use 3.5 for coolers, 2.0 for freezers, or 2.5 for unknown cooler type ⁹²¹

For example, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\begin{aligned}\Delta \text{kWh} &= (W_{\text{Output}} / \text{EFF}_{\text{Base}} - W_{\text{Output}} / \text{EFF}_{\text{EE}}) / 1,000 \times \text{Hours} \times \text{DC} \times \text{LF} \times (1 + 1/\text{COP}) \\ \Delta \text{kWh} &= (14.95/0.29 - 14.95/0.66) / 1,000 * 8760 * 1.00 * 0.90 * (1 + 1/2.5) \\ &= 319.0 \text{ kWh}\end{aligned}$$

Savings for all efficient motor types are presented in the table below:

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
Cooler	Display Case	ECM	319.0
		Q-Sync	349.0
	Walk-in	ECM	896.2

⁹¹⁶ 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

⁹¹⁷ 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.

⁹¹⁸ Chapter 5 of Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Refrigeration Equipment, Table 5.5.12, June 2022

⁹¹⁹ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁹²⁰ Duty cycle from 2023 IL TRM Version 11 Measure 4.6.4: “operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit”

⁹²¹ COP values from Efficiency Vermont October 22, 2015 TRM, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F (freezers) and 20°F (coolers), and a condensing temperature of 90°F. Unknown cooler type COP value is sourced from Oak Ridge National Laboratory, “Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report”, 2019, Section 4.3.2.2

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.3 Efficient Motors for Walk-in and Display Case Coolers / Freezers

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
		Q-Sync	980.4
Freezer	Display Case	ECM	299.8
		Q-Sync	328.1
	Walk-in	ECM	842.4
		Q-Sync	921.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh/Hours) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 96.4%

Other variables as defined above.

For example, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (319.0/8760) * 0.964 \\ &= 0.0351 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECMF-V04-240101

SUNSET DATE: 1/1/2028

3.8.4. NIGHT COVERS FOR OPEN REFRIGERATED DISPLAY CASES

DESCRIPTION

This measure applies to the installation of retractable covers on existing open-type refrigerated and freezer display cases that are deployed during the facility unoccupied hours. Night covers are designed to reduce refrigeration energy consumption by reducing the work done by the compressor. Night covers reduce the heat and moisture entry into the refrigerated space through various heat transfer mechanisms. By fully or partially covering the case opening, night covers reduce the convective heat transfer into the case through reduced air infiltration. Additionally, they provide a measure of insulation, reducing conduction into the case, and also decrease radiation into the case by blocking radiated heat from entering the refrigerated space.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be retractable covers installed on existing open-type, commercial refrigerated or freezer display cases.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is existing open-type, commercial refrigerated or freezer display cases with no night covers installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 5 years, based on DEER 2014.⁹²²

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.⁹²³

LOADSHAPE

Loadshape NRE12: Night Covers for Refrigeration Display Cases

Algorithm

CALCULATION OF 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

⁹²² 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

⁹²³ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.4 Night Covers for Open Refrigerated Display Cases

= Actual; or if unknown, use savings rate from table below depending on display case temperature:⁹²⁴

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 day⁹²⁵

Days = Number of days per year that night covers are in use

= Actual or if unknown, use 365 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:

$$\Delta \text{kWh} = \text{CaseFt} * \text{SavingsRate} * \text{Hours} * \text{Days}$$

$$\Delta \text{kWh} = 12 * 0.03 * 6 * 365$$

$$= 788.4 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Peak savings are null because savings occur at night only.

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-NCOV-V03-240101

SUNSET DATE: 1/1/2025*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to

⁹²⁴ "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.

⁹²⁵ 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.

start using this measure again, it should be reviewed accordingly.

3.8.5. REFRIGERATED BEVERAGE VENDING MACHINE

DESCRIPTION

This measure applies to new ENERGY STAR⁹²⁶ Class A, Class B, Combination A, or Combination B refrigerated vending machines. A refrigerated beverage vending machine is a commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages (a beverage in a sealed container) on payment. ENERGY STAR vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR Class A, Class B, Combination A, or Combination B refrigerated vending machine meeting energy consumptions requirements as determined by equipment type.

Class A Machine: A refrigerated bottled and/or canned beverage vending machine that is not a combination vending machine and in which 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Class B Machine: Any refrigerated bottled and/or canned beverage vending machine not considered to be Class A, and is not a combination vending machine.

Combination Vending Machine: A bottled and/or canned beverage vending machine containing two or more compartments separated by a solid partition, that may or may not share a product delivery chute, in which at least one compartment is designed to be refrigerated, as demonstrated by the presence of temperature controls, and at least one compartment is not.

Combination A Machine: A combination vending machine where 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Combination B Machine: A combination vending machine that is not considered to be Combination A.

ENERGY STAR Requirements (Version 4.0, Effective April 29, 2020)

Equipment Type	Maximum Daily Energy Consumption (kWh/day)
Class A	$\leq 0.04836V + 2.2599$
Class B	$\leq 0.04576V + 1.936$
Combination A	$\leq 0.07998V + 2.4738$
Combination B	$\leq 0.09768V + 1.7952$

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new or rebuilt, Class A, Class B, Combination A, or Combination B refrigerated vending machine that is not ENERGY STAR certified, but adheres to Federal Energy Conservation Standards.⁹²⁷

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

⁹²⁶ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁹²⁷ 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.⁹²⁸

DEEMED MEASURE COST

The incremental cost of this measure is \$199.⁹²⁹

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}^{930}
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}^{931}
Class A	$\leq 0.04836V + 2.2599$
Class B	$\leq 0.04576V + 1.936$
Combination A	$\leq 0.07998V + 2.4738$
Combination B	$\leq 0.09768V + 1.7952$

V = Refrigerated volume⁹³² (ft³)

⁹²⁸ Measure life from Final Report: Volume 2, Assessment of Energy and Capacity Savings Potential in Iowa: Appendices. The Cadmus Group, February 28, 2012

⁹²⁹ Incremental cost from Focus on Energy, Business Programs Incremental Cost Study, PA Consulting Group, October 28, 2009

⁹³⁰ 10 CFR §431.296 (b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

⁹³¹ ENERGY STAR Version 4.0 requirements for maximum daily energy consumption

⁹³² V = the refrigerated volume (ft³) of the refrigerated bottled or canned beverage vending machine, as specified in Appendix C of the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 32.1 - 2010, "Methods of Testing for Rating Vending Machines for Bottled, Canned or Other Sealed Beverages." For combination vending machines, the refrigerated volume does not include any non-refrigerated compartments.

= Actual installed

Days = Days of vending machine operation per year

= 365 days per year

For example, an ENERGY STAR, Class A vending machine with a volume of 30 ft³ would save:

$$\Delta \text{kWh} = (\text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}) * \text{Days}$$

$$\begin{aligned} \Delta \text{kWh} &= [(0.052 * 30 + 2.43) - (0.04836 * 30 + 2.2599)] * 365 \\ &= 101.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

 ΔkWh = Electric energy savings, calculated above

Hours = Hours of vending machine operation per year

= 8,760⁹³³

CF = Summer peak coincidence factor

= 96.4%⁹³⁴**For example**, an ENERGY STAR vending machine with a volume of 30 ft³ would save:

$$\begin{aligned} \Delta kW &= (101.9 / 8,760) * 0.964 \\ &= 0.0112 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ESVE-V03-210101**SUNSET DATE: 1/1/2024***

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

⁹³³ Equipment is assumed to operate continuously, 24 hour per day, 365 days per year

⁹³⁴ 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.

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.⁹³⁵

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.⁹³⁶

LOADSHAPE

Loadshape RE09 - Residential Refrigerator

Loadshape RE02 – Residential Freezer

⁹³⁵ DOE refrigerator and freezer survival curves are used to calculate RUL for each equipment age and develop a RUL schedule. The RUL of each unit in the ARCA database is calculated and the average RUL of the dataset serves as the final measure RUL. Refrigerator recycling data from ComEd (PY7-PY9) and Ameren (PY6-PY8) were used to determine EUL with the DOE survival curves from the 2009 TSD. A weighted average of the retailer ComEd data and the Ameren data results in an average of 6.5 years. See Navigant ‘ComEd Effective Useful Life Research Report’, May 2018.

⁹³⁶ Based on program costs provided by Mid American and Alliant Energy in 2021.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS****Regression Analysis: Refrigerators**

Energy savings for refrigerators are based upon a linear regression model using the following coefficients:⁹³⁷

Independent Variable Description	Estimate Coefficient
Intercept	83.324
Age (years)	3.678
Pre-1990 (=1 if manufactured pre-1990)	485.037
Size (cubic feet)	27.149
Dummy: Side-by-Side (= 1 if side-by-side)	406.779
Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)	161.857
Interaction: Located in Unconditioned Space x CDD/365	15.366
Interaction: Located in Unconditioned Space x HDD/365	-11.067

$$\Delta kWh_{unit} = \left[83.32 + (Age * 3.68) + (Pre - 1990 * 485.04) + (Size * 27.15) \right. \\ \left. + (Side - by - side * 406.78) + (Primary Usage * 161.86) \right. \\ \left. + \left(\frac{CDD}{365} * unconditioned * 15.37 \right) + \left(\frac{HDD}{365} * unconditioned * -11.07 \right) \right] \\ - UEC_{BaseRefrig}$$

Where:

Age	= Age of retired unit
Pre-1990	= Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
Size	= Capacity (cubic feet) of retired unit
Side-by-side	= Side-by-side dummy (= 1 if side-by-side, else 0)
Primary Usage	= Primary Usage Type (in absence of the program) dummy (= 1 if Primary, else 0)
CDD	= Cooling Degree Days = Dependent on location: ⁹³⁸

⁹³⁷ 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.

⁹³⁸ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 65°F. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Climate Zone (City based upon)	GHCNd ID	Official Name	CDD 65	CDD 65 / 365
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	1,105	3.03
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	644	1.76
Average (Des Moines)	USW00014933	DES MOINES INTL AP, IA US	1,134	3.10

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

HDD = Heating Degree Days

= Dependent on location:⁹³⁹

Climate Zone (City based upon)	GHCNd ID	Official Name	HDD 60	HDD 60 / 365
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	4,832	13.23
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	6,356	17.41
Average (Des Moines)	USW00014933	DES MOINES INTL AP, IA US	5,013	13.73

UEC_{BaseRefrig} = Assumed consumption of a new baseline residential-sized refrigerator

= 558.3 kWh⁹⁴⁰

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 data⁹⁴¹:

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

⁹³⁹ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 60°F. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁴⁰ 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.

⁹⁴¹ See IA Refrig Freezer Recycling Excel Analysis File for details.

= 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)	944.9	301.6
6 (Mason City)	903.9	264.3
Average (Des Moines) ⁹⁴²	942.2	299.1

Regression Analysis: Freezers

Energy savings for freezers are based upon a linear regression model using the following coefficients:⁹⁴³

Independent Variable Description	Estimate Coefficient
Intercept	132.122
Age (years)	12.130
Pre-1990 (=1 if manufactured pre-1990)	156.181
Size (cubic feet)	31.839
Chest Freezer Configuration (=1 if chest freezer)	-19.709
Interaction: Located in Unconditioned Space x CDD/365	9.778
Interaction: Located in Unconditioned Space x HDD/365	-12.755

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

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

⁹⁴² Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁴³ 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.

$$= 381.2 \text{ kWh}^{944}$$

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 data⁹⁴⁵:

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

Deemed freezer savings are provided below:

Climate Zone (City based upon)	UEC	ΔkWh per unit
5 (Burlington)	950.4	436.1
6 (Mason City)	896.2	389.5
Average (Des Moines) ⁹⁴⁶	945.8	432.2

Additional Waste Heat Impacts⁹⁴⁷

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

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

Where:

Conditioned = % of units in conditioned space
 = 100% if unit in conditioned space, 0% if unit in unconditioned space,
 = If unknown assume unit is in conditioned space – 100%

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

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

$$= - (HF / \eta_{HeatElectric}) * \%ElecHeat$$

⁹⁴⁴ 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.

⁹⁴⁵ See IA Refrig Freezer Recycling Excel file for details.

⁹⁴⁶ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁴⁷ 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.

HF = Heating Factor or percentage of reduced waste heat that must now be heated
 = 52% for unit in heated space⁹⁴⁸
 = 0% for unit in heated space

$\eta_{\text{HeatElectric}}$ = Efficiency in COP of Heating equipment
 = Actual - If not available, use:⁹⁴⁹

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.38 ⁹⁵⁰

%ElecHeat = Percentage of businesses with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	30% ⁹⁵¹

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

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

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

= 35% for unit in cooled space⁹⁵²

= 0% for unit in uncooled space

η_{Cool} = Efficiency in COP of Cooling equipment

⁹⁴⁸ Based on 190 days where HDD 55>0, divided by 365.25. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁴⁹ 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.

⁹⁵⁰ 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.

⁹⁵¹ 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).

⁹⁵² Based on 128 days where CDD 65>0, divided by 365.25. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

= Actual - If not available, assume 2.8 COP⁹⁵³

%Cool = Percentage of businesses with cooling

AC use	%Cool
Cooling	100%
No Cooling	0%
Unknown	74% ⁹⁵⁴

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta kWh_{WasteHeat}$
Refrigerator	5 (Burlington)	-6.2
	6 (Mason City)	-5.4
	Average (Des Moines) ⁹⁵⁵	-6.1
Freezer	5 (Burlington)	-9.0
	6 (Mason City)	-8.0
	Average (Des Moines) ⁹⁵⁶	-8.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

HOURS = Equivalent Full Load Hours as calculated using eShapes loadprofile

Refrigerators = 5280

Freezers = 5895

WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat:⁹⁵⁷

Refrigerator Location	WHFdCool
Cooled space	1.33 ⁹⁵⁸
Uncooled	1.0

⁹⁵³ 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).

⁹⁵⁴ 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).

⁹⁵⁵ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁵⁶ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁵⁷ 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.

⁹⁵⁸ The value is estimated at 1.29 (calculated as $1 + (0.915 / 2.8)$). See footnote relating to WHFe for details. Note the 79.8% factor represents the non-residential average cooling coincidence factor.

CF = Coincident factor as calculated using eShapes loadprofile

Refrigerators = 70.9%

Freezers = 95.3%

Deemed approach: Refrigerators

Climate Zone (City based upon)	ΔkW per unit
5 (Burlington)	0.0387
6 (Mason City)	0.0339
Average (Des Moines)	0.0383

Deemed approach: Freezers

Climate Zone (City based upon)	ΔkW per unit
5 (Burlington)	0.0673
6 (Mason City)	0.0601
Average (Des Moines)	0.0667

NATURAL GAS SAVINGS

Heating penalty for reduction in waste heat, only for retired units from conditioned space in gas heated businesses (if unknown, assume unit is from conditioned space).⁹⁵⁹

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

Where:

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

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

$$= - (HF / \eta_{HeatGas}) * \%GasHeat$$

Where:

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

= 52.1% for unit in heated space⁹⁶⁰

= 0% for unit in unheated space

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

=Actual, if unknown assume 74%⁹⁶¹

⁹⁵⁹ 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.

⁹⁶⁰ Based on 190 days where HDD 55>0, divided by 365. NCDC US Climate Hourly Normals 15 yr (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁶¹ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy

%GasHeat = Percentage of businesses with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	70% ⁹⁶²

0.03412 = Converts kWh to Therms

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta\text{Therms}_{\text{WasteHeat}}$
Refrigerator	5 (Burlington)	-5.1
	6 (Mason City)	-4.4
	Average (Des Moines)	-5.0
Freezer	5 (Burlington)	-7.3
	6 (Mason City)	-6.5
	Average (Des Moines)	-7.3

PEAK GAS SAVINGS

Heating penalty for reduction in waste heat, only for retired units from conditioned space in gas heated businesses

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

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 190⁹⁶³

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta\text{PeakTherms}$
Refrigerator	5 (Burlington)	-0.0266
	6 (Mason City)	-0.0233

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: $((0.60 \times 0.92) + (0.40 \times 0.8)) \times (1 - 0.15) = 0.74$. Heating assumptions for small commercial buildings are expected to be similar to assumptions for residential buildings.

⁹⁶² 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.

⁹⁶³ Number of days where HDD 55 > 0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

	Average (Des Moines)	-0.0264
Freezer	5 (Burlington)	-0.0385
	6 (Mason City)	-0.0344
	Average (Des Moines)	-0.0382

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-REF-RFRC-V04-240101

SUNSET DATE: 1/1/2029

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.⁹⁶⁴ Supermarket refrigeration systems typically operate at two temperatures, medium and low. Medium temperatures are typically used for walk-in coolers where as low-temperature cases are used for walk-in freezers.

Scroll compressors have fewer moving parts than reciprocating compressors and as such operate more smoothly, quietly, and continuously.⁹⁶⁵ In addition the scroll compressor design allows them to be nearly 100% volumetrically efficient in pumping the trapped fluid.

This measure applies to one-for-one replacement of 1 to 10 horsepower refrigeration compressors and was developed to be applicable to retrofit (RF) opportunities only where an existing reciprocating compressor is being replaced with an equivalent efficient refrigeration scroll compressor.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient system is assumed to be a scroll refrigeration compressor replacing a reciprocating compressor.⁹⁶⁶

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.⁹⁶⁷

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

⁹⁶⁴ 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.

⁹⁶⁵ 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.

⁹⁶⁶ 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.

⁹⁶⁷ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.5, "Effective/Remaining Useful Life Values", California Public Utilities Commission. See "DEER2014-EUL- 2014-02-05.xlsx".

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{\left((Avg\ Cap * FLH) * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right) \right)}{1000} * units$$

Where:

Avg Cap	= Compressor average capacity in Btu/h. See reference table for values. For prescriptive measures the average capacity for each range of size is used. ⁹⁶⁸
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. ⁹⁶⁹

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

Units	= Number of units
	= Actual number of units installed

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

kW	= gross customer connected load kW savings for the measure (kW)
FLH	= Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3,910 hours for medium temperature applications and 4,139 hours for low temperature applications. ⁹⁷⁰
CF	= System Peak Coincidence Factor. Assume non-residential average of 96.4%.

NATURAL GAS SAVINGS

N/A

⁹⁶⁸ 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.

⁹⁶⁹ 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.

⁹⁷⁰ 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 Tables⁹⁷¹Baseline and Qualifying EER Values by Capacity and Temperature Application⁹⁷²

Low Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp -25°F			
Capacity Bins in BTU/Hr	HP equivalent ⁹⁷³	Average EER _{base}	Average EER _{ee}
0-4,200	1	3.85	4.39
4,200-8,399	2	4.83	5.21
8,400-12,599	3	5.06	5.37
12,600-16,799	4	5.26	5.59
16,800-20,999	5	5.36	5.80
21,000-25,199	6	5.69	6.06
25,200-29,399	7	5.71	6.15
29,400-33,599	8	6.14	6.39
33,600-37,800	9	5.64	6.06
37,800-42,000	10	5.73	6.06

Medium Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EER _{base}	Average EER _{ee}
0-7,500	1	8.14	9.03
7,500-14,999	2	9.28	10.86
15,000-22,499	3	10.64	11.83

⁹⁷¹ 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.

⁹⁷² 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.

⁹⁷³ At low temperatures the standard calculation for Compressor HP vs. Btu/Hr is 4,226 Btu/hr per HP. Round numbers to 4,200 for ease of binning.

Medium Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EER _{base}	Average EER _{ee}
22,500-29,999	4	11.18	12.15
30,000-37,499	5	11.12	12.39
37,500-44,999	6	11.74	12.70
45,000-52,499	7	11.68	12.52
52,500-59,999	8	12.54	13.12
60,000-67,499	9	12.46	13.13
67,500-75,000	10	11.44	12.37

MEASURE CODE: NR-RFG-SCR-V02-190101**SUNSET DATE: 1/1/2023***

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

3.8.8. STRIP CURTAIN FOR WALK-IN COOLERS AND FREEZERS

DESCRIPTION

This measure applies to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the cooling load. As a result, compressor run time and energy consumption are reduced.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a strip curtain added to a walk-in cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a walk-in cooler or freezer that previously had no strip curtain installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 4 years.⁹⁷⁴

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.⁹⁷⁵

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below,⁹⁷⁶ 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

⁹⁷⁴ DEER 2014 Effective Useful Life

⁹⁷⁵ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008.

⁹⁷⁶ Algorithms and assumptions from Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Strip Curtains v.1.4

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.8 Strip Curtain for Walk-in Coolers and Freezers

= 561 Btu/hr for coolers and 898 Btu/hr for freezers

	Grocery Store		Restaurant		Convenience Store		Unknown Building Type	
	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer
Q_{Base}	4,661	7,464	1,054	2,136	895	485	2,012	3,128
Q_{EE}	559	896	211	406	188	82	355	500

EER = Energy efficiency ratio of cooler or freezer

= Custom or if unknown, use value from table below as determined by building type

	Grocery Store		Restaurant or Convenience Store		Unknown Building Type	
	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer
EER	10.6	4.1	9.8	4.0	10.2	4.0

1,000 = Conversion factor from watts to kilowatts

EFLH = Equivalent full load hours of cooler or freezer

= Custom or if unknown, use 7,693 for coolers and 8,121 for freezers

A = Area (ft²) of cooler or freezer covered by strip curtains

= Custom or if unknown, assume 21 ft²

For example, a cooler with strip curtains installed at a grocery store, using the defaults from above, would save:

$$\Delta kWh = ((Q_{Base}/EER \times 1000) - (Q_{EE}/EER \times 1000)) \times EFLH/A \times A$$

$$\begin{aligned} \Delta kWh &= ((4,661/10.6 \times 1000) - (559/10.6 \times 1000)) \times 7,693/21 \times 21 \\ &= 2,977.0 \text{ kWh} \end{aligned}$$

Savings for grocery stores, restaurants, convenient stores, and unknown building types are presented in the table below.⁹⁷⁷

	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

⁹⁷⁷ Savings for unknown building types represent the average of grocery store, restaurant, and convenience store savings.

= 96.4%

Other variables as defined above.

For example, a cooler with strip curtains installed at a restaurant, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (2,977.0/7,693) * 0.964 \\ &= 0.3730 \text{ kW}\end{aligned}$$

NATURAL GAS 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 STAR⁹⁷⁸ 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.⁹⁷⁹

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	

⁹⁷⁸ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁹⁷⁹ ENERGY STAR Commercial Ice Makers Version 3.0, January 28th, 2018

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new commercial ice maker that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.⁹⁸⁰

DEEMED MEASURE COST

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is \$250 for Batch-Type and \$250 for Continuous-Type ice makers.⁹⁸¹

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.⁹⁸²

$$\Delta kWh = \left[\frac{(kWh_{Base} - kWh_{ESTAR})}{100} \right] * (Duty * H) * Days$$

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)

⁹⁸⁰Measure life from ENERGY STAR Commercial Food Service Savings Calculator updated July 15th, 2021x

⁹⁸¹Incremental costs from ENERGY STAR Commercial Food Service Savings Calculator updated July 15th, 2021. Calculator cites EPA research using AutoQuotes, October 2020.

⁹⁸²Algorithms and assumptions derived from ENERGY STAR Commercial Food Service Savings Calculator updated October July 15th, 2021

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh _{Base}	kWh _{ESTAR}
IMH	H < 300	10-0.01233H	≤ 9.20 - 0.01134H
	300 ≤ H < 800	7.05-0.0025H	≤ 6.49 - 0.0023H
	800 ≤ H < 1500	5.55-0.00063H	≤ 5.11 - 0.00058H
	1500 ≤ H ≤ 4000	4.61	≤ 4.24
RCU	H < 988	7.97-0.00342H	≤ 7.17 - 0.00308H
	988 ≤ H ≤ 4000	4.59	≤ 4.13
SCU	H < 110	14.79-0.0469H	≤ 12.57 - 0.0399H
	110 ≤ H < 200	12.42-0.02533H	≤ 10.56 - 0.0215H
	200 ≤ H ≤ 4000	7.35	≤ 6.25
Energy Consumption of Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh _{Base}	kWh _{ESTAR}
IMH	H < 310	9.19-0.00629H	≤ 7.90 - 0.005409H
	310 ≤ H < 820	8.23-0.0032H	≤ 7.08 - 0.002752H
	820 ≤ H ≤ 4000	5.61	≤ 4.82
RCU	H < 800	9.7-0.0058H	≤ 7.76 - 0.00464H
	800 ≤ H ≤ 4000	5.06	≤ 4.05
SCU	H < 200	14.22-0.03H	≤ 12.37 - 0.0261H
	200 ≤ H < 700	9.47-0.00624H	≤ 8.24 - 0.005429H
	700 ≤ H ≤ 4000	5.1	≤ 4.44

100 = Factor to convert kWh_{Base} and kWh_{ESTAR} into energy consumption per pound of ice

Duty = Duty cycle (%) of ice maker

= Custom or if unknown, use 0.75

H = Ice harvest rate (pounds of ice/day)

= Custom or if unknown, use value from table below as determined by equipment type

Ice Harvest Rate (H) of Air-Cooled Batch-Type Ice Makers		
IMH	RCU	SCU
650	1,150	170
Ice Harvest Rate (H) of Air-Cooled Continuous-Type Ice Makers		
IMH	RCU	SCU
680	1,170	240

Days = Annual days of operation

= Custom or if unknown, use 365 days per year

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned}\Delta kWh &= (((7.05 - 0.0025 * 650) - (6.49 - 0.0023 * 650)) / 100) * (0.75 * 650) * 365 \\ &= (((5.425) - (4.995)) / 100) * (0.75 * 650) * 365 \\ &= 765.1 kWh\end{aligned}$$

Savings for all ice maker types are presented in the table below.

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
IMH	9,659.7	8,894.1	765.7
RCU	14,459.8	13,010.7	1,449.1
SCU	3,778.6	3,215.6	563.0
Energy Consumption of Air Cooled Continuous-Type Ice Makers			
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
IMH	11,277.2	9,702.5	1,574.7
RCU	16,217.6	12,980.5	3,237.1
SCU	5,241.5	4,560.8	680.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- Hours = Average daily hours of operation
- = Custom or if unknown, use 12 hours per day
- CF = Summer peak coincidence factor
- = 96.4%

Other variables as defined above.

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned}\Delta kW &= 765.1 / (12 * 365) * 0.964 \\ &= 0.1684kW\end{aligned}$$

NATURAL GAS 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.⁹⁸³ Therefore, there are no assumed water impacts for this measure.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ESIM-V03-240101

SUNSET DATE: 1/1/2028

⁹⁸³ AHRI Certification Directory, Accessed on 3/14/2023

3.8.10. EFFICIENT MOTOR CONTROLS FOR WALK-IN AND DISPLAY CASE COOLERS/FREEZERS

DESCRIPTION

This measure is for the installation of controls for efficient motors – defined as electrically commutated motors (ECM) or Q-Sync motors, per measure 3.8.3 – in existing walk-in and display case coolers or freezers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow.

This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 3.8.3 Efficient Motor for Walk-in and Display Case Coolers / Freezers.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The measure must control a minimum of 16 Watts where fans operate continuously at full speed. This measure is limited to motors that are rated equal to or less than 3/4 HP output capacity. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

- The compressor runs more than 4380 hours annually
- The evaporator fan does not run at full speed all the time
- The evaporator fan motor runs on poly-phase power
- Evaporator does not use off-cycle or time-off defrost.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by electrically commutated motors (ECM) or Q-Sync motors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.⁹⁸⁴

DEEMED MEASURE COST

The measure cost is assumed to be \$58.25 (controller equipment) plus \$44.53 (controller labor) = \$102.78 per motor controlled.⁹⁸⁵

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

⁹⁸⁴ Average EUL from DEER 2014 Analysis, Energy & Resource Solutions (ERS) 2005 Measure Life Study, and ComEd 2018 Effective Useful Life Research Report

⁹⁸⁵ Southern California Edison (SCE), Emerging Products. February 2020. *Permanent Magnet Synchronous Motors in Refrigerated Display Cases*. Emerging Technologies project ET17SCE8020, Table 3.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.10 Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

Municipal Utilities Association⁹⁸⁶ and supported by a PGE workpaper. Note that climate differences across all California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Iowa. Savings found in the aforementioned source are presented in combination with savings from an ECM upgrade, however for the purposes of this measure only those associated with the controller are considered.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((5988.5 * kW_{Output}) + 63.875) * \#Motors$$

Where:

kW_{Output} = Output wattage of installed fan motor, in kW
 (From linear trend line where 5988.5 = kWh savings/kW_{output}, and 63.875 = kWh savings at 0 kW_{output})
 = Actual or if unknown, use 0.01495 kW⁹⁸⁷
 $\#Motors$ = number of fan motors controlled

For example, a cooler with ECM motor controls for three 0.15 kW evaporator fans would save:

$$\begin{aligned}\Delta kWh &= ((5988.5 * kW_{Output}) + 63.875) * \#Motors \\ \Delta kWh &= ((5988.5 * 0.15) + 63.875) * 3 \\ &= 2886.5 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above
 Hours = Annual hours of cooler or freezer operation
 = Assume 8,760 hours
 CF = Summer peak coincidence factor
 = 96.4%⁹⁸⁸

For example, a cooler with ECM motor controls for three 0.15 kW evaporator fans would save:

$$\begin{aligned}\Delta kW &= (\Delta kWh / \text{Hours}) * CF \\ \Delta kW &= ((2886.5 / 8760) * 0.964 \\ &= 0.32 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

⁹⁸⁶ See '3.8.10_Ver8_Evap Fan Control Analysis.xlsx'.

⁹⁸⁷ 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.

⁹⁸⁸ Based on modeling performed by VEIC of Grocery building type. This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.10 Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECMC-V03-250101

SUNSET DATE: 1/1/2028

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.⁹⁸⁹

DEEMED MEASURE COST

The incremental cost, which includes both material and labor, is \$522 per linear foot.⁹⁹⁰

LOADSHAPE

⁹⁸⁹ The measure life is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

⁹⁹⁰ The incremental cost is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.11 Adding Doors to Open Refrigeration Display Cases

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

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

Algorithm

CALCULATION OF 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 ⁹⁹¹
CL	= Case Length, refrigerated case length in feet = Actual
EER	= Energy Efficiency Ratio; display case compressor efficiency (Btu/hr-watt) = Actual. If unknown, use 11.36 ⁹⁹²
1000	= Conversion from watts to kilowatts (W / kW)
8760	= Annual operating hours of the refrigerated display case ⁹⁹³
$MMBtu_{HVAC\ Cool}$	= Total cooling load increase on the HVAC equipment per linear foot of display case = -2.789 MMBtu/ft ⁹⁹⁴

⁹⁹¹ 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.

⁹⁹² 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.

⁹⁹³ 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.

⁹⁹⁴ 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"

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.11 Adding Doors to Open Refrigeration Display Cases

SEER = Seasonal Energy Efficiency Ratio; HVAC equipment operating efficiency (Btu/hr-watt)
 = Actual. If unknown, use 13.00⁹⁹⁵

For example, a grocery store installed doors on four open refrigerated cases, which amounted to 12 linear feet of retrofitted display cases, saving the site:

$$\Delta kWh = ((1148 \times 12) / (11.36 \times 1000) \times 8760) + (-2.789 \times 12 \times (1 / 13) \times 1000)$$

$$= 8,049 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((\Delta HG * CL) / (EER * 1000) * CF_{Refrigeration}) + ((MMBtu_{HVAC \text{ Cool}} / Hours_{Cool} * CL * (1 / SEER) * 1000) * CF_{Cool})$$

Where:

Hours_{Cool} = Total combined hours the site is providing cooling
 = 3,530 hours⁹⁹⁶

CF_{Refrigeration} = Summer peak coincidence factor for the refrigerated display case
 = 96.4%

CF_{Cool} = Summer peak coincidence factor for the HVAC cooling system (dependent on building type)

Building Type	CF _{Cool} ⁹⁹⁷	Model Source
Convenience	91.0%	eQuest
Education	95.8%	OpenStudio
Grocery	100.0%	OpenStudio
Health	98.9%	OpenStudio
Hospital	93.6%	OpenStudio
Industrial	43.9%	eQuest
Lodging	95.5%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	93.3%	OpenStudio
Office - Small	99.7%	OpenStudio
Religious	92.9%	eQuest
Restaurant	99.7%	OpenStudio
Retail - Large	86.3%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	76.8%	eQuest
Nonresidential Average ⁹⁹⁸	91.5%	N/A

⁹⁹⁵ 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

⁹⁹⁶ 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 TMYX data for Des Moines, IA. For more information on the derivation of these hours, please see "TMYx Weather Data IA All 3 Zones.xlsx"

⁹⁹⁷ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁹⁹⁸ For weighting factors, see HVAC variable table in section 3.3.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.11 Adding Doors to Open Refrigeration Display Cases

NATURAL GAS SAVINGS

$$\Delta Therms = MMBtu_{HVAC\ Heat} * CL * (1 / AFUE) * 10$$

Where:

$\Delta Therms$	= gross customer annual therms savings
$MMBtu_{HVAC\ Heat}$	= Total heating load decrease on the HVAC equipment per linear foot of display case = 4.754 MMBtu/ft ⁹⁹⁹
CL	= Case Length, refrigerated case length in feet = Actual
AFUE	= 80% ¹⁰⁰⁰
10	= Conversion from MMBtu to therms

PEAK GAS SAVINGS

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

Where:

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

Building Type	GCF ¹⁰⁰¹	Model Source
Convenience	1.7751%	eQuest
Education	1.3853%	OpenStudio
Grocery	1.3338%	OpenStudio
Health	0.9309%	OpenStudio
Hospital	1.8875%	OpenStudio
Industrial	1.5396%	eQuest
Lodging	1.4956%	OpenStudio
Multifamily	1.2864%	OpenStudio
Office - Large	1.1592%	OpenStudio
Office - Small	1.6211%	OpenStudio
Religious	1.2885%	eQuest
Restaurant	1.8843%	OpenStudio

⁹⁹⁹ 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"

¹⁰⁰⁰ Typical heating system efficiency of 80%, consistent with current heating efficiency assumptions for lighting HVAC interactive effects for commercial fossil fuel-fired systems.

¹⁰⁰¹ Calculated as the percentage of total savings in the maximum saving day, from models.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.11 Adding Doors to Open Refrigeration Display Cases

Building Type	GCF ¹⁰⁰¹	Model Source
Retail - Large	1.4303%	eQuest
Retail - Small	1.6064%	OpenStudio
Warehouse	1.6883%	eQuest
Nonresidential Average ¹⁰⁰²	1.5713%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFR-DOOR-V02-250101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

¹⁰⁰² 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° 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.¹⁰⁰³

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 SAVINGS**ELECTRIC ENERGY SAVINGS**

Electric energy savings is dependent on whether the economizer system is installed with an auxiliary circulator fan

¹⁰⁰³ Estimated life from Efficiency Vermont TRM

and controls necessary to turn off evaporator fans when the compressor is not operating.

With Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] + [(kWEvap * nFans * DCComp * BF) - kWComp - (kWEcon * DCEcon)] * Hours$$

Without Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] - [kWEcon * DCEcon * Hours]$$

Where:

HP = Horsepower of Compressor

= actual installed

kWhCond = Condensing unit savings, per hp. Based on climate zone and compressor type (value from savings table):¹⁰⁰⁴

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:¹⁰⁰⁵

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	1,604
Zone 6 (Mason City)	2,463
Average/unknown	1,709

DCComp = Duty cycle of the compressor

= 50%¹⁰⁰⁶

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW¹⁰⁰⁷

kWComp = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW¹⁰⁰⁸

¹⁰⁰⁴ 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.

¹⁰⁰⁵ Based on TMYx 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). Please see "TMYx Weather Data IA All 3 Zones.xlsx"

¹⁰⁰⁶ 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.

¹⁰⁰⁷ Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

¹⁰⁰⁸ 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

nFans	= Number of evaporator fans = 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% ¹⁰⁰⁹
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 ¹⁰¹⁰
kWEcon	= Connected load kW of the economizer fan(s) = If known, actual installed. Otherwise assume 0.227 kW. ¹⁰¹¹

For example, adding an outdoor air economizer with an efficient circulator fan and controls in climate zone 5 to a 5 hp walk in refrigeration unit with 3 evaporator fans and a scroll compressor would annually save (assuming other default assumptions):

$$\begin{aligned}\Delta \text{kWh} &= [\text{HP} * \text{kWhCond}] + [((\text{kWEvap} * \text{nFans} * \text{DCComp} * \text{BF}) - \text{kWCirc} - (\text{kWEcon} * \text{DCEcon})) * \text{Hours}] \\ &= [5 * 665] + [((0.123 * 3 * .5 * 1.3) - 0.035 - (0.227 * 0.63)) * 1604] \\ &= 3,424.2 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No savings are expected since all savings occur during the winter months.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECON-V01-210101

SUNSET DATE: 1/1/2024*

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

¹⁰⁰⁹ Average of two manufacturer estimates of 50% and 75%.

¹⁰¹⁰ 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

¹⁰¹¹ 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.¹⁰¹²

DEEMED MEASURE COST

The deemed measure cost is \$157.19 for a walk-in cooler or freezer.¹⁰¹³ 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”.¹⁰¹⁴

Annual Savings	Refrigerated Space Temperature	kWh
Walk in Cooler	Medium	215
Walk in Freezer	Low	2,730

SUMMER COINCIDENT PEAK DEMAND SAVINGS

¹⁰¹² DEER 2014 Effective Useful Life

¹⁰¹³ Southern California Edison “Refrigerated Storage Auto Closer: Work Paper SCE17RN024 Revision 0”, pg 10. November 4, 2016.

¹⁰¹⁴ Based on NW RTF measure (v.2 from 2014) savings, which were based on the consumptions found in lab tests by Emerson Gasket Test Lab, conducted in September 2008. For specific set points & values, please see NW RTF_ComGroceryAutoCloser_v1_2.xlsm.

The measure has deemed kW savings¹⁰¹⁵ 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 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*

* 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.

¹⁰¹⁵ 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.¹⁰¹⁶

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

¹⁰¹⁶ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.14 Refrigeration Tune-Up – Remote Condensing Unit

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{\left(Capacity * FLH * \left(\frac{1}{EER_{base}} \right) \right)}{1000} * SF$$

Where:

- Capacity = Refrigeration system capacity in Btu/h. See reference table for values based on system compressors. For prescriptive measures the average capacity for each range of size is used.¹⁰¹⁷
- 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.¹⁰¹⁸

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

- SF = Refrigeration savings factor from tune-up
= 6%¹⁰¹⁹

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.¹⁰²⁰
- CF = System Peak Coincidence Factor. Assume non-residential average of 96.4%

¹⁰¹⁷ 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.

¹⁰¹⁸ 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

¹⁰¹⁹ 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.

¹⁰²⁰ 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

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.14 Refrigeration Tune-Up – Remote Condensing Unit

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

Reference Tables¹⁰²¹

Baseline and Qualifying EER Values by Capacity, and Temperature Application¹⁰²²

Low Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp -25°F		
Capacity Bins in BTU/Hr	HP equivalent ¹⁰²³	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

¹⁰²¹ 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.

¹⁰²² 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.

¹⁰²³ 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.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.14 Refrigeration Tune-Up – Remote Condensing Unit

Medium Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp 20°F		
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase
15000-22499	3	10.64
22500-29999	4	11.18
30000-37499	5	11.12
37500-44999	6	11.74
45000-52499	7	11.68
52500-59999	8	12.54
60000-67499	9	12.46
67500-75000	10	11.44

MEASURE CODE: NR-RFG-TURU-V01-220101

SUNSET DATE: 1/1/2028

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.¹⁰²⁴

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

¹⁰²⁴ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

Algorithm

CALCULATION OF 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:¹⁰²⁵

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%

¹⁰²⁵ 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

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.15 Refrigeration Tune-Up – Self-Contained Unit

Hours	= 8,760 hours
DC	=Duty cycle of compressor ¹⁰²⁶ = 62% for refrigerators = 80% for freezers
SF	= Refrigeration savings factor from tune-up = 6% ¹⁰²⁷

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 ¹⁰²⁸ = 62% for refrigerators = 80% for freezers
CF	= System Peak Coincidence Factor. Assume non-residential average of 96.4%

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-TUSC-V01-220101

SUNSET DATE: 1/1/2028

¹⁰²⁶ 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,

¹⁰²⁷ 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.

¹⁰²⁸ 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 STAR¹⁰²⁹ 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.¹⁰³⁰

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 5 years.¹⁰³¹

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: \$224¹⁰³²

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

¹⁰²⁹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

¹⁰³⁰ 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.

¹⁰³¹ 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.

¹⁰³² Southern California Edison (SCE) “SWAP011_Cost_Data_2024-03-27.xlsx

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \Delta kWh_{Lighting} + \Delta kWh_{Ref BMC}$$

$$\Delta kWh_{Lighting} = ((8760 - HOURS_{Occupied}) * WBulb) / 1000$$

$$\Delta kWh_{Ref BMC} = MDEC * SleepHours / 24 * Days$$

Where:

$HOURS_{Occupied}$ = Assumed hours of occupancy¹⁰³³

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".

$WBulb$ = Wattage of bulb in Refrigerated Beverage Vending Machine.

= Actual, if unknown use 56.4 W¹⁰³⁴ for fluorescent T8 bulbs¹⁰³⁵ and 34.2 W¹⁰³⁶ for TLEDs.

¹⁰³³ 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.

¹⁰³⁴ See IA TRM, Section 3.4.5 LED Fixtures for the F32T8 Standard Lamp - 4 foot x 2 bulbs.

¹⁰³⁵ 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)

¹⁰³⁶ See IA TRM, Section 3.4.5 LED Fixtures for the TLED Lamp x 2 bulbs.

MDEC = Maximum Daily Energy Consumption per Federal regulations¹⁰³⁷.

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. ¹⁰³⁸

SleepHours = Maximum hours of sleep mode per day.

= 4 hrs ¹⁰³⁹

Days = Operating Days/yr.

= 365

For example, adding controls to a Class B, post-2019 Vintage, Refrigerated Beverage Vending Machine, with 2 T8 bulbs, located in a Small Office:

$$\Delta kWh = \Delta kWh_{\text{lighting}} + \Delta kWh_{\text{Ref BMC}}$$

$$\begin{aligned} \Delta kWh_{\text{lighting}} &= ((8760 - \text{HOURS}_{\text{Occupied}}) * W_{\text{Bulb}}) / 1000 \\ &= ((8760 - 2920) * 56.4 \text{ W}) / 1000 \\ &= 329 \text{ kWh/yr} \end{aligned}$$

$$\begin{aligned} \Delta kWh_{\text{Ref BMC}} &= \text{MDEC} * \text{Usage Reduction Rate} * \text{Days} \\ &= 3.29 * 4/24 * 365 \\ &= 200 \text{ kWh/yr} \end{aligned}$$

$$\Delta kWh = 530 \text{ kWh/yr}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

¹⁰³⁷ 10 CFR 431. Subpart Q §431.296 (a) & (b).

¹⁰³⁸ 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.

¹⁰³⁹ 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-V02-270101

SUNSET DATE: 1/1/2030

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 ≤ 10 HP and a condensing temperature set to 70°F. This measure is strictly limited to single compressor systems.

As illustrated in the Algorithms section, impacts for this measure are influenced by compressor horsepower, temperature application (refrigerator or freezer) and whether the system is self-contained or relies on remote condensing. Self-contained units are assumed to reject heat to conditioned or semi-conditioned space, whereas remote condensing units are assumed to reject heat to the outdoor environment.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a fully commissioned single-compressor refrigeration system that has been retrofitted with floating head pressure control.

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing, single-compressor refrigeration system without floating head pressure control.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 15 years.¹⁰⁴⁰

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:¹⁰⁴¹

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

¹⁰⁴⁰ California DEER 2014 Effective Useful Life (EUL) table. See Reference file “DEER2014 EUL Table Update.xlsx”.

¹⁰⁴¹ 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 tables¹⁰⁴²:

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:

$$\Delta kWh = HP * Savings Factor$$

$$\Delta kWh = 5 * 386$$

$$= 1930 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / Hours) * CF$$

Where:

¹⁰⁴² Derived from RTF saving estimates for the NW climate zone and extrapolated to Iowa climate zone by using heating degree-days. RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v2_1.xlsm, 2020. See supporting workbook "fhp savings extrapolation iowa.xlsx" for full extrapolation.

ΔkWh = Electric energy savings, calculated above

Hours = Operating hours below the assumed 70°F setpoint, which represents hours where floating head pressure controls will produce savings:¹⁰⁴³

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	6,603
Zone 6 (Mason City)	7,229
Average/unknown	6,471

CF = Summer peak coincidence factor
= 96.4%

For example, a medium temperature, remote condensing system with 5 horsepower compressor in Zone 5, would save:

$$\begin{aligned}\Delta kW &= (1930/6603) * 0.964 \\ &= 0.2817 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-FHPC-V01-220101

SUNSET DATE: 1/1/2025*

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

¹⁰⁴³ Annual average of hours for Iowa weather zones where temperature is below 70°F. This is the assumed condensing temperature that is set for the floating head pressure control. Hours are deemed from TMYx weather data. See "TMYx Weather Data IA All 3 Zones.xlsx" for further details.

3.8.18. HIGH-SPEED ROLL UP DOORS**DESCRIPTION**

This measure involves the installation of High-Speed Doors in refrigerated warehouses. High-speed doors can save energy by reducing the time in which air infiltration occurs between refrigerated spaces and ambient outdoor conditions. This lowers the total refrigeration demand on the space, thus leading to 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

To qualify for this measure the installed equipment must be a high-speed door installed on the loading dock of a refrigerated space. The high-speed door is assumed to act as a primary door. It should be noted that for high-traffic applications (about 45 door passages per hour, using the defaults for this measure) a custom analysis is necessary to ensure that high-speed rollup doors will provide savings, because strip curtains may outperform the high-speed door, if no other open-door protection device is installed.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is existing strip curtains on doorways to a loading dock. During times of use, primary doors are left open, leaving just the strip curtains as open-doorway protection.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.¹⁰⁴⁴

DEEMED MEASURE COST

The incremental measure cost is \$96/sqft.¹⁰⁴⁵

LOADSHAPE

Loadshape C22 - Commercial Refrigeration

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Electric savings consider the change in loading on the refrigeration system as well as the consumption of the high-speed door motor. The following algorithms are based heavily on those derived and described in chapter 24 Refrigerated-Facility Loads of the ASHRAE Refrigeration Handbook.

$$\Delta kWh = (0.00008333 * q * D_f * \eta * [D_{tB}(1 - E_B) - D_{tE}(1 - E_E)] - D_{HM}M) * H$$

Where:

0.00008333 = conversion from Btu/h to tons

¹⁰⁴⁴ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

¹⁰⁴⁵ Latestcost.com, average of total costs divided by average door size. Factors influencing costs of overhead doors include the door assembly, motors, controls, installation labor, permits/codes, and removal and disposal of existing door. See reference doc "High Speed Rollup Doors costs.xlsx" for details.

q = sensible and latent refrigeration load for fully established flow, Btu/h

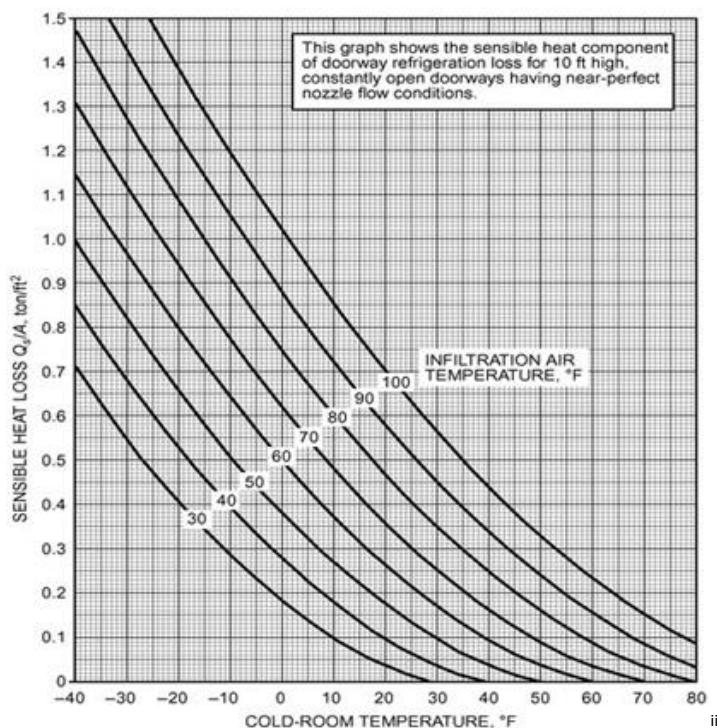
$$= 3790 * w * h^{1.5} * \left(\frac{Q_s}{A}\right) * \left(\frac{1}{R_s}\right)$$

w = width of doorway, in feet. Custom input.

h = height of doorway, in feet. Custom input.

$\frac{Q_s}{A}$ = Sensible heat load of infiltration air per square foot of door way opening, tons/sqft

As read from the following figure¹⁰⁴⁶ and dependent on infiltration air temperature and cooled space temperature. If unknown, infiltration temperature can be assumed to be 49°F,¹⁰⁴⁷ cooler temperature 35°F, and freezer temperature -10°F,¹⁰⁴⁸ resulting in values of 0.05 tons/sqft for a cooler and 0.49 tons/sqft for a freezer.



R_s = Sensible heat ratio of the infiltration air heat gain, as read or interpolated from the chart below¹⁰⁴⁹ or from a psychrometric chart, dependent on temperature and relative humidity of infiltration air and cooled space temperature. If unknown, use the same assumptions as previously, with a warm space relative humidity value of 70%,¹⁰⁵⁰ resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.

¹⁰⁴⁶ Illinois TRM V14, Volume 2, section 4.6.10 "High-speed rollup doors"

¹⁰⁴⁷ Represents the overall annual average temperature in Iowa. TMYx data for the three weather regions defined by the TRM indicate averages of 42F (Mason City), 52F (Des Moines), and 53F (Burlington).

¹⁰⁴⁸ Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011,

¹⁰⁴⁹ Illinois TRM V14, Volume 2, section 4.6.10 "High-speed rollup doors"

¹⁰⁵⁰ Represents the overall annual average in Iowa (69% rounded to nearest 10%). TMYx data for the three weather regions defined by the TRM indicate averages of 72% (Mason City), 67% (Des Moines), and 69% (Burlington).

Warm Space		Cold Space at 90% rh									
Temp.	rh,	Dry-Bulb Temperature, °F									
°F	%	-40	-30	-20	-10	0	10	20	30	40	50
70	100	0.60	0.58	0.56	0.53	0.50	0.47	0.44	0.41	0.37	0.34
	80	0.66	0.64	0.61	0.59	0.56	0.53	0.50	0.48	0.46	0.44
	60	0.72	0.70	0.68	0.66	0.63	0.61	0.59	0.58	0.59	0.64
	40	0.79	0.78	0.76	0.75	0.73	0.72	0.71	0.73	0.80	—
60	100	0.66	0.64	0.62	0.59	0.56	0.52	0.49	0.45	0.41	0.35
	80	0.71	0.69	0.67	0.64	0.62	0.59	0.56	0.53	0.52	0.53
	60	0.77	0.75	0.73	0.71	0.69	0.67	0.65	0.65	0.70	—
	40	0.83	0.82	0.81	0.79	0.78	0.77	0.78	0.83	—	—
50	100	0.72	0.70	0.67	0.64	0.61	0.57	0.53	0.49	0.43	—
	80	0.76	0.74	0.72	0.70	0.67	0.64	0.61	0.59	0.62	—
	60	0.81	0.80	0.78	0.76	0.74	0.72	0.71	0.75	—	—
	40	0.87	0.86	0.84	0.83	0.82	0.82	0.85	—	—	—
40	100	0.77	0.75	0.72	0.69	0.66	0.62	0.57	0.51	—	—
	80	0.81	0.79	0.77	0.74	0.72	0.69	0.66	0.67	—	—
	60	0.85	0.84	0.82	0.80	0.78	0.77	0.79	0.99	—	—
	40	0.90	0.89	0.88	0.87	0.86	0.88	0.97	—	—	—
30	100	0.82	0.80	0.77	0.74	0.70	0.66	0.59	—	—	—
	80	0.85	0.83	0.81	0.79	0.76	0.73	0.73	—	—	—
	60	0.88	0.87	0.86	0.84	0.83	0.83	0.94	—	—	—
	40	0.92	0.91	0.90	0.90	0.91	0.96	—	—	—	—
20	100	0.86	0.84	0.82	0.79	0.75	0.69	—	—	—	—
	80	0.89	0.87	0.85	0.83	0.81	0.80	—	—	—	—
	60	0.91	0.90	0.89	0.88	0.88	0.95	—	—	—	—
	40	0.94	0.94	0.93	0.94	0.97	—	—	—	—	—
10	100	0.90	0.88	0.86	0.83	0.78	—	—	—	—	—
	80	0.92	0.90	0.89	0.87	0.86	—	—	—	—	—
	60	0.94	0.93	0.92	0.92	0.96	—	—	—	—	—
	40	0.96	0.96	0.96	0.98	—	—	—	—	—	—
0	100	0.92	0.91	0.89	0.85	—	—	—	—	—	—
	80	0.94	0.93	0.92	0.91	—	—	—	—	—	—
	60	0.96	0.95	0.95	0.97	—	—	—	—	—	—
	40	0.97	0.97	0.98	—	—	—	—	—	—	—

D_f = doorway flow factor. Equal to 0.8 for a doorway between a freezer and a dock and 1.1 for a doorway between a cooler and a dock.¹⁰⁵¹

η = Efficiency of refrigeration system. Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton for freezers.¹⁰⁵²

D_{tB} = decimal portion of time doorway is open in the baseline condition. If during facility operating hours, the primary doors are left open, leaving only open-doorway protective devices (e.g., strip curtains) as a barrier, this is considered 1.0. If primary doors are actively operated and do not remain open for the entire time the facility is in operation, refer to the following calculation.

D_{tE} = decimal portion of time doorway is open in the efficient condition.

$$D_{tE} = \frac{(P t_{pE} + 60 t_{oE})}{3600}$$

P = Number of passages through doorway per hour. Custom input; assume 5.9 if unknown.¹⁰⁵³

3600 = Conversion from seconds to 1 hour

t_{pE} = Door open to close time in seconds. Custom input; assume 7.5 seconds if unknown.¹⁰⁵⁴

¹⁰⁵¹ ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7.

¹⁰⁵² Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD).

¹⁰⁵³ ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.11

¹⁰⁵⁴ ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.6

t_{oE} = Time door remains open in minutes. Custom input; assume 3 minutes if unknown.¹⁰⁵⁵

D_{HM} = decimal portion of time high speed door motor is operational.

$$D_{HM} = \frac{P t_{pE}}{3600}$$

Variables defined above.

E_B = effectiveness of baseline open-doorway protective device (strip curtains). Equal to 0.85.¹⁰⁵⁶

E_E = effectiveness of efficient open-doorway protective device. Equal to 0, unless an additional protective device exists to limit infiltration during times when the high-speed door is open.

M = operating input power of the high speed door motor, in kW.

= Custom input; assume 1.49kW if unknown.¹⁰⁵⁷

H = hours per year when primary doors to the cooled space are open.

= Custom input; assume 2,959 hrs/yr if unknown.¹⁰⁵⁸

Example: A refrigerated warehouse in Iowa installs a high-speed door, with a width of 8ft, a height of 10ft, a motor input power of 1.3kW, and open to close time of 6 seconds. The warehouse is maintained by the refrigeration system at 35 degrees Fahrenheit, with a full-load efficiency of 1.6kW/ton. Before installation of the high-speed door, the primary door is assumed to be open 2,500 hours per year. Passages per hour, and time spent open are unknown.

$$\begin{aligned} \Delta kWh &= (0.00008333 * q * D_f * \eta * [D_{tB}(1 - E_B) - D_{tE}(1 - E_E)] - D_{HM}M) * H \\ Q &= 3790 * 8 * 10^{1.5} * (0.05) * \left(\frac{1}{0.61}\right) \\ Q &= 78,590.35 \text{ btuh} \\ D_{tE} &= \frac{(5.9*6 + 60*3)}{3600} \\ D_{tE} &= 0.0598 \\ D_{HM} &= \frac{5.9*6}{3600} \\ D_{HM} &= 0.0098 \\ &= (0.00008333 * 78,590.35 * 1.1 * 1.6 * [1.0(1 - 0.85) - 0.0598(1-0)] - 0.0098*1.3)*2,500 \\ &= \mathbf{226.6 \text{ kWh}} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

¹⁰⁵⁵ Professional judgement.

¹⁰⁵⁶ ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7

¹⁰⁵⁷ Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives.

¹⁰⁵⁸ Based on a ComEd survey that obtained the number of hours per week certain building types operate. Warehouses had an average response of 55.6 and industrials had 58.2. Calculated by taking the simple average of the two and multiplying by 52 weeks/yr.

$$\Delta kW = (\Delta kWh / H) * CF$$

Where

CF = Summer peak coincidence factor for this measure
= 1.0

All other variables as defined above.

Example: A refrigerated warehouse, as described in previous example.

$$\begin{aligned}\Delta kW &= (226.6 kWh / 2,500) * 1.0 \\ &= \mathbf{0.0906 kW}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Manufacturers suggest annual inspection and maintenance (such as patching tears) of high-speed doors. At a minimum, greasing of fittings and oil top-off should be carried out annually. This is estimated at a cost of \$150 per year.¹⁰⁵⁹

MEASURE CODE: NR-RFG-HSRD-V01-260101

SUNSET DATE: 1/1/2029

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.

¹⁰⁵⁹ Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets.

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.¹⁰⁶⁰

DEEMED MEASURE COST

$$\text{Incremental cost} = ((\$127 \times \text{hp}_{\text{compressor}}) + \$1,446^{1061}) \times 1.51^{1062}$$

Where:

\$127 and \$1,446 = compressor motor nominal hp to incremental cost conversion factor and offset

$\text{hp}_{\text{compressor}}$ = compressor motor nominal hp

LOADSHAPE

NRE13 – Indust. 1-shift (8/5)

NRE14 – Indust. 2-shift (16/5)

NRE15 – Indust. 3-shift (24/5)

NRE16 – Indust. 4-shift (24/7)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.9 * \text{hp}_{\text{compressor}} * \text{Hours} * (CF_b - CF_e)$$

Where:

ΔkWh = gross customer annual kWh savings

0.9^{1063} = compressor motor nominal hp to full load kW conversion factor

¹⁰⁶⁰ “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)

¹⁰⁶¹ 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.

¹⁰⁶² Adjustment for inflation since the incremental cost study, as sourced from the Illinois TRM, was completed using 2008 values. The U.S. Bureau of Labor Statistic CPI Inflation Calculator was used to adjust \$2008 (January) to \$2025 (January). The resulting factor was 1.51.

¹⁰⁶³ Conversion factor based on a review of CAGI data sheets from 200 compressors. The survey and the resulting factor are

$hp_{\text{compressor}}$ = 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 ¹⁰⁶⁴	5,680 hours

CF_b = baseline compressor factor

Baseline Compressor	Compressor Factor (≤ 40 hp) ¹⁰⁶⁵	Compressor Factor (50 - 200 hp) ¹⁰⁶⁶
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/ 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

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).

¹⁰⁶⁴ 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)

¹⁰⁶⁵ 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).

¹⁰⁶⁶ 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).

For example, a 20-horsepower compressor with inlet modulating with blowdown controls is integrated with a VSD, operating a single-shift facility would save:

$$\Delta kWh = 0.9 \times 20 \times 1,976 \times (0.890 - 0.705)$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹⁰⁶⁷	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-V02-260101

SUNSET DATE: 1/1/2029

¹⁰⁶⁷ 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.¹⁰⁶⁸

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)

¹⁰⁶⁸ 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 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:¹⁰⁶⁹

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:¹⁰⁷⁰

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%¹⁰⁷¹

kW/CFM_{Saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:¹⁰⁷²

Air Compressor Type	kW/CFM_{Saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136
Screw – Load/Unload	0.152

¹⁰⁶⁹ Review of manufacturer's information and data as sourced from "Technical Reference Manual (TRM) for Ohio, Senate Bill 221: Energy Efficiency and Conservation Program", October 15, 2009 (pg. 170-171)

¹⁰⁷⁰ 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

¹⁰⁷¹ 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.

¹⁰⁷² 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 ¹⁰⁷³	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 ¹⁰⁷⁴	5,680 hours

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹⁰⁷⁵	80%

NATURAL GAS SAVINGS

¹⁰⁷³ 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

¹⁰⁷⁴ 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)

¹⁰⁷⁵ 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: 1/1/2029

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.¹⁰⁷⁶

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.¹⁰⁷⁷

LOADSHAPE

NRE03 – Industrial Motor

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{reduced} * kW/CFM_{Saved} * Hours$$

¹⁰⁷⁶ “Measure Life Study”, prepared for the Massachusetts Joint Utilities, Energy & Resources Solutions, 2005. Value is based on C&I compressor retrofit effective useful lives.

¹⁰⁷⁷ Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data. The cost analysis and product review is sourced from the Illinois TRM, version 8.0, October 2019 analysis file “CAS Cost Data.xls” (4.7.3 Compressed Air No-Loss Condensate Drains)

Where:

ΔkWh = gross customer annual kWh savings

CFM_{reduced} = Reduced air consumption per drain

= 3 CFM^{1078}

kW/CFM_{saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:¹⁰⁷⁹

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 ¹⁰⁸⁰	0.107

Hours = Compressed air system pressurized hours

= 6,136 hours¹⁰⁸¹

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

= 95%

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

¹⁰⁷⁸ 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).

¹⁰⁷⁹ 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).

¹⁰⁸⁰ 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

¹⁰⁸¹ “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: 1/1/2029

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 ¹⁰⁸²

DEEMED MEASURE COST

The incremental cost for this measure is estimated to be \$1,000 per filter. ¹⁰⁸³

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:

¹⁰⁸² Based on survey of manufacturer claims (Zeks, Van Air, Quincy).

¹⁰⁸³ Based on incremental cost research found in 'CAS Cost Data LPDF. xls'.

Control Type	kW _{typical} ¹⁰⁸⁴
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 ¹⁰⁸⁵	77.6

ΔP = Reduction in pressure differential across the filter (psi)

=2 psi¹⁰⁸⁶

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 0.005¹⁰⁸⁷

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 HP¹⁰⁸⁸

HP_{Actual} = Total HP of actual compressors distributing air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

¹⁰⁸⁴ See “Industrial System Standard Deemed Saving Analysis.xls”.

¹⁰⁸⁵ 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

¹⁰⁸⁶ 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

¹⁰⁸⁷ “Optimizing Pneumatic Systems for Extra Savings,” Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.

¹⁰⁸⁸ See “Industrial System Standard Deemed Saving Analysis.xls”.

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹⁰⁸⁹	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***

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

¹⁰⁸⁹ 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.¹⁰⁹⁰

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 years¹⁰⁹¹

DEEMED MEASURE COST

$$\text{Incremental cost (\$)} = 4.67 * (\text{TANK}_E - \text{TANK}_B)^{1092}$$

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

¹⁰⁹⁰ 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.

¹⁰⁹¹ 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions

¹⁰⁹² 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$DkWh = 0.9 * HP_{compressor} * HOURS * (CF_b - CF_e)$$

Where:

0.9^{1093} = 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 ¹⁰⁹⁴	5,680 hours

CF_b = baseline compressor factor¹⁰⁹⁵

= 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.

¹⁰⁹³ Conversion factor based on Survey of CAGI data sheets from 200 compressors. See “IL TRM VSD Air Compressor – Supporting Information.xls” for more information.

¹⁰⁹⁴ 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)

¹⁰⁹⁵ 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) ¹⁰⁹⁶	Compressor Factor (50 – 200 hp) ¹⁰⁹⁷
Modulating w/ Blowdown	0.890	0.863
Load/No Load w/ 1 Gallon/CFM	0.909	0.887
Load/No Load w/ 3 Gallon/CFM	0.831	0.811
Load/No Load w/ 4 Gallon/CFM	0.812	0.792
Load/No Load w/ 5 Gallon/CFM	0.806	0.786

CF_e = efficient compressor factor

= See table above for load/no load compressors with the adequate storage capacity installed. If unknown, default to load/no load compressors w/ 4 gallons/cfm.

For example, a 2-shift facility with a 100-hp modulating (with blowdown) adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

$$\begin{aligned} \text{Capacity Check:} &= 2,000 \text{ gallons} / (100 \text{ hp} * 4.5 \text{ cfm/hp}) \\ &= 4.4 \text{ gallons per cfm} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh} &= 0.9 * 100 * 3,952 * (0.863 - 0.792) \\ &= 25,253 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$DkW = \frac{DkWh}{HOURS} * CF$$

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹⁰⁹⁸	80%

¹⁰⁹⁶ 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.

¹⁰⁹⁷ 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.

¹⁰⁹⁸ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

For example, a 2-shift facility with a 100-hp VSD modulating (with blowdown) compressor adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

$$\begin{aligned}\Delta kW &= 25,253 / 3,952 * 0.95 \\ &= 6.1 \text{ kW}\end{aligned}$$

NATURAL GAS 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-CSRT-V01-220101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

3.9.6. COMPRESSED AIR HEAT RECOVERY**DESCRIPTION**

Air compressors are inherently inefficient, converting 80 to 93% of the electrical input energy into heat.¹⁰⁹⁹ Recovering this wasted heat for useful purposes is one method for reducing facility-level energy use. Typical air compressor heat recovery involves ducting air-cooled air compressor exhaust for space heat. Recovered heat can also be used for process heating, water heating, and boiler makeup water heating, but this workpaper only addresses the most common scenario.

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 air-cooled air compressor that is ducted for heat recovery during the heating season. The ducting must include a thermostat that controls the heat recovery based on whether heating is needed.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an air-cooled air compressor whose exhaust is ducted to the outdoors or to a space where heat is not needed (e.g., compressor room, unoccupied space).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

15 years¹¹⁰⁰

DEEMED MEASURE COST

\$80/hp¹¹⁰¹

LOADSHAPE

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

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

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

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

¹⁰⁹⁹ Ron Marshall, William Scales, Gary Shafer, Paul Shaw, Paul Sheaffer, Rick Stasyshan, H.P. Improving Compressed Air System Performance: A Sourcebook for Industry v3. United States: N. p., 2016.

¹¹⁰⁰ The 15-year measure life is based on the value for HVAC controls within the ComEd EUL research. The ductwork has an estimated 20-year measure life but is limited by the mechanical and thermostatic controls.

¹¹⁰¹ This estimate is based on three representative projects received through the Nicor Custom Program. The costs in these three projects were \$73/hp, \$76/hp, and \$84/hp.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta \text{therms} = \eta_{\text{HR}} * 2,545 * \text{hp} * \text{PP} * \text{Hours} * \text{CHF} / 100,000 / \eta_{\text{heat}}$$

Where:

η_{HR} = Efficiency of heat recovery

= 80%¹¹⁰²

2,545 = Conversion factor, Btu/hp-hr

hp = Nominal horsepower of the compressor

PP = Percent power at average load (% flow or capacity) conditions. See table below.

If average flow is unknown, assume 65%.¹¹⁰³

If compressor type is unknown, assume Load/No-load (1 gal/CFM).

= 94%

Avg. % Capacity	On/Off Control	Load/No-Load (1 gal/cfm)	Load/No-Load (10 gal/cfm)	Inlet Valve Modulation (w/o Blowdown)	Inlet Valve Modulation (w/ Blowdown)	Variable Displacement	VSD w/ Unloading	VSD w/ Stopping
0%	0%	27%	27%	71%	26%	25%	12%	0%
10%	10%	32%	35%	74%	40%	34%	20%	12%
20%	20%	63%	42%	76%	54%	44%	28%	24%
30%	30%	74%	52%	79%	62%	52%	36%	33%
40%	40%	81%	60%	82%	82%	61%	45%	41%
50%	50%	87%	68%	86%	86%	63%	53%	53%
60%	60%	92%	76%	88%	88%	69%	60%	60%
65%	65%	94%	80%	90%	90%	73%	66%	66%
70%	70%	95%	83%	92%	92%	77%	71%	71%
80%	80%	98%	89%	94%	94%	85%	80%	80%
90%	90%	100%	96%	97%	97%	91%	89%	89%
100%	100%	100%	100%	100%	100%	100%	100%	100%

Hours = Compressor hours of operation below depending on shift.

= Use actual hours if known, otherwise assume values in table below:

¹¹⁰² Ron Marshall, William Scales, Gary Shafer, Paul Shaw, Paul Sheaffer, Rick Stasyshan, H.P. Improving Compressed Air System Performance: A Sourcebook for Industry v3. United States: N. p., 2016 (page 14).

¹¹⁰³ The analysis of compressor load factors for the Illinois TRM's 4.7.1 VSD Air Compressor measure show an average load factor range of 63 – 65%. For more information, please see: "IL TRM VSD Air Compressor – Supporting Information.xls".

Shift	Hours
Single Shift	1,976
Two Shifts	3,952
Three Shifts	5,928
Four Shifts or Continual Operation	8,320
Unknown / Weighted average ¹¹⁰⁴	5,680

CHF = Climate heating factor. This value represents the amount of time that the facility has a use for space heating. See table below for values.¹¹⁰⁵

Zone	Climate Heating Factor
5 – Mason City	58%
Average/Unknown – Des Moines	51%
6 – Burlington	51%

100,000 = Conversion factor, Btu/therm

η_{heat} = Heating system efficiency

= If actual heating system efficiency is unknown, assume 80%¹¹⁰⁶

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-CAHR-V01-250101

SUNSET DATE: 1/1/2028

¹¹⁰⁴ 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).

¹¹⁰⁵ These values reflect a ratio of the hours below a heating balance point over 8,760. The heating balance point is assumed to be 55°F. The data source is TMYX data. See “Compressed Air Heat Recovery – Climate Heating Factor.xlsx” file for derivation.

¹¹⁰⁶ 80% is the federal minimum efficiency of gas-fired unit heaters. Unit heaters are a common heat source in industrial and manufacturing settings, where compressed air is likely to be in place.

3.9.7. COMPRESSED AIR CYCLING DRYER**DESCRIPTION**

An air dryer is an essential component in a compressed air system that prevents condensate from being deposited in the compressed air supply lines of a facility. If warm saturated compressed air is supplied directly to the plant, excess condensate will form in the compressed air supply lines. Uncontrolled condensate can damage demand-side tools and process equipment. Secondly, in an oil-flooded rotary screw compressor, the residual oil from compression can be carried along the supply lines potentially damaging process equipment. Industries that use compressed air for processes make use of various types of dryers including refrigerated dryers (both cycling and non-cycling). For this measure, three types of refrigerated air dryers will be considered: thermal mass, variable speed, and digital scroll. All these technologies offer better part load performance compared to non-cycling refrigerated dryers, thereby offering energy savings during periods when the dryer is not operating at peak capacity.

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

A new, high efficiency thermal mass dryer, variable speed dryer, or digital scroll dryer.

DEFINITION OF BASELINE EQUIPMENT

A standard non-cycling refrigerated compressed air dryer of comparable capacity.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 13 years.¹¹⁰⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$6 per CFM.¹¹⁰⁸

LOADSHAPE

Loadshape NRE13 – Indust. 1-shift (8/5)

Loadshape NRE13 – Indust. 2-shift (16/5)

Loadshape NRE13 – Indust. 3-shift (24/5)

Loadshape NRE13 – Indust. 4-shift (24/7)

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = P_s * (\text{EC50}_{\text{baseline}} - \text{EC50}_{\text{efficient}}) * \text{HOURS} * \text{CFM}$$

¹¹⁰⁷ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

¹¹⁰⁸ Analysis of material cost between cycling and non-cycling dryers according to online prices from Grainger. Cost provided is the average incremental cost when comparing non-cycling and cycling dryers of the same CFM capacity.

Where:

- P_s = Full flow specific power of the dryer
 = 0.007 kW/CFM¹¹⁰⁹ (for both baseline and efficient equipment)
- $EC50_{baseline}$ = Energy consumption ratio of baseline dryer at 50%¹¹¹⁰ inlet load capacity as compared to fully loaded operating conditions.¹¹¹¹
 = 0.843
- $ECF50_{efficient}$ = Energy consumption ratio of efficient dryer at 50% inlet load capacity as compared to fully loaded operating conditions.
 = Dependent on efficient dryer type, refer to the following table:¹¹¹²

Dryer Type	$EC50_{efficient}$
Thermal-Mass	0.729
VSD	0.501
Digital Scroll	0.551

HOURS = Compressed air system pressurized hours, depending on shift. If unknown, use weighted average. This value is the weighted average of facility owner responses from the DOE evaluation of the Compressed Air Challenge. Facility owners with compressed air systems were surveyed detailing the number of shifts their facilities operated.

Shift	Shift	Hours	Distribution of Facilities by Hours of Operation ¹¹¹³	Weighted Hours
Single Shift	7 AM – 3 PM, weekdays, minus some holidays and scheduled down time	1,976	16%	316
Two Shift	7AM – 11 PM, weekdays, minus some holidays and scheduled down time	3,952	23%	909
Three Shift	24 hours per day, weekdays, minus some holidays and scheduled down time	5,928	25%	1,482
Four Shifts or Continual Operation	24 hours per day, 7 days a week minus some holidays and scheduled down time	8,320	36%	2,995
			Total Weighted Average:	5,680

CFM = Cubic feet per minute, rated capacity of refrigerated dryer
 = Assume 100% of actual rated capacity.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

¹¹⁰⁹ Compressed Air Challenge: Compressed Air Best Practice; “Cycling Air Dryers – Are Savings Significant?” Fox, Timothy J. and Marshall, Ron.

¹¹¹⁰ Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50% capacity.

¹¹¹¹ Compressed Air Challenge: Compressed Air Best Practice; “Cycling Air Dryers – Are Savings Significant?” Fox, Timothy J. and Marshall, Ron.

¹¹¹² Compressed Air Challenge: Compressed Air Best Practice; “Cycling Air Dryers – Are Savings Significant?” Fox, Timothy J. and Marshall, Ron.

¹¹¹³ DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.

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

Where:

CF = Summer peak coincidence factor, depending on shift. If unknown, use weighted average.

Shift	Coincidence Factor
Single Shift	0.59
Two Shifts	0.95
Three Shifts	0.95
Four Shifts or Continual Operation	0.95
Unknown / Weighted average ¹¹¹⁴	0.89

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-CACD-CADR-V01-250101

SUNSET DATE: 1/1/2028

¹¹¹⁴ Weighting of 16% single shift, 23% two shift, 25% three shift and 36% continual based on DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.

3.9.8. COMPRESSED AIR LEAK REPAIR

DESCRIPTION

This measure outlines the potential energy savings by reducing losses and repairing leaks in a compressed air system. Leaks can be responsible for 20-30% of the total air compressor output in a facility. This measure is applicable to compressed air systems in manufacturing environments where blow off, pneumatic tools and manufacturing processes of many varieties are utilized.

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 for this measure is a compressed air system with identified air leaks that have been repaired to minimize the compressed air being wasted.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is an existing compressed air system.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected life of this measure is 2 years¹¹¹⁵.

DEEMED MEASURE COST

The incremental cost for this measure is \$8 per horsepower¹¹¹⁶.

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)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (N_{leaks} * CFM_{leaks} * Hours * C_{aircomp} * \frac{Control Factor}{hp_{typical}}) * hp_{real}$$

Where:

ΔkWh = Gross customer annual kWh savings

N_{leaks} = Number of leaks repaired

¹¹¹⁵ PA Consulting Group. Focus on Energy, Business Programs: Measure Life Study Final Report. August 25, 2009.

¹¹¹⁶ Engineering estimate from previous project cost data review and engineering judgment as obtained from Minnesota Technical Reference Manual Version 4.1, Industrial Compressed Air – Compressed Air Leak Detection, effective January 1, 2025.

CFM_{leaks} = CFM loss per leak from table below¹¹¹⁷:

Pressure (psig)	Leak Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.3	1.2	4.8	19.2	76.7	173
80	0.33	1.3	5.4	21.4	85.7	193
90	0.37	1.5	5.9	23.8	94.8	213
100	0.41	1.6	6.5	26	104	234
125	0.49	2	7.9	31.6	126	284

*Values in CFM

$C_{aircomp}$ = Compressor efficiency

= Actual. If compressor type is unknown, use 0.19 kW/CFM.¹¹¹⁸

Type	$C_{aircomp}$ kW/CFM
Single-acting Reciprocating Air Compressor	0.23
Double-acting Reciprocating Air Compressor	0.155
Lubricant-injected Rotary Screw Compressor	0.185
Lubricant-free Rotary Screw Compressor	0.2
Centrifugal Compressor	0.18
Average/unknown	0.19

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)

¹¹¹⁷ Leakage rates(cfm) for different supply pressures and approximately equivalent orifice sizes obtained from Energy Tips – Minimize Compressed Air Leaks

¹¹¹⁸ Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg 28-32.

Unknown / Weighted average ⁵	5,680 hours
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Control Factor = Efficiency Factors per control type for air compressors, see table below. If the control type is unknown, use 0.3 %kW/%load¹¹¹⁹

Control Type	Control factor (%kW/%load)
Inlet Valve Modulated	0.31
Variable Displacement	0.69
Variable Speed Drive	0.85

$hp_{typical}$ = Nominal HP for typical compressor
= 100 HP¹¹²⁰

hp_{real} = total hp of real compressors. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors
= Actual

For example, the repair of a 500hp system running at 100psig in a 3-shift facility that fixes 10 leaks that are 1/32" in size and has an unknown compressor and control type would save the following:

$$\Delta kWh = (N_{leaks} * CFM_{leaks} * Hours * C_{aircomp} * \frac{Control Factor}{hp_{typical}}) * hp_{real}$$

$$= (10 * 5,928 * 1.6 * 0.19 * 0.3 / 100) * 500$$

$$= 27,032 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\Delta kWh}{Hours} \right) * CF$$

Where:

CF = Summer peak coincidence factor, see table below:

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹¹²¹	80%

¹¹¹⁹ Compressed Air Challenge "Fundamentals of Compressed Air Systems" Pg 90-91.

¹¹²⁰ Consistent with 3.9.4 Low Pressure Drop Filters. See "Industrial System Standard Deemed Saving Analysis.xls".

¹¹²¹ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, "Evaluation of

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-CALR-V01-260101

SUNSET DATE: 1/1/2029

the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules).

3.9.9. EFFICIENT DESICCANT DRYER

DESCRIPTION

Reduction or elimination of condensation that can be harmful to a compressed air system or end use equipment can be done by drying the air with desiccant dryers. Regenerative desiccant air dryers are typically used for applications that require air to be dried below a dew point of 35°F¹¹²². Typically, these dryers can achieve pressure dew points as low as -40°F.

Regenerative desiccant dryers generally consist of two towers (or vertical tanks) filled with porous desiccant media. “Wet” compressed air flows through one tower, exiting as dried compressed air, while the other tower is dried out (or regenerated). To prevent the compressed air from flowing through saturated towers which could result in damage to end use equipment, the dryer alternates the process between the two towers. There are different types of regenerative dryers which are differentiated by the means of regeneration for the unit. These include heatless, heated, and externally heated blower purge units, as described below.

Heatless Desiccant Dryer: Uses compressed air (“purge air”) to dry out the regenerating tower. The amount of purge air is typically between 15-20% of the dryer’s rate flow (CFM), regardless of the flow rate that the compressor is supplying.¹¹²³ This type of dryer alternates tower regeneration approximately every 5 minutes.¹¹²⁴

Heated Desiccant Dryer: Uses a combination of compressed purge air and heat for regeneration. The amount of purge air is typically 5-10% of the dryer’s rate flow (CFM), regardless of the flow rate that the compressor is supplying.¹¹²⁵ This type of dryer alternates tower regeneration approximately every 8 hours.¹¹²⁶

Externally Heated Blower Purge Dryer: Uses an external blower and heat source for regeneration. This type of dryer requires a small amount (2%) of purge air or ambient air to cool the tower after heating. This type of dryer alternates tower regeneration approximately every 8 hours.¹¹²⁷ There is also a type of blower purge dryer called a zero-purge dryer that eliminates all compressed purge air.

The energy use of these dryers is primarily due to regeneration of the desiccant. Standard dryers come equipped with a fixed, timer regeneration control. However, the actual load on the dryer is variable. Optional dew point demand controls (DPDC) adjust the amount of regeneration to the moisture load on the dryer, reducing unnecessary purge energy.

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

DEFINITION OF EFFICIENT EQUIPMENT

¹¹²² The dew point limitation of the most common refrigerant-type air dryer. Improving Compressed Air System Performance: A Sourcebook for Industry, US Department of Energy. Page 48.

<https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf>

¹¹²³ Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers, Marshall, Ron.

<https://airbestpractices.com/system-assessments/air-treatment2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹²⁴ Regenerative Desiccant Compressed Air Dryers. White, Donald. <https://airbestpractices.com/technology/air-treatment2/regenerative-desiccant-compressed-air-dryers>

¹¹²⁵ Types of Compressed Air Dryers 2: Refrigerant and Regenerative Desiccant, Compressed Air and Gas Institute (CAGI). <https://airbestpractices.com/technology/air-treatment/n2/types-compressed-air-dryers-refrigerant-and-regenerative-desiccant>

¹¹²⁶ Regenerative Desiccant Compressed Air Dryers. White, Donald. <https://airbestpractices.com/technology/air-treatment2/regenerative-desiccant-compressed-air-dryers>

¹¹²⁷ Regenerative Desiccant Compressed Air Dryers. White, Donald. <https://airbestpractices.com/technology/air-treatment2/regenerative-desiccant-compressed-air-dryers>

The efficient condition for this measure is a heated desiccant dryer (or externally heated via blower purge) without dew point demand controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is a heatless desiccant dryer without dew point demand controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 15 years.¹¹²⁸

DEEMED MEASURE COST

The incremental cost for this measure is \$3/CFM for a heated unit and \$12/CFM for blower purge.¹¹²⁹

LOADSHAPE

Loadshape NRE13 – Indust. 1-shift (8/5)

Loadshape NRE13 – Indust. 2-shift (16/5)

Loadshape NRE13 – Indust. 3-shift (24/5)

Loadshape NRE13 – Indust. 4-shift (24/7)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{Dryer} * (P_{Baseline} - P_{Efficient} * RF_{Purge}) * Hours$$

Where:

CFM_{Dryer} = Rated capacity of the dryer in cubic feet per minute (CFM)

$P_{Baseline}$ = Power required of the baseline dryer (kW/CFM)

= $PF_{Baseline} * kW_{Compressor}$

$PF_{Baseline}$ = Purge flow of the baseline, heatless dryer

= 15%¹¹³⁰

$kW_{Compressor}$ = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:¹¹³¹

Air Compressor Type	kW/CFM _{Saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136

¹¹²⁸ Focus on Energy Evaluation Business Programs: Measure Life Study, p. 91-92. PA Consulting Group. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

¹¹²⁹ Analysis of equipment cost between heatless, heated, blower purge dryers according to available online pricing. The capacity range considered was 250 – 1,500 CFM. Cost provided is the average incremental cost when comparing heated and blower purge dryers to baseline heatless dryers of the same CFM capacity.

¹¹³⁰ Typical estimates of purge flow for heatless dryers range from 15-20% of dryer rated capacity. 15% was selected as a conservative value.

¹¹³¹ 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 – 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 ¹¹³²	0.107

Note: Dryers installed on inlet modulation compressors do not qualify for this measure.

$P_{\text{Efficient}}$ = Power required of the efficient, heated or blower purge dryer (kW/CFM)

= ($PF_{\text{Efficient}} * kW_{\text{Compressor}} + kW_{\text{Heater}} + kW_{\text{Blower}}$)

$PF_{\text{Efficient}}$ = Purge flow of efficient dryer¹¹³³

= 7.5% for heated units

= 2% for blower purge units (with compressed air cooling)

= 0% for blower purge units (with “zero-purge”)

kW_{Heater} = Average power of heater per CFM of dryer^{1134,1135}

= 0.007 kW/CFM for heated units

= 0.013 kW/CFM for blower purge units

kW_{Blower} = Average power of blower per CFM of dryer¹¹³⁶

= 0 kW/CFM for heated units

= 0.003 kW/CFM for blower purge units

RF_{Purge} = Purge reduction factor

= 50% for heatless dryers¹¹³⁷

= 60% for externally heated or heated blower purge dryers¹¹³⁸

¹¹³² 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

¹¹³³ Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers, Marshall, Ron.

<https://airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹³⁴ Based on a review of data sheets from six manufacturers. These values reflect average heater kW and not nominal heater kW. The heater operation will vary based on moisture load to the dryer.

¹¹³⁵ The heater operation will be controlled by temperature to avoid overheating the desiccant media. Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers, Marshall, Ron. <https://airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹³⁶ Based on a review of data sheets from six manufacturers. These values reflect average blower kW and not nominal blower kW. The blower operation will in many cases vary based on moisture load to the dryer.

¹¹³⁷ “For heatless desiccant dryers, the reduction in purge tends to be proportional only to the reduction of flow, not the reduction in moisture load due to the lower inlet temperatures.” The 50% value is based on the Illinois TRM’s assumption of a 50% dryer load factor for its 4.7.5 measure. Marshall, Ron. Lessons Learned: Saving Energy Costs with Heated Blower Desiccant Dryers. <https://www.airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹³⁸ “But for heated style units, the dryer reacts to both reductions. This means some energy is saved due to flow reduction,

Hours = Compressor hours of operation, depending on shift.
= Use actual hours if known, otherwise assume values in table below:

Shift	Hours
Single Shift	1,976
Two Shifts	3,952
Three Shifts	5,928
Four Shifts or Continual Operation	8,320
Unknown / Weighted average ¹¹³⁹	5,680

For example, a 500 cfm heated blower purge dryer with zero purge and an unknown air compressor type for a single shift would save the following:

$$\begin{aligned}\Delta kWh &= CFM_{Dryer} * (P_{Baseline} - P_{Efficient} * RF_{Purge}) * Hours \\ &= 500 * ([0.15 * 0.107] - [0 * 0.107 + 0.013 + 0.003] * 0.60) * 1,976 \\ &= 29.64 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW_{Peak} = \frac{\Delta kWh}{Hours} * CF$$

Where:

CF = Summer peak coincidence factor, see table below:

Shift	Coincidence Factor
Single shift (8/5)	59%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹¹⁴⁰	89%

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

and additional energy is saved due to the lower moisture load in the cooler inlet air, resulting in more energy savings when compared with heatless styles.” Marshall, Ron. Lessons Learned: Saving Energy Costs with Heated Blower Desiccant Dryers. <https://www.airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹³⁹ 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).

¹¹⁴⁰ 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).

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-EDAD-V01-270101

SUNSET DATE: 1/1/2030

3.9.10. DEW POINT DEMAND CONTROLS FOR DESICCANT DRYER

DESCRIPTION

Reduction or elimination of condensation that can be harmful to a compressed air system or end use equipment can be done by drying the air with desiccant dryers. Regenerative desiccant air dryers are typically used for applications that require air to be dried below a dew point of 35°F¹¹⁴¹. Typically, these dryers can achieve pressure dew points as low as -40°F.

The energy use of these dryers is primarily due to regeneration of the desiccant. Standard dryers come equipped with a fixed, timer regeneration control. However, the actual load on the dryer is variable. Optional dew point demand controls (DPDC) adjust the amount of regeneration to the moisture load on the dryer, reducing unnecessary purge energy.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition for this measure is heatless, externally heated, or blower purge dryer with dew point demand controls. These controls should be able to respond to changes in the flow and moisture loading of the system.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is a heatless, externally heated, or blower purge dryer without dew point demand controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 5 years.¹¹⁴²

DEEMED MEASURE COST

The estimated total cost for this measure is \$4,000.¹¹⁴³

LOADSHAPE

Loadshape NRE13 – Indust. 1-shift (8/5)

Loadshape NRE13 – Indust. 2-shift (16/5)

Loadshape NRE13 – Indust. 3-shift (24/5)

Loadshape NRE13 – Indust. 4-shift (24/7)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{Dryer} * (PF * kW_{Compressor} + kW_{Heater} + kW_{Blower}) * RF_{Purge} * Hours$$

¹¹⁴¹ The dew point limitation of the most common refrigerant-type air dryer. Improving Compressed Air System Performance: A Sourcebook for Industry, US Department of Energy. Page 48.

<https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf>

¹¹⁴² Since this is a retrofit, the EUL is one-third of the dryer life which is 15 years (TRM 3.9.9). Focus on Energy Evaluation Business Programs: Measure Life Study, p. 91-92. PA Consulting Group. August 25, 2009.

¹¹⁴³ Desiccant Air Dryer Control: Seeing Isn't Always Believing. Marshall, Ron.

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Where:

CFM_{Dryer} = Rated capacity of the dryer in cubic feet per minute (CFM)PF = Purge flow of the dryer¹¹⁴⁴

Air Compressor Type	Purge Flow
Heatless	15%
Externally-Heated	7.5%
Blower Purge	2.0%

kW_{Compressor} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:¹¹⁴⁵

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 ¹¹⁴⁶	0.107

Note: Dryers installed on inlet modulation compressors do not qualify for this measure.

kW_{Heater} = Average power of heater per CFM of dryer^{1147,1148}

= 0.007 kW/CFM for heated units

= 0.013 kW/CFM for blower purge units

kW_{Blower} = Average power of blower per CFM of dryer¹¹⁴⁹

= 0 kW/CFM for heated units

= 0.003 kW/CFM for blower purge units

RF_{Purge} = Purge reduction factor= 50% for heatless dryers¹¹⁵⁰¹¹⁴⁴ Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers, Marshall, Ron.¹¹⁴⁵ 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).¹¹⁴⁶ 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 compressors¹¹⁴⁷ Based on a review of data sheets from six manufacturers. These values reflect average heater kW and not nominal heater kW. The heater operation will vary based on moisture load to the dryer¹¹⁴⁸ The heater operation will be controlled by temperature to avoid overheating the desiccant media. Lessons Learned: Saving Energy Costs with Heated Blower Purge Desiccant Dryers, Marshall, Ron.¹¹⁴⁹ Based on a review of data sheets from six manufacturers. These values reflect average blower kW and not nominal blower kW. The blower operation will in many cases vary based on moisture load to the dryer.¹¹⁵⁰ "For heatless desiccant dryers, the reduction in purge tends to be proportional only to the reduction of flow, not the reduction in moisture load due to the lower inlet temperatures." The 50% value is based on the Illinois TRM's assumption of a 50% dryer load factor for its 4.7.5 measure. Marshall, Ron. Lessons Learned: Saving Energy Costs with Heated Blower Desiccant

Iowa Energy Efficiency Statewide Technical Reference Manual –3.9.10 Dew Point Demand Controls for Desiccant Dryer

= 60% for externally heated or heated blower purge dryers¹¹⁵¹

Hours

= Compressor hours of operation, depending on shift.

= Use actual hours if known, otherwise assume values in table below:

Shift	Hours
Single Shift	1,976
Two Shifts	3,952
Three Shifts	5,928
Four Shifts or Continual Operation	8,320
Unknown / Weighted average ¹¹⁵²	5,680

For example, a 500 cfm heated blower purge dryer with an unknown air compressor type for a single shift would save the following:

$$\begin{aligned}\Delta kWh &= CFM_{Dryer} * (PF * kW_{Compressor} - kW_{Heater} * kW_{Blower}) * RF_{Purge} * Hours \\ &= 500 * (0.020 * 0.107 + 0.013 + 0.003) * 0.60 * 1,976 \\ &= 10,753.4 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW_{Peak} = \frac{\Delta kWh}{Hours} * CF$$

Where:

CF = Summer peak coincidence factor, see table below:

Shift	Coincidence Factor
Single shift (8/5)	59%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹¹⁵³	89%

NATURAL GAS SAVINGS

N/A

Dryers. <https://www.airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹⁵¹ “But for heated style units, the dryer reacts to both reductions. This means some energy is saved due to flow reduction, and additional energy is saved due to the lower moisture load in the cooler inlet air, resulting in more energy savings when compared with heatless styles.” Marshall, Ron. Lessons Learned: Saving Energy Costs with Heated Blower Desiccant Dryers. <https://www.airbestpractices.com/system-assessments/air-treatmentn2/lessons-learned-saving-energy-costs-heated-blower-desiccant-dry-0>

¹¹⁵² 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).

¹¹⁵³ 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).

Iowa Energy Efficiency Statewide Technical Reference Manual –3.9.10 Dew Point Demand Controls for Desiccant Dryer

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSC-DPDC-V01-270101

SUNSET DATE: 1/1/2030

3.9.11. REDUCED PRESSURE SETPOINT

DESCRIPTION

Reducing the compressed air setpoint results in energy savings, as a lower setpoint pressure will reduce the work required work from the system. The energy savings assumptions are based on compressors operating at 100 psi.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition for this measure is a compressor with a decreased pressure setpoint, along with known and verifiable specification and location of the system.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is a compressor with a pressure setpoint higher than necessary: a line pressure that is >115% of the highest end use requirement.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 5 years.¹¹⁵⁴

DEEMED MEASURE COST

The incremental cost for this measure is \$0.

LOADSHAPE

Loadshape NRE13 – Indust. 1-shift (8/5)

Loadshape NRE13 – Indust. 2-shift (16/5)

Loadshape NRE13 – Indust. 3-shift (24/5)

Loadshape NRE13 – Indust. 4-shift (24/7)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (kW_{\text{Compressor}} * \Delta P * SF * \frac{\text{Hours}}{hp_{\text{nominal}}}) * hp_{\text{Total}}$$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

$kW_{\text{Compressor}}$ = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use actual compressor control type if known:

¹¹⁵⁴ Based on ComEd Operational Efficiency CY2018 Impact Evaluation.

Control Type	kW _{Typical} ¹¹⁵⁵
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 ¹¹⁵⁶	77.6

ΔP = Reduction in pressure differential between efficient and base case (psi)

= Actual

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 0.005¹¹⁵⁷

HOURS = Compressor hours of operation, depending on shift.

= Use actual hours if known, otherwise assume values in table below:

Shift	Hours
Single Shift	1,976
Two Shifts	3,952
Three Shifts	5,928
Four Shifts or Continual Operation	8,320
Unknown / Weighted average ¹¹⁵⁸	5,680

hp_{Nominal} = Nominal hp for a typical air compressor

= 100 hp¹¹⁵⁹

hp_{Total} = Total hp of a real air compressor distributing air through the filter. This should include the total horsepower of the compressors that normally run, not backup compressors.

For example, a 125 hp compressed air system with an unknown control type for a single shift where the pressure is reduced by 5 psi would save the following:

$$\begin{aligned} \Delta kWh &= (kW_{Compressor} * \Delta P * SF * \frac{Hours}{hp_{nominal}}) * hp_{Total} \\ &= (77.6 * 5 * 0.005 * \frac{1,976}{100}) * 125 \\ &= 4,791.8 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

¹¹⁵⁵ Consistent with 3.9.4 Low Pressure Drop Filters. See “Industrial System Standard Deemed Saving Analysis.xls”.

¹¹⁵⁶ 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.

¹¹⁵⁷ “Optimizing Pneumatic Systems for Extra Savings,” Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.

¹¹⁵⁸ 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).

¹¹⁵⁹ Consistent with 3.9.4 Low Pressure Drop Filters. See “Industrial System Standard Deemed Saving Analysis.xls”.

$$\Delta kW_{Peak} = \frac{\Delta kWh}{Hours} * CF$$

Where:

CF = Summer peak coincidence factor, see table below:

Shift	Coincidence Factor
Single shift (8/5)	59%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ¹¹⁶⁰	89%

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MSR-RPSP-V01-270101

SUNSET DATE: 1/1/2030

¹¹⁶⁰ 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).