2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

Version 7.0

Volume 2: Commercial and Industrial Measures

FINAL

September 13th, 2018

Effective:

January 1st, 2019

[INTENTIONALLY LEFT BLANK]

VOLUME 1: OVERVIEW AND USER GUIDE

VOLUME 2: COMMERCIAL AND INDUSTRIAL MEASURES 7

4.1 AGRICULTURAL END USE 7

4.1.1 Engine Block Timer for Agricultural Equipment 7

4.1.2 High Volume Low Speed Fans....9

4.1.3 High Speed Fans 11

4.1.4 Livestock Waterer....13

4.2 FOOD SERVICE EQUIPMENT END USE 15

4.2.1 Combination Oven....15

4.2.2 Commercial Solid and Glass Door Refrigerators & Freezers....22

4.2.3 Commercial Steam Cooker 25

4.2.4 Conveyor Oven 32

4.2.5 ENERGY STAR Convection Oven 34

4.2.6 ENERGY STAR Dishwasher 37

4.2.7 ENERGY STAR Fryer....47

4.2.8 ENERGY STAR Griddle 51

4.2.9 ENERGY STAR Hot Food Holding Cabinets....56

4.2.10 ENERGY STAR Ice Maker....59

4.2.11 High Efficiency Pre-Rinse Spray Valve 63

4.2.12 Infrared Charbroiler....68

4.2.13 Infrared Rotisserie Oven....70

4.2.14 Infrared Salamander Broiler 72

4.2.15 Infrared Upright Broiler 74

4.2.16 Kitchen Demand Ventilation Controls 76

4.2.17 Pasta Cooker....79

4.2.18 Rack Oven - Double Oven 81

4.2.19 ENERGY STAR Electric Convection Oven....83

4.3 HOT WATER....87

4.3.1 Storage Water Heater....87

4.3.2 Low Flow Faucet Aerators 93

4.3.3 Low Flow Showerheads 100

4.3.4 Commercial Pool Covers....106

4.3.5 Tankless Water Heater 109

4.3.6 Ozone Laundry....116

4.3.7 Multifamily Central Domestic Hot Water Plants 122
4.3.8 Controls for Central Domestic Hot Water 126
4.3.9 Heat Recovery Grease Trap Filter 129
4.3.10 DHW Boiler Tune-up 133
4.4 HVAC End Use 137
4.4.1 Air Conditioner Tune-up 140
4.4.2 Space Heating Boiler Tune-up 143
4.4.3 Process Boiler Tune-up 146
4.4.4 Boiler Lockout/Reset Controls 149
4.4.5 Condensing Unit Heaters 151
4.4.6 Electric Chiller 153
4.4.7 ENERGY STAR and CEE Super Efficient Room Air Conditioner 160
4.4.8 Guest Room Energy Management (PTAC & PTHP) 164
4.4.9 Air and Water Source Heat Pump Systems 171
4.4.10 High Efficiency Boiler 181
4.4.11 High Efficiency Furnace 184
4.4.12 Infrared Heaters (all sizes), Low Intensity 190
4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP) 192
4.4.14 Pipe Insulation 197
4.4.15 Single-Package and Split System Unitary Air Conditioners 211
4.4.16 Steam Trap Replacement or Repair 222
4.4.17 Variable Speed Drives for HVAC Pumps and Cooling Tower Fans 227
4.4.18 Small Commercial Programmable Thermostats 231
4.4.19 Demand Controlled Ventilation 237
4.4.20 High Turndown Burner for Space Heating Boilers 242
4.4.21 Linkageless Boiler Controls for Space Heating 245
4.4.22 Oxygen Trim Controls for Space Heating Boilers 247
4.4.23 Shut Off Damper for Space Heating Boilers or Furnaces 249
4.4.24 Small Pipe Insulation 251
4.4.25 Small Commercial Programmable Thermostat Adjustments 257
4.4.26 Variable Speed Drives for HVAC Supply and Return Fans 264
4.4.27 Energy Recovery Ventilator 270
4.4.28 Stack Economizer for Boilers Serving HVAC Loads 275
4.4.29 Stack Economizer for Boilers Serving Process Loads 278

4.4.30 Notched V Belts for HVAC Systems 281
4.4.31 Small Business Furnace Tune-Up 288
4.4.32 Combined Heat and Power 291
4.4.33 Industrial Air Curtain 299
4.4.34 Destratification Fan 309
4.4.35 Economizer Repair and Optimization 316
4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls 325
4.4.37 Unitary HVAC Condensing Furnace 327
4.4.38 Covers and Gap Sealers for Room Air Conditioners 335
4.4.39 High Temperature Heating and Ventilation (HTHV) Direct Fired Heater 341
4.4.40 Gas High Efficiency Single Package Vertical Air Conditioner 346
4.4.41 Advanced Rooftop Controls (ARC) 350
4.4.42 Advanced Thermostats for Small Commercial 357
4.4.43 Packaged RTU Sealing 360
4.4.44 Commercial Ground Source and Ground Water Source Heat Pump 365
4.4.45 Adsorbent Air Cleaning 389
4.5 Lighting End Use 396
4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL) 399
4.5.2 Fluorescent Delamping 405
4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps 409
4.5.4 LED Bulbs and Fixtures 422
4.5.5 Commercial LED Exit Signs 440
4.5.6 LED Traffic and Pedestrian Signals 444
4.5.7 Lighting Power Density 447
4.5.8 Miscellaneous Commercial/Industrial Lighting 465
4.5.9 Multi-Level Lighting Switch 469
4.5.10 Lighting Controls 472
4.5.11 Solar Light Tubes 476
4.5.12 T5 Fixtures and Lamps 479
4.5.13 Occupancy Controlled Bi-Level Lighting Fixtures 488
4.5.14 Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL) 492
4.5.15 LED Open Sign 500
4.5.16 LED Streetlighting 504
4.6 Refrigeration End Use 507

4.6.1 Automatic Door Closer for Walk-In Coolers and Freezers 507
4.6.2 Beverage and Snack Machine Controls 509
4.6.3 Door Heater Controls for Cooler or Freezer 512
4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers 515
4.6.5 ENERGY STAR Refrigerated Beverage Vending Machine 517
4.6.6 Evaporator Fan Control for Electrically Commutated Motors 519
4.6.7 Strip Curtain for Walk-in Coolers and Freezers 521
4.6.8 Refrigeration Economizers 524
4.6.9 Night Covers for Open Refrigerated Display Cases 527
4.6.10 High Speed Rollup Doors 530
4.6.11 Q-Sync Motors for Reach-in Coolers/Freezers 535
4.6.12 Variable Frequency Drive for Condenser Fans 540

4.7 Compressed Air 542

4.7.1 VSD Air Compressor 542
4.7.2 Compressed Air Low Pressure Drop Filters 545
4.7.3 Compressed Air No-Loss Condensate Drains 548
4.7.4 Efficient Compressed Air Nozzles 550
4.7.5 Efficient Refrigerated Compressed Air Dryer 553

4.8 Miscellaneous End Use 556

4.8.1 Pump Optimization 556
4.8.2 Roof Insulation for C&I Facilities 558
4.8.3 Computer Power Management Software 563
4.8.4 Modulating Commercial Gas Clothes Dryer 565
4.8.5 High Speed Clothes Washer 567
4.8.6 ENERGY STAR Computers 571
4.8.7 Advanced Power Strip – Tier 1 Commercial 574
4.8.8 High Efficiency Transformer 577
4.8.9 High Frequency Battery Chargers 581
4.8.10 Commercial Clothes Dryer Moisture Sensor 584
4.8.11 Efficient Thermal Oxidizers 587

Volume 3: Residential Measures

Volume 4: Cross Cutting Measures and Attachments

Volume 2: Commercial and Industrial Measures

4.1 Agricultural End Use

4.1.1 Engine Block Timer for Agricultural Equipment

DESCRIPTION

The measure is a plug-in timer that is activated below a specific outdoor temperature to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience, heaters are typically plugged in considerably longer than necessary to improve startup performance. A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time even if the baseline equipment has an engine block temperature sensor.

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 measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when the outdoor temperature is below 25 °F.

DEFINITION OF BASELINE EQUIPMENT

The baseline scenario is an engine block heater that is manually plugged in by the farmer to facilitate equipment startup at a later time.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life if assumed to be 3 years[1]

DEEMED MEASURE COST

The incremental cost per installed plug-in timer is $10.19[2].

COINCIDENCE FACTOR

Engine block timers only operate in the winter so the summer peak demand savings is zero.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ISR * Use\ Season * \%Days * HrSave/Day * kW_{heater} - ParaLd$$

Where:

ISR = In Service Rate

= 78.39%[3]

---

[1] Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

[2] Based on bulk pricing reported by EnSave, which administers the rebate in Vermont

[3] Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015. Based on field study conducted by Efficiency Vermont on 352 sites in Vermont and Minnesota.

Use Season = The number of days in the use season in which the temperature drops below 25°F in the state of Illinois

= 75 days[4]

%Days = Propoortion of days timer is used with the Use Season

= 84.23%[5]

HrSave/Day = Hours of savings per day when timer is used

= 7.765 hours per day[6]

kW_{heater} = Connected load of the engine block heater

= 1.5 kW[7]

ParaLd = Parasitic load

= 5.46 kWh[8]

For example, using the default assumptions on the installation of a timer on an engine block with a 1.5 kW heater:

ΔkWh = 78.39% * 75 days * 84.23% * 7.765 Hr/Day * 1.5 kW - 5.46 kWh

= 571 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-AGE-EBLT-V02-190101

REVIEW DEADLINE: 1/1/2024

[4] The number of days in the use season in which the temperature drops below 25°F in the state of Illinois. The data is sourced as an average from TMY3 weather data for five different weather zones within the state.
[5] EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota.
[6] Ibid. The hours per day saved is sourced as the difference between the baseline run hours per day without the timer, 10.66 hours, and the efficient run hours per day with the timer, 2.90 hours.
[7] Ibid. Based on an average sized engine block heater, which typically ranges in connected load from 0.20 kW and 2 kW, as sourced from Efficiency Vermont program data.
[8] Ibid.

4.1.2 High Volume Low Speed Fans

DESCRIPTION

The measure applies to 20-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non HVLS fans that have reached the end of 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 is assumed to be classified as HVLS and have a VFD[9].

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be multiple non HVLS existing fans that have reached the end of useful life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

The incremental capital cost for the fans are as follows[11]:

Fan Diameter Size (feet)	Incremental Cost
20	$4150
22	$4180
24	$4225

LOADSHAPE

Loadshape C34 - Industrial Motor

COINCIDENCE FACTOR

The measure has deemed kW savings therefore, a coincidence factor is not applied.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [12]

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

Fan Diameter Size (feet)	kWh Savings
20	6,577
22	8,543
24	10,018

[9] Act on Energy Commercial Technical Reference Manual No. 2010-4
[10] Ibid.
[11] Ibid.
[12] Ibid.

SUMMER COINCIDENT PEAK DEMAND SAVINGS[13]

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

Fan Diameter Sixe (feet)	kW Savings
20	2.4
22	3.1
24	3.7

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-AGE-HVSF-V02-190101

REVIEW DEADLINE: 1/1/2024

[13] Ibid.

4.1.3 High Speed Fans

Description

The measure applies to high speed exhaust, ventilation and circulation fans that are 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 is assumed to be diffuser equipped and meet the following minimum efficiency criteria[14].

Diameter of Fan (inches)	Minimum Efficiency for Exhasut & Ventilation Fans	Minimum Efficiency for Circulation Fans
24 through 35	14.0 cfm/W at 0.10 static pressure	12.5 lbf/kW
36 through 47	17.1 cfm/W at 0.10 static pressure	18.2 lbf/kW
48 through 71	20.3 cfm/W at 0.10 static pressure	23.0 lbf/kW

Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be an existing fan that reached the end of its useful life.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years[15].

Deemed Measure Cost

The incremental capital cost for all fan sizes is $150[16].

Loadshape

Loadshape C34 - Industrial Motor

Coincidence Factor

The measure has deemed kW savings therefore, a coincidence factor is not applied.

Algorithm

Calculation of Savings

Electric Energy Savings [17]

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

Diameter of Fan (inches)	kWh
24 through 35	372
36 through 47	625

[14] Act on Energy Commercial Technical Reference Manual No. 2010-4
[15] Ibid.
[16] Ibid.
[17] Ibid.

Diameter of Fan (inches)	kWh
48 through 71	1,122

SUMMER COINCIDENT PEAK DEMAND SAVINGS[18]

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

Diameter of Fan (inches)	kW
24 through 35	0.118
36 through 47	0.198
48 through 71	0.356

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-AGE-HSF_-V02-190101

REVIEW DEADLINE: 1/1/2024

[18] Ibid.

4.1.4 Livestock Waterer

DESCRIPTION

This measure applies to the replacement of electric open waterers with sinking or floating water heaters with equivalent herd size watering capacity of the old unit. Livestock waterers utilize electric heating elements and are used in cold climate locations in order to prevent water from freezing. Energy efficient livestock waterers, also called no or low energy livestock waterers, are closed and insulated watering containers that use lower wattage heating elements, thermostatically controlled, and water agitation (either in the form of air bubbles or floating balls), to prevent water from freezing.

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 is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts[19].

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[20].

DEEMED MEASURE COST

The incremental capital cost for the waters are $787.50:[21]

LOADSHAPE

Loadshape C04 - Non-Residential Electric Heating

COINCIDENCE FACTOR

Heated livestock waterers only operate in the winter in order to keep water from freezing so the summer peak coincident demand savings is zero.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [22]

The annual electric savings from this measure is a deemed value and assumed to be 1,592.85 kWh.

[19] Act on Energy Commercial Technical Reference Manual No. 2010-4
[20] Ibid.
[21] Ibid.
[22] Ibid.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

The annual kW savings from this measure is a deemed value and assumed to be 0.525 kW. [23]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-AGE-LSW1-V02-190101

REVIEW DEADLINE: 1/1/2024

[23] Ibid.

4.2 Food Service Equipment End Use

4.2.1 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, 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 new natural gas or electric combination oven meeting the ENERGY STAR idle rate and cooking efficiency requirements as specified below.[24]

ENERGY STAR Requirements (Version 2.1, Effective January 1, 2014)

Fuel Type	Operation	Idle Rate (Btu/h for Gas, kW for Electric)	Cooking-Energy Efficiency, (%)
Natural Gas	Steam Mode Convection Mode	≤ 200P+6,511 ≤ 150P+5,425	≥ 41 ≥ 56
Electric	Steam Mode Convection Mode	≤ 0.133P+0.6400 ≤ 0.080P+0.4989	≥ 55 ≥ 76

Note: P = Pan capacity as defined in Section 1.S, of the Commercial Ovens Program Requirements Version 2.1[25]

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.[26]

DEEMED MEASURE COST

The costs vary based on the efficiency and make of the equipment. Actual costs should be used.

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[27]:

Location	CF
Fast Food Limited Menu	0.32
Fast Food Expanded Menu	0.41
Pizza	0.46

[24] ENERGY STAR Commercial Ovens Key Product Criteria, version 2.2, effective October 7, 2015

[25] Ibid. 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.

[26] The measure life is sourced from the Food Service Technology Center's energy savings calculator for combination ovens.

[27] 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

Location	CF
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.39

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

The algorithm below applies to electric combination ovens only.[28]

$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec}) * Days / 1,000$

Where:

$\Delta CookingEnergy_{ConvElec}$ = Change in total daily cooking energy consumed by electric oven in convection mode

$= LB_{Elec} * (EFOOD_{ConvElec} / ElecEFF_{ConvBase} - EFOOD_{ConvElec} / ElecEFF_{ConvEE}) * \%_{Conv}$

$\Delta CookingEnergy_{SteamElec}$ = Change in total daily cooking energy consumed by electric oven in steam mode

$= LB_{Elec} * (EFOOD_{SteamElec} / ElecEFF_{SteamBase} – EFOOD_{SteamElec} / ElecEFF_{SteamEE}) * \%_{Steam}$

$\Delta IdleEnergy_{ConvElec}$ = 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 convection mode

$= [(ElecIDLE_{SteamBase} * ((HOURS – LB_{Elec}/ElecPC_{SteamBase}) * \%_{Steam})) - (ElecIDLE_{SteamEE} * ((HOURS - LB_{Elec}/ElecPC_{SteamEE}) * \%_{Steam}))]$

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 >= 15)

$EFOOD_{ConvElec}$ = 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
$ElecEFF_{Conv}$	72%	76%

[28] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

	Base	EE
$ElecEFF_{Steam}$	49%	55%

$\%_{Conv}$ = Percentage of time in convection mode

= Custom or if unknown, use 50%

$EFOOD_{SteamElec}$ = Energy absorbed by food product for electric oven in steam mode

= Custom or if unknown, use 30.8 Wh/lb

$\%_{steam}$ = Percentage of time in steam mode

= 1 - $\%_{conv}$

$ElecIDLE_{Base}$ = Idle energy rate (W) of baseline electric oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecIDLE_{ConvBase}$)	Steam Mode ($ElecIDLE_{SteamBase}$)
< 15	1,320	5,260
> = 15	2,280	8,710

HOURS = Average daily hours of operation

= Custom or if unknown, use 12 hours

$ElecPC_{Base}$ = Production capacity (lbs/hr) of baseline electric oven

= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecPC_{ConvBase}$)	Steam Mode ($ElecPC_{SteamBase}$)
< 15	79	126
> = 15	166	295

$ElecIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR electric oven in convection mode

= (0.08*P +0.4989)*1000

$ElecPC_{EE}$ = 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

= (0.133* P+0.64)*1000

Days = Days of operation per year

= Custom or if unknown, use 365 days per year

1,000 = Wh to kWh conversion factor

EXAMPLE

For example, a 10-pan capacity electric combination oven would save:

$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec})$ * Days / 1,000

$\Delta CookingEnergy_{ConvElec}$ = 200 * (73.2 / 0.72 – 73.2 / 0.76) * 0.50

= 535 Wh

$\Delta CookingEnergy_{SteamElec}$ = 200 * (30.8 / 0.49 – 30.8 / 0.55) * (1 – 0.50)

= 686 Wh

$\Delta IdleEnergy_{ConvElec}$ = [(1,320 * ((12 – 200/79) * 0.50)) - (1,299 *((12 - 200/119) * 0.50))]

= -453 Wh

$\Delta IdleEnergy_{SteamElec}$ = [(5,260 * ((12 – 200/126) * (1 – 0.50))) - (1,970 * ((12 - 200/177) * (1 – 0.50)))]

= 16,678 Wh

ΔkWh = (535 + 686 + -453 + 16,678) * 365 /1,000

= 6,368 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / (HOURS * DAYS) *CF

Where:

CF = Summer peak coincidence factor is dependent on building type[29]:

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

All other variables as defined above.

EXAMPLE

For example, a 10-pan capacity electric combination oven in a Full Service Limited Menu restaurant would save:

ΔkW = ΔkWh / (HOURS * DAYS) *CF

= 6,368/ (12 * 365) * 0.51

= 0.74 kW

NATURAL GAS ENERGY SAVINGS

The algorithm below applies to natural gas combination ovens only.[30]

[29]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

[30] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

$$\Delta Therms = (\Delta CookingEnergy_{ConvGas} + \Delta CookingEnergy_{SteamGas} + \Delta IdleEnergy_{ConvGas} + \Delta IdleEnergy_{SteamGas}) * Days / 100{,}000$$

Where:

$\Delta CookingEnergy_{ConvGas}$ = Change in total daily cooking energy consumed by gas oven in convection mode

$= LB_{Gas} * (EFOOD_{ConvGas} / GasEFF_{ConvBase} - EFOOD_{ConvGas} / GasEFF_{ConvEE}) * \%_{Conv}$

$\Delta CookingEnergy_{SteamGas}$ = Change in total daily cooking energy consumed by gas oven in steam mode

$= LB_{Gas} * (EFOOD_{SteamGas} / GasEFF_{SteamBase} – EFOOD_{SteamGas} / GasEFF_{SteamEE}) * \%_{Steam}$

$\Delta IdleEnergy_{ConvGas}$ = Change in total daily idle energy consumed by gas oven in convection mode

$= [(GasIDLE_{ConvBase} * ((HOURS – LB_{Gas}/GasPC_{ConvBase}) * \%_{Conv})) - (GasIDLE_{ConvEE} * ((HOURS - LB_{Gas}/GasPC_{ConvEE}) * \%_{Conv}))]$

$\Delta IdleEnergy_{SteamGas}$ = Change in total daily idle energy consumed by gas oven in convection mode

$= [(GasIDLE_{SteamBase} * ((HOURS – LB_{Gas}/GasPC_{SteamBase}) * \%_{Steam})) - (GasIDLE_{SteamEE} * ((HOURS - LB_{Gas}/GasPC_{SteamEE}) * \%_{Steam}))]$

Where:

LB_{Gas} = 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)

$EFOOD_{ConvGas}$ = Energy absorbed by food product for gas oven in convection mode

= Custom or if unknown, use 250 Btu/lb

GasEFF = Cooking energy efficiency of gas oven

= Custom or if unknown, use values from table below

	Base	EE
$GasEFF_{Conv}$	52%	56%
$GasEFF_{Steam}$	39%	41%

$EFOOD_{SteamGas}$ = 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	8,747	18,656
15-30	10,788	24,562
>30	13,000	43,300

$GasPC_{Base}$ = Production capacity (lbs/hr) of baseline gas oven

= Custom of 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

= 150*P + 5,425

$GasPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR gas oven

= Custom of 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

= 200 * P +6511

100,000 = Conversion factor from Btu to therms

All other variables as defined above.

EXAMPLE

For example, a 10-pan capacity gas combination oven would save:

ΔTherms = ($\Delta CookingEnergy_{ConvGas}$ + $\Delta CookingEnergy_{SteamGas}$ + $\Delta IdleEnergy_{ConvGas}$ + $\Delta IdleEnergy_{SteamGas}$) * Days / 100,000

$\Delta CookingEnergy_{ConvGas}$ = 200 * (250 / 0.52 – 250 / 0.56) * 0.50

=3,434 therms

$\Delta CookingEnergy_{SteamGas}$ = 200 * (105 / 0.39 – 105 / 0.41) * (1 – 0.50)

= 1,313 therms

$\Delta IdleEnergy_{ConvGas}$ = [(8,747 * ((12 – 200/125) * 0.50)) - (6,925 *((12 - 200/124) * 0.50))]

= 9,519 therms

$\Delta IdleEnergy_{SteamGas}$ = [(18,658 * ((12 – 200/195) * (1 – 0.50))) - (8,511 * ((12 - 200/172) * (1 – 0.50)))]

= 56,251 therms

ΔTherms = (3,434 + 1,313 + 9,519 + 56,251) * 365 /100,000

= 257 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

MEASURE CODE: CI-FSE-CBOV-V02-160601

REVIEW DEADLINE: 1/1/2023

4.2.2 Commercial Solid and Glass Door Refrigerators & Freezers

Description

This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. ENERGY STAR labeled 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 and 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 new ENERGY STAR certified vertical closed solid or glass door refrigerator or freezer meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V).

ENERGY STAR Requirements (Version 4.0, Effective March 27, 2017)

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.022V + 0.97	≤ 0.21V + 0.9
15 ≤ V < 30	≤ 0.066V + 0.31	≤ 0.12V + 2.248
30 ≤ V < 50	≤ 0.04V + 1.09	≤ 0.285V -2.703
V ≥ 50	≤ 0.024V + 1.89	≤ 0.142V + 4.445
Glass Door		
0 < V < 15	≤ 0.095V + 0.445	≤ 0.232V + 2.36
15 ≤ V < 30	≤ 0.05V + 1.12	
30 ≤ V < 50	≤ 0.076V + 0.34	
V ≥ 50	≤ 0.105V – 1.111	

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a new vertical closed solid or glass door refrigerator or freezer that is not ENERGY STAR certified.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years [31].

Deemed Measure Cost

The incremental capital cost per cubic foot of chilled or frozen compartment volume for this measure is provided below[32].

Equipment Type	Incremental Cost per Cubic Foot (ft^3)
Solid Door	

[31] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

[32] Incremental costs are based on the Northwest Regional Technical Forum, ENERGY STAR Version 4.0 Analysis. For cost calculation details, see the CostData&Analysis tab within the file Commercial Refrigerators & Freezers_Costs_Nov 2017.xlsm.

Equipment Type	Incremental Cost per Cubic Foot (ft^3)
Refrigerator	$24.21
Freezer	$30.41
Glass Door	
Refrigerator	$24.77
Freezer	$33.01

LOADSHAPE

Loadshape C23 - Commercial Refrigeration

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 0.937.[33]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = (kWhbase – kWhee) * 365.25

Where:

kWhbase= baseline maximum daily energy consumption in kWh

= calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the table below.

Type	kWhbase[34]
Solid Door Refrigerator	0.05 * V + 1.36
Glass Door Refrigerator	0.1 * V + 0.86
Solid Door Freezer	0.22 * V + 1.38
Glass Door Freezer	0.29 * V + 2.95

kWhee[35] = efficient maximum daily energy consumption in kWh

= calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the table below.

Volume (ft^3)	kWhee	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.022V + 0.97	≤ 0.21V + 0.9
15 ≤ V < 30	≤ 0.066V + 0.31	≤ 0.12V + 2.248
30 ≤ V < 50	≤ 0.04V + 1.09	≤ 0.285V -2.703
V ≥ 50	≤ 0.024V + 1.89	≤ 0.142V + 4.445

[33] The CF for Commercial Refrigeration was calculated based upon the Ameren provided eShapes

[34] Federal standards for equipment manufactured on or after March 27, 2017: 10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers.

[35] ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 4.0, effective March 27, 2017

Volume (ft^3)	kWhee	
	Refrigerator	Freezer
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	

V = the chilled or frozen compartment volume (ft^3) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979)

= Actual installed

365.25 = days per year

For example, a solid door refrigerator with a volume of 15 would save

ΔkWh = (2.11 – 1.30) * 365.25

= 296 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / HOURS * CF

Where:

HOURS = equipment is assumed to operate continuously, 24 hours per day, 365.25 days per year.

= 8766

CF = Summer Peak Coincidence Factor for measure

= 0.937

For example a solid door refrigerator with a volume of 15 would save

ΔkW = 296/ 8766 * .937

=0.0316 kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-CSDO-V02-190101

REVIEW DEADLINE: 1/1/2024

4.2.3 Commercial Steam Cooker

DESCRIPTION

To qualify for this measure the installed equipment must be an ENERGY STAR® steamer in place of a standard steamer in a commercial kitchen. Savings are presented dependent on the pan capacity and corresponding idle rate at heavy load cooking capacity and if the steamer is gas or electric.

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 as follows:

Gas	Electric
ENERGY STAR® qualified with 38% minimum cooking energy efficiency at heavy load (potato) cooking capacity for gas steam cookers.	ENERGY STAR® qualified with 50% minimum cooking energy efficiency at heavy load (potato) cooking capacity for electric steam cookers.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a non-ENERGY STAR® commercial steamer at end of life. It is assumed that the efficient equipment and baseline equipment have the same number of pans.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[36]

DEEMED MEASURE COST

The incremental capital cost for this measure is $998[37] for a natural gas steam cooker or $2490[38] for an electric steam cooker.

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[39]:

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

[36]California DEER 2008 which is also used by both the Food Service Technology Center and ENERGY STAR®.
[37]Source for incremental cost for efficient natural gas steamer is RSG Commercial Gas Steamer Workpaper, January 2012.
[38]Source for efficient electric steamer incremental cost is $2,490 per 2009 PG&E Workpaper - PGECOFST104.1 - Commercial Steam Cooker - Electric and Gas as reference by KEMA in the ComEd C & I TRM.
[39] 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.Unknown is an average of other location types

Location	CF
Cafeteria	0.39
Unknown	0.41

Algorithm

CALCULATION OF SAVINGS

Formulas below are applicable to both gas and electric steam cookers. Please use appropriate lookup values and identified flags.

ENERGY SAVINGS

ΔSavings = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Z

For a gas cooker: ΔSavings = ΔBtu * 1/100,000 * Z

For an electric steam cooker: ΔSavings = ΔkWh *Z

Where:

Z = days/yr steamer operating (use 365.25 days/yr if heavy use restaurant and exact number unknown)

ΔIdle Energy = $((((1- CSM_{\%Baseline})* IDLE_{BASE} + CSM_{\%Baseline} * PC_{BASE} * E_{FOOD} / EFF_{BASE}) * (HOURS_{day} - (F / PC_{Base}) - (PRE_{number} *0.25))) - (((1- CSM_{\%ENERGYSTAR}) * IDLE_{ENERGYSTAR} + CSM_{\%ENERGYSTAR} * PC_{ENERGY} * E_{FOOD} / EFF_{ENERGYSTAR}) * (HOURS_{Day} - (F l/ PC_{ENERGY}) - (PRE_{number} * 0.25))))$

Where:

$CSM_{\%Baseline}$ = Baseline Steamer Time in Manual Steam Mode (% of time)

= 90%[40]

$IDLE_{Base}$ = Idle Energy Rate of Base Steamer[41]

Number of Pans	$IDLE_{BASE}$ - Gas, Btu/hr	$IDLE_{BASE}$ - Electric, kw
3	11,000	1.0
4	14,667	1.33
5	18,333	1.67
6	22,000	2.0

PC_{Base} = Production Capacity of Base Steamer[42]

Number of Pans	PC_{BASE}, gas (lbs/hr)	PC_{BASE}, electric (lbs/hr)
3	65	70
4	87	93
5	108	117
6	130	140

[40] Food Service Technology Center 2011 Savings Calculator
[41] Food Service Technology Center 2011 Savings Calculator
[42] Production capacity per Food Service Technology Center 2011 Savings Calculator of 23.3333 lb/hr per pan for electric baseline steam cookers and 21.6667 lb/hr per pan for natural gas baseline steam cookers. ENERGY STAR® savings calculator uses 23.3 lb/hr per pan for both electric and natural gas baseline steamers.

E_{FOOD}= Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food (Btu/lb or kW/lb)

=105 Btu/lb[43] (gas steamers) or 0.0308[8] (electric steamers)

EFF_{BASE} =Heavy Load Cooking Efficiency for Base Steamer

=15%[44] (gas steamers) or 26%[9] (electric steamers)

$HOURS_{day}$ = Average Daily Operation (hours)

Type of Food Service	Hoursday[45]
Fast Food, limited menu	4
Fast Food, expanded menu	5
Pizza	8
Full Service, limited menu	8
Full Service, expanded menu	7
Cafeteria	6
Unknown	6[46]
Custom	Varies

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[47]

$CSM_{\%ENERGYSTAR}$ = ENERGY *STAR Steamer's Time in Manual Steam Mode (% of time)*[48]

= 0%

$IDLE_{ENERGYSTAR}$ = *Idle E*nergy Rate of ENERGY STAR®[49]

Number of Pans	$IDLE_{ENERGY\ STAR}$ – gas, (Btu/hr)	$IDLE_{ENERGY\ STAR}$ – electric, (kW)
3	6,250	0.40
4	8,333	0.53
5	10,417	0.67
6	12,500	0.80

PC_{ENERGY} = Production Capacity of ENERGY STAR® Steamer[50]

---

[43]ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations

[44]Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.

[45] 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.

[46]Unknown is average of other locations

[47]Reference amount used by both Food Service Technology Center and ENERGY STAR® savings calculator

[48]Reference information from the Food Service Technology Center siting that ENERGY STAR® steamers are not typically operated in constant steam mode, but rather are used in timed mode. Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker CalculationsBoth baseline & efficient steamer mode values should be considered for users in Illinois market.

[49]Food Service Technology Center 2011 Savings Calculator

[50]Production capacity per Food Service Technology Center 2011 Savings Calculator of 18.3333 lb/hr per pan for gas ENERGY STAR® steam cookers and 16.6667 lb/hr per pan for electric ENERGY STAR® steam cookers. ENERGY STAR® savings calculator uses 16.7 lb/hr per pan for electric and 20 lb/hr for natural gas ENERGY STAR® steamers.

Number of Pans	PC_{ENERGY} - gas(lbs/hr)	PC_{ENERGY} – electric (lbs/hr)
3	55	50
4	73	67
5	92	83
6	110	100

$EFF_{ENERGYSTAR}$ = Heavy Load Cooking Efficiency for ENERGY STAR® Steamer(%)

=38%[51] (gas steamer) or 50%[15] (electric steamer)

PRE_{number} = Number of preheats per day

=1[52] (if unknown, use 1)

ΔPreheat Energy = (PRE_{number} * Δ Pre_{heat})

Where:

PRE_{number} = Number of Preheats per Day

=1[53](if unknown, use 1)

PRE_{heat} = Preheat energy savings per preheat

= 11,000 Btu/preheat[54] (gas steamer) or 0.5 kWh/preheat[55] (electric steamer)

ΔCooking Energy = ((1/ EFFBASE) - (1/ EFFENERGY STAR®)) * F * E_{FOOD}

Where:

EFF_{BASE} =Heavy Load Cooking Efficiency for Base Steamer

=15%[56] (gas steamer) or 26%[28] (electric steamer)

$EFF_{ENERGYSTAR}$ =Heavy Load Cooking Efficiency for ENERGY STAR® Steamer

=38%[57] (gas steamer) or 50%[23] (electric steamer)

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[58]

E_{FOOD} = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food[59]

[51]Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for Tier 1A and Tier 1B qualified electric and natural gas steamer heavy cooking load energy efficiencies, as sourced from ENERGY STAR Program Requirements Product Specification for Commercial Steam Cookers, version 1.2, effective August 1, 2013.

[52]Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations

[53]Ibid.

[54]Ohio TRM which references 2002 Food Service Technology Center "Commercial Cooking Appliance Technology Assessment" Chapter 8: Steamers. This is also used by the ENERGY STAR Commercial Kitchen Equipment Savings Calculator. 11,000 Btu/preheat is from 72,000 Btu/hr * 15 min/hr /60 min/hr for gas steamers and 0.5 kWh/preheat is from 6 kW/preheat * 15 min/hr / 60 min/hr

[55] Reference Food Service Technology Center 2011 Savings Calculator values for Baseline Preheat Energy.

[56] Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.

[57] Ibid.

[58]Amount used by both Food Service Technology Center and ENERGY STAR® savings calculator

[59]Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations.

E_{FOOD} - gas(Btu/lb)	E_{FOOD} (kWh/lb)
105[60]	0.0308[61]

EXAMPLE

For a gas steam cooker: A 3 pan steamer in a full service restaurant

ΔSavings = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Z * 1/100.000

ΔIdle Energy = ((((1- 0.9)* 11000 + 0.9 * 65 * 105 /0.15)*(7 - (100 / 65)-(1*0.25))) - (((1-0) * 6250 + 0 * 55 * 105 / 0.38) * (7 - (100 / 55) - (1*0.25))))

= 188,321

ΔPreheat Energy = (1 *11,000)

= 11,000

ΔCooking Energy = (((1/ 0.15) - (1/ 0.38)) * (100 lb/day * 105 btu/lb)))

= 42368

ΔTherms = (188321 + 11000 + 42368) * 365.25 *1/100,000

= 883 therms

For an electric steam cooker: A 3 pan steamer in a cafeteria:

ΔSavings = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Z

ΔIdle Energy = ((((1- .9)* 1.0 + .9 * 70 * 0.0308 /0.26)*(6 - (100 / 70)-(1*.25))) - (((1-0) * 0.4 + 0 * 50 * 0.0308 / 0.50) * (6 - (100 / 50) - (1*0.25))))

= 31.18

ΔPreheat Energy = (1 *0.5))

= 0.5

ΔCooking Energy = (((1/ 0.26) - (1/ 0.5)) * (100 * 0.0308)))

= 5.69

ΔkWh = (31.18 + 0.5 + 5.69) * 365.25 days

= 13,649 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

ΔkWh_{water} = ΔWater (gallons) / 1,000,000 * $E_{water\ supply}$

Where

$E_{water\ supply}$ = IL Supply Energy Factor (kWh/Million Gallons)

=2,571[62]

[60] Ibid.

[61] Ibid.

[62] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'. Note that the Commercial Steam Cooker does not discharge its water into the wastewater system so only the water supply factor is used here.

EXAMPLE

For example, an electric 3 pan steamer with average efficiency in a full service restaurant

$\Delta Water (gallons) = (40 - 10) * 7 * 365.25$

$= 76,703$ gallons

$\Delta kWh_{water} = 76,703/1,000,000*2,571$

$= 197$ kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

This is only applicable to the electric steam cooker.

$$\Delta kW = (\Delta kWh/(HOURSDay * DaysYear)) * CF$$

Where:

ΔkWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

CF =Summer Peak Coincidence Factor for measure is provided below for different locations[63]:

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

$Days_{Year}$ =Annual Days of Operation

=custom or 365.25 days a year

Other values as defined above

EXAMPLE

For 3 pan electric steam cooker located in a cafeteria:

$\Delta kW = (\Delta kWh/(HOURS_{Day} * Days_{Year})) * CF$

$= (13,649/ (6 * 365.25)) * 0.39$

$= 2.43$ kW

WATER IMPACT DESCRIPTIONS AND CALCULATION

This is applicable to both gas and electric steam cookers.

$$\Delta Water (gallons) = (W_{BASE} - W_{ENERGYSTAR®}) * HOURS_{Day} * Days_{Year}$$

Where

[63]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.

W_{BASE} = Water Consumption Rate of Base Steamer (gal/hr)

= 40[64]

$W_{ENERGYSTAR}$ = Water Consumption Rate of ENERGY STAR® Steamer look up[65]

CEE Tier	gal/hr
Tier 1A	15
Tier 1B	4
Avg Efficient	10
Avg Most Efficient	3

$Days_{Year}$ =Annual Days of Operation

=custom or 365.25 days a year[66]

EXAMPLE

For example, an electric 3 pan steamer with average efficiency in a full service restaurant

ΔWater (gallons) = (40 -10) * 7 * 365.25

= 76,703 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-STMC-V05-190101

REVIEW DEADLINE: 1/1/2023

64 FSTC (2002). Commercial Cooking Appliance Technology Assessment. Chapter 8: Steamers.

65 Source Consortium for Energy Efficiency, Inc. September 2010 "Program Design Guidance for Steamers" for Tier 1A and Tier 1B water requirements. Ohio Technical Reference Manual 2010 for 10 gal/hr water consumption which can be used when Tier level is not known.

66 Source for 365.25 days/yr is ENERGY STAR® savings calculator which references Food Service Technology research on average use, 2009.

4.2.4 Conveyor Oven

DESCRIPTION

This measure applies to natural gas fired high efficiency conveyor ovens installed in commercial kitchens replacing existing natural gas units with conveyor width greater than 25 inches.

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. They are highly flexible and can be used to bake or roast a wide variety of products including pizza, casseroles, meats, breads, and pastries.

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. 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 conveyor oven with a tested baking energy efficiency > 42% and an idle energy consumption rate < 57,000 Btu/hr utilizing ASTM standard F1817.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing pizza deck oven at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 17 years.[67]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1800[68].

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[67]See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.
[68] Ibid.

Natural Gas Energy Savings

The annual natural gas energy savings from this measure is a deemed value equaling 884 Therms[69].

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-FSE-CVOV-V02-180101

Review Deadline: 1/1/2024

[69] The Resource Solutions Group Commercial Conveyor Oven – Gas workpaper from January 2012; Commercial Gas Conveyor Oven – Large Gas Savings (therms/unit).

4.2.5 ENERGY STAR Convection Oven

Description

This measure applies to natural gas fired ENERGY STAR convection ovens 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 natural gas convection oven with a cooking efficiency ≥ 46% utilizing ASTM standard 1496 and an idle energy consumption rate < 12,000 Btu/hr[70]

Definition of Baseline Equipment

The baseline equipment is a natural gas convection oven that is not ENERGY STAR certified and is at end of life.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[71]

Deemed Measure Cost

The incremental capital cost for this measure is $50[72]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

ustom calculation below, otherwise use deemed value of 306 therms. [73]

$$\Delta Therms = (\Delta DailyIdle\ Energy + \Delta DailyPreheat\ Energy + \Delta DailyCooking\ Energy) * Days / 100000$$

Where:

[70] Version 2.2. of the ENERGY STAR specification.

[71] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Oven Calculations, which cites reference as "FSTC research on available models, 2009".

[72] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2010".

[73] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Oven Calculations.

ΔDailyIdleEnergy = (IdleBase* IdleBaseTime)- (IdleENERGYSTAR * IdleENERGYSTARTime)

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase) – (PreheatNumberENERGYSTAR * PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where:

HOURSday = Average Daily Operation

= custom or if unknown, use 12 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

LB = Food cooked per day

= custom or if unknown, use 100 pounds

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 46%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 30%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 80 pounds/hr

PCBase = Production Capacity base

= custom or if unknown, use 70 pounds/hr

PreheatNumberENERGYSTAR = Number of preheats per day

= custom or if unknown, use 1

PreheatNumberBase = Number of preheats per day

= custom or if unknown, use 1

PreheatTimeENERGYSTAR = preheat length

= custom or if unknown, use 15 minutes

PreheatTimeBase = preheat length

= custom or if unknown, use 15 minutes

PreheatRateENERGYSTAR = preheat energy rate high efficiency

= custom or if unknown, use 44000 btu/h

PreheatRateBase = preheat energy rate baseline

= custom or if unknown, use 76000 btu/h

IdleENERGYSTAR = Idle energy rate

= custom or if unknown, use 12000 btu/h

IdleBase = Idle energy rate

= custom or if unknown, use 18000 btu/h

IdleENERGYSTARTime	= ENERGY STAR Idle Time
	=HOURsday-LB/PCENERGYSTAR –PreHeatTimeENERGYSTAR/60
	=12 – 100/80 – 15/60
	=10.5 hours
IdleBaseTime	= BASE Idle Time
	= HOURsday-LB/PCbase –PreHeatTimeBase/60
	=Custom or if unknown, use
	=12 – 100/70-15/60
	=10.3 hours
EFOOD	= ASTM energy to food
	= 250 btu/pound

EXAMPLE

For example, an ENERGY STAR Oven with a cooking energy efficiency of 46% and default values from above would save.

ΔTherms = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /100000

Where:

ΔDailyIdleEnergy	=(18000*10.3)- (12000*10.5)
	= 59,400 btu
ΔDailyPreheatEnergy	= (1 * 15 / 60 *76000) – (1 * 15 / 60 *44000)
	= 8,000 btu
ΔDailyCookingEnergy	= (100 * 250/ .30) - (100 * 250/ .46)
	=28,986 btu
ΔTherms	= (59,400 + 8,000 + 28,986) * 365.25 /100000
	= 352 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESCV-V02-180101

REVIEW DEADLINE: 1/1/2024

4.2.6 ENERGY STAR Dishwasher

DESCRIPTION

This measure applies to ENERGY STAR high and low temp under counter, stationary single tank door type, single tank conveyor, and multiple tank conveyor dishwashers, as well as high temp pot, pan, and utensil dishwashers 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 an 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 temp versus high temp).

ENERGY STAR Requirements (Effective February 1, 2013)

Dishwasher Type	High Temp Efficiency Requirements		Low Temp Efficiency Requirements	
	Idle Energy Rate	Water Consumption	Idle Energy Rate	Water Consumption
Under Counter	≤ 0.50 kW	≤ 0.86 GPR	≤ 0.50 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.70 kW	≤ 0.89 GPR	≤ 0.60 kW	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 1.20 kW	≤ 0.58 GPSF	≤ 1.00 kW	≤ 0.58 GPSF
Single Tank Conveyor	≤ 1.50 kW	≤ 0.70 GPR	≤ 1.50 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 2.25 kW	≤ 0.54 GPR	≤ 2.00 kW	≤ 0.54 GPR

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new dishwasher that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be[74]

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

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below:[75]

Dishwasher Type		Incremental Cost
Low	Under Counter	$50

[74] Lifetime from ENERGY STAR Commerical Kitchen Equipment Savings Calculator which cites reference as "EPA/FSTC research on available models, 2013"
[75] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2012"

Dishwasher Type		Incremental Cost
Temp	Stationary Single Tank Door	$0
	Single Tank Conveyor	$0
	Multi Tank Conveyor	$970
High Temp	Under Counter	$120
	Stationary Single Tank Door	$770
	Single Tank Conveyor	$2,050
	Multi Tank Conveyor	$970
	Pot, Pan, and Utensil	$1,710

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different restaurant types[76]:

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

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.

$$\Delta kWh^{77} = \Delta BuildingEnergy + \Delta BoosterEnergy^{78} + \Delta IdleEnergy$$

Where:

ΔBuildingEnergy = Change in annual electric energy consumption of building water heater

$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}412)]$

ΔBoosterEnergy = Annual electric energy consumption of booster water heater

$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}412)]$

[76] 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

[77]Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

[78] Booster water heater energy only applies to high-temperature dishwashers.

ΔIdleEnergy = Annual idle electric energy consumption of dishwasher

$= [IdleDraw_{Base} * (Hours * Days – Days * RacksWashed * WashTime \div 60)] –$

$[IdleDraw_{ESTAR} * (Hours * Days – Days * RacksWashed * WashTime \div 60)]$

Where:

$WaterUse_{Base}$ = Water use per rack (gal) of baseline dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

$WaterUse_{ESTAR}$ = Water use per rack (gal) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

Days = Annual days of dishwasher operation

= Custom or if unknown, use 365.25 days per year

ΔT_{in} = Inlet water temperature increase (°F)

= Custom or if unknown, use 70 °F for building water heaters and 40 °F for booster water heaters

1.0 = Specific heat of water (Btu/lb/°F)

8.2 = Density of water (lb/gal)

Eff_{Heater} = Efficiency of water heater

= Custom or if unknown, use 98% for electric building and booster water heaters

3,412 = kWh to Btu conversion factor

$IdleDraw_{Base}$ = Idle power draw (kW) of baseline dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

$IdleDraw_{ESTAR}$ = Idle power draw (kW) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

Hours = Average daily hours of dishwasher operation

= Custom or if unknown, use 18 hours per day

WashTime = Typical wash time (min)

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

60 = Minutes to hours conversion factor

EXAMPLE

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

ΔkWh = ΔBuildingEnergy + ΔBoosterEnergy + ΔIdleEnergy

Where:

ΔBuildingEnergy = [(1.09 * 75 * 365.25) * (70 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)] - [(0.86 * 75 * 365.25) * (70 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)]

= 1,082 kWh

ΔBoosterEnergy = [(1.09 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)] - [(0.86 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)]

= 618 kWh

ΔIdleEnergy = [0.76 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)] – [0.50 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)]

= 1,472 Wh

ΔkWh = 1,082 + 618 + 1,472

= 3,172 kWh

Default values for WaterUse, RacksWashed, kW_{Idle}, and WashTime are presented in the table below.

	RacksWashed	WashTime	WaterUse		IdleDraw	
Low Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.73	1.19	0.50	0.50
Stationary Single Tank Door	280	1.5	2.10	1.18	0.60	0.60
Single Tank Conveyor	400	0.3	1.31	0.79	1.60	1.50
Multi Tank Conveyor	600	0.3	1.04	0.54	2.00	2.00
High Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.09	0.86	0.76	0.50
Stationary Single Tank Door	280	1.0	1.29	0.89	0.87	0.70
Single Tank Conveyor	400	0.3	0.87	0.70	1.93	1.50
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	2.25
Pot, Pan, and Utensil	280	3.0 3.0	0.70	0.58	1.20	1.20

Savings for all water heating combinations are presented in the tables below (calculated without rounding variables as provided above).

Electric building and electric booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	10,972	8,431	2,541
	Stationary Single Tank Door	39,306	23,142	16,164
	Single Tank Conveyor	42,230	28,594	13,636
	Multi Tank Conveyor	50,112	31,288	18,824
High Temp	Under Counter	12,363	9,191	3,173
	Stationary Single Tank Door	39,852	27,981	11,871
	Single Tank Conveyor	45,593	36,375	9,218
	Multi Tank Conveyor	72,523	45,096	27,426

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
	Pot, Pan, and Utensil	21,079	17,766	3,313

Electric building and natural gas booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	10,972	8,431	2,541
	Stationary Single Tank Door	39,306	23,142	16,164
	Single Tank Conveyor	42,230	28,594	13,636
	Multi Tank Conveyor	50,112	31,288	18,824
High Temp	Under Counter	9,432	6,878	2,554
	Stationary Single Tank Door	26,901	19,046	7,856
	Single Tank Conveyor	33,115	26,335	6,780
	Multi Tank Conveyor	51,655	33,479	18,176
	Pot, Pan, and Utensil	14,052	11,943	2,108

Natural gas building and electric booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	2,831	2,831	0
	Stationary Single Tank Door	2,411	2,411	0
	Single Tank Conveyor	9,350	8,766	584
	Multi Tank Conveyor	10,958	10,958	0
High Temp	Under Counter	7,234	5,143	2,090
	Stationary Single Tank Door	17,188	12,344	4,844
	Single Tank Conveyor	23,757	18,806	4,951
	Multi Tank Conveyor	36,004	24,766	11,238
	Pot, Pan, and Utensil	8,781	7,576	1,205

Natural gas building and natural gas booster water heating

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
Low Temp	Under Counter	2,831	2,831	0
	Stationary Single Tank Door	2,411	2,411	0
	Single Tank Conveyor	9,350	8,766	584
	Multi Tank Conveyor	10,958	10,958	0
High Temp	Under Counter	4,303	2,831	1,472
	Stationary Single Tank Door	4,237	3,409	828
	Single Tank Conveyor	11,279	8,766	2,513
	Multi Tank Conveyor	15,136	13,149	1,987
	Pot, Pan, and Utensil	1,753	1,753	0

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[79]

EXAMPLE
For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:
$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$
ΔWater (gallons) = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)
= 14,793 gallons
ΔkWh_{water} = 14,793/1,000,000*5,010
= 74 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/ AnnualHours * CF

Where:

ΔkWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

AnnualHours = Hours * Days

= Custom or if unknown assume (18 * 365.25 =) 6575 annual hours

CF = Summer Peak Coincidence Factor

= dependent on restaurant type[80]:

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

Example:
A low temperature undercounter dishwasher in a Full Service Limited Menu restaurant with electric building and booster water heaters would save:
ΔkW = ΔkWh/ AnnualHours * CF
= 2541/6575*0.51
= 0.197 kW

[79] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[80] 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

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms^{81} = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

ΔBuildingEnergy = Change in annual natural gas consumption of building water heater

= [(WaterUse$_{Base}$ * RacksWashed * Days)*(ΔT$_{in}$ * 1.0 * 8.2 ÷ Eff$_{Heater}$ ÷ 100,000)] - [(WaterUse$_{ESTAR}$* RacksWashed * Days)*(ΔT$_{in}$ * 1.0*8.2 ÷ Eff$_{Heater}$ ÷ 100,000)]

ΔBoosterEnergy = Change in annual natural gas consumption of booster water heater

= [(WaterUse$_{Base}$ * RacksWashed * Days)*(ΔT$_{in}$ * 1.0 * 8.2 ÷ Eff$_{Heater}$ ÷ 100,000)] - [(WaterUse$_{ESTAR}$* RacksWashed * Days)*(ΔT$_{in}$ * 1.0*8.2 ÷ Eff$_{Heater}$ ÷ 100,000)]

Where:

WaterUse$_{Base}$ = Water use per rack (gal) of baseline dishwasher

= Custom or if unknown, 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

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table within the electric energy savings characterization 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 70 °F for building water heaters and 40 °F for booster water heaters

1.0 = Specific heat of water (Btu/lb/°F)

8.2 = Density of water (lb/gal)

Eff$_{Heater}$ = Efficiency of water heater

= Custom or 80% for gas building and booster water heaters

100,000 = Therms to Btu conversion factor

[81] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

EXAMPLE

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔTherms = ΔBuildingEnergy + ΔBoosterEnergy

Where:

ΔBuildingEnergy = [(1.09 * 75 * 365.25)*(70 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(70 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)]

= 45 therms

ΔBoosterEnergy = [(1.09 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)]

= 26 therms

ΔTherms = 45 + 26

= 71 therms

Savings for all water heating combinations are presented in the tables below.

Electric building and natural gas booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	NA	NA	NA
	Stationary Single Tank Door	NA	NA	NA
	Single Tank Conveyor	NA	NA	NA
	Multi Tank Conveyor	NA	NA	NA
High Temp	Under Counter	123	97	26
	Stationary Single Tank Door	541	374	168
	Single Tank Conveyor	522	420	102
	Stationary Single Tank Door	872	486	387
	Pot, Pan, and Utensil	294	243	50

Natural gas building and natural gas booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	340	234	106
	Stationary Single Tank Door	1,543	867	676
	Single Tank Conveyor	1,375	829	546
	Multi Tank Conveyor	1,637	850	787
High Temp	Under Counter	337	266	71
	Stationary Single Tank Door	1,489	1,027	462
	Single Tank Conveyor	1,435	1,154	280
	Multi Tank Conveyor	2,399	1,336	1,064
	Pot, Pan, and Utensil	808	669	139

Natural gas building and electric booster water heating

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
Low Temp	Under Counter	340	234	106
	Stationary Single Tank Door	1,543	867	676
	Single Tank Conveyor	1,375	829	546
	Multi Tank Conveyor	1,637	850	787

Dishwasher type		$Therms_{Base}$	$Therms_{ESTAR}$	ΔTherms
High Temp	Under Counter	214	169	45
	Stationary Single Tank Door	948	654	294
	Single Tank Conveyor	913	735	178
	Multi Tank Conveyor	1,527	850	677
	Pot, Pan, and Utensil	514	426	88

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

= Custom or if unknown, 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

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

Days = Annual days of dishwasher operation

= Custom or if unknown, use 365 days per year

EXAMPLE

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔWater = ($WaterUse_{Base}$ * RacksWashed * Days) - ($WaterUse_{ESTAR}$ * RacksWashed * Days)

ΔWater (gallons) = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)

= 14,793 gallons

Savings for all dishwasher types are presented in the table below.

	Annual Water Consumption (gallons)		
	Baseline	ENERGY STAR	Savings
Low Temperature			
Under Counter	47,391	32,599	14,793
Stationary Single Tank Door	214,767	120,679	94,088
Single Tank Conveyor	191,391	115,419	75,972
Multi Tank Conveyor	227,916	118,341	109,575
High Temperature			
Under Counter	29,859	23,559	6,301
Stationary Single Tank Door	131,928	91,020	40,908
Single Tank Conveyor	127,107	102,270	24,837
Multi Tank Conveyor	212,576	118,341	94,235
Pot, Pan, and Utensil	71,589	59,317	12,272

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESDW-V04-190101

REVIEW DEADLINE: 1/1/2023

4.2.7 ENERGY STAR Fryer

Description

This measure applies to electric or natural gas fired ENERGY STAR certified fryers 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 an ENERGY STAR certified fryer meeting idle energy rate (W 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 Consumption	Idle Energy Rate	Cooking Efficiency Consumption
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.[82]

Deemed Measure Cost

The incremental capital cost for this measure is $1200.[83]

Loadshape

Loadshape C01 - Commercial Electric Cooking

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[84]:

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

[82]Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator ,which cites reference as "FSTC research on available models, 2009

[83]Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2010".

[84]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

Location	CF
Cafeteria	0.39

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation for an electric fryer below, otherwise use deemed value of 2,378.0 kWh for standard fryers and 2,537.9 kWh for large vat fryers.[85]

ΔkWh = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /1,000

Where:

ΔDailyIdleEnergy = $(ElecIdle_{Base} * (HOURS - LB/ElecPC_{Base})) - (ElecIdle_{ESTAR} * (HOURS - LB/ElecPC_{ESTAR}))$

ΔDailyCookingEnergy = $(LB * EFOOD_{Elec}/ ElecEff_{Base}) - (LB * EFOOD_{Elec}/ElecEff_{ESTAR})$

Where:

ΔDailyIdleEnergy = Difference in idle energy between baseline and efficient fryer

ΔDailyCookingEnergy = Difference in cooking energy between baseline and efficient fryer

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

$ElecIdle_{Base}$ = Idle energy rate of baseline electric fryer

= 1,050 W for standard fryers and 1,350 W for large vat fryers

$ElecIdle_{ESTAR}$ = 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

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

LB = Food cooked per day

= Custom or if unknown, use 150 pounds

$ElecPC_{Base}$ = Production capacity of baseline electric fryer

= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$ElecPC_{ESTAR}$ = 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

$EFOOD_{Elec}$ = ASTM energy to food for electric fryers

[85] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

= 167 Wh/lb

$ElecEff_{Base}$ = Cooking efficiency of baseline electric fryer

= 75% for standard fryers and 70% for large vat fryers

$ElecEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR electric fryer

= Custom or if unknown, use 83% for standard fryers and 80% for large vat fryers

EXAMPLE

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

ΔkWh = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /1,000

Where:

ΔDailyIdleEnergy = (1,050 * (16 – 150 / 65)) - (800 * (16 – 150 / 70))

= 3,291 Wh

ΔDailyCookingEnergy = (150 * 167/ 0.75) - (150 * 167/ 0.83)

= 3,219 Wh

ΔkWh = (3,291 + 3,219) * 365.25 / 1,000

= 2,378.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/(HOURS * Days) * CF

Where:

ΔkWh = Electric energy savings, calculated above

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR standard-sized electric fryer in a cafeteria, using default values from the calculation above, would save:

ΔkW = ΔkWh/(HOURS * Days) * CF

= 2,378.0 / (16 * 365.25) * 0.36

= 0.1465 kW

NATURAL GAS ENERGY SAVINGS

Custom calculation for a gas fryer below, otherwise use deemed value of 507.9 therms for standard fryers and 415.1 therms for large vat fryers.[86]

ΔTherms = (ΔDailyIdle Energy + ΔDailyCooking Energy) * Days /100,000

Where:

ΔDailyIdleEnergy = $(GasIdle_{Base} * (HOURS – LB/GasPC_{Base})) – (GasIdle_{ESTAR} * (HOURS – LB/GasPC_{ESTAR}))$

ΔDailyCookingEnergy = $(LB * EFOOD_{Gas}/ GasEff_{Base}) – (LB * EFOOD_{Gas}/GasEff_{ESTAR})$

Where:

[86] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

100,000 = Btu to therms conversion factor

$GasIdle_{Base}$ = Idle energy rate of baseline gas fryer

= 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers

$GasIdle_{ESTAR}$ = 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

$GasPC_{Base}$ = Production capacity of baseline gas fryer

= 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$GasPC_{ESTAR}$ = Production capacity of ENERGY STAR gas fryer

= Custom or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers

$EFOOD_{Gas}$ = ASTM energy to food

= 570 Btu/lb

$GasEff_{Base}$ = Cooking efficiency of baseline gas fryer

= 35% for both standard and large vat fryers

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR gas fryer

= Custom or if unknown, use 50% for both standard and large vat fryers

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

ΔTherms = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /100,000

Where:

ΔDailyIdleEnergy = (14,000 * (16 – 150 / 60)) - (9,000 * (16 – 150 / 65))

= 65,769 Btu/day

ΔDailyCookingEnergy = (150 * 570/ 0.35) - (150 * 570/ 0.50)

=73,286 Btu/day

ΔTherms = (65,769 + 73,286) * 365.25 / 100,000

= 507.9 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESFR-V02-190101

REVIEW DEADLINE: 1/1/2022

4.2.8 ENERGY STAR Griddle

Description

This measure applies to electric and natural gas fired high efficiency griddle 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 an ENERGY STAR natural gas or electric griddle with a tested heavy load cooking energy efficiency of 70 percent (electric) 38 percent (gas) or greater and an idle energy rate of 2,650 Btu/hr per square foot of cooking surface or less, utilizing ASTM F1275. The griddle must have an Idle Energy Consumption Rate < 2,600 Btu/hr per square foot of cooking surface.

Definition of Baseline Equipment

The baseline equipment is an existing natural gas or electric griddle that's not ENERGY STAR certified and is at end of use.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[87]

Deemed Measure Cost

The incremental capital cost for this measure is $0 for and electric griddle and $60 for a gas griddle.[88]

Loadshape

Loadshape C01 - Commercial Electric Cooking

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[89]:

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

[87] Lifetime from ENERGY STAR Commercial Kitchen Equipment Calculator, Commercial Griddle Calculations, which cites reference as "FSTC research on available models, 2009".

[88] Measure cost from ENERGY STAR Commercial Kitchen Equipment Calculator, which cites reference as "EPA research on available models using AutoQuotes, 2010".

[89]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

Algorithm

CALCULATION OF SAVINGS [90]

ELECTRIC ENERGY SAVINGS

ΔkWh = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /1000

Where:

ΔDailyIdleEnergy =[(IdleBase * Width * Depth * (HOURSday – (LB/(PCBase * Width * Depth)) – (PreheatNumberBase* PreheatTimeBase/60)]- [(IdleENERGYSTAR * Width * Depth * (HOURSday – (LB/(PCENERGYSTAR * Width * Depth)) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60]

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase * Width * Depth) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR * Width * Depth)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where:

HOURSday = Average Daily Operation

= custom or if unknown, use 12 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

LB = Food cooked per day

= custom or if unknown, use 100 pounds

Width = Griddle Width

= custom or if unknown, use 3 feet

Depth = Griddle Depth

= custom or if unknown, use 2 feet

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 70%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 65%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 40/6 = 6.67 pounds/hr/sq ft

PCBase = Production Capacity base

= custom or if unknown, use 35/6 = 5.83 pounds/hr/sq ft

PreheatNumberENERGYSTAR = Number of preheats per day

= custom or if unknown, use 1

PreheatNumberBase = Number of preheats per day

[90] Algorithms and assumptions derived from ENERGY STAR Griddle Commercial Kitchen Equipment Savings Calculator.

= custom or if unknown, use 1

PreheatTimeENERGYSTAR = preheat length

= custom or if unknown, use 15 minutes

PreheatTimeBase = preheat length

= custom or if unknown, use 15 minutes

PreheatRateENERGYSTAR = preheat energy rate high efficiency

= custom or if unknown, use 8000/6 = 1333 W/sq ft

PreheatRateBase = preheat energy rate baseline

= custom or if unknown, use 16000/6 = 2667 W/sq ft

IdleENERGYSTAR = Idle energy rate

= custom or if unknown, use 320 W/sq ft

IdleBase = Idle energy rate

= custom or if unknown, use 400 W/sq ft

EFOOD = ASTM energy to food

= 139 w/pound

For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save.

ΔDailyIdleEnergy =[400 * 3 * 2 * (12 – (100/(35/6 * 3 * 2)) – (1 *15/60)]- [320 * 3 * 2 * (12 – (100/(40/6 * 3 * 2)) – (1* 15/60]

= 3583 W

ΔDailyPreheatEnergy = (1* 15 / 60 * 16000/6 * 3 * 2) – (1* 15/60 * 8000/6 * 3 * 2)

= 2000W

ΔDailyCookingEnergy = (100 * 139 / 0.65) - (100 * 139 / 0.70)

= 1527 W

ΔkWh = (2000+1527+3583) * 365.25 /1000

= 2597 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

kW = ΔkWh/Hours * CF

For example, an ENERGY STAR griddle in a cafeteria with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save

=2597 kWh/4308 * 0.39

= 0.24 kW

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 149 therms.

ΔTherms = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /100000

Where:

ΔDailyIdleEnergy =[(IdleBase * Width * Depth * (HOURSday - LB/(PCBase * Width * Depth)) – (PreheatNumberBase* PreheatTimeBase/60)]- [(IdleENERGYSTAR * Width * Depth * (HOURSday – (LB/(PCENERGYSTAR * Width * Depth)) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60]

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase * Width * Depth) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR * Width * Depth)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where (new variables only):

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 38%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 32%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 45/6 = 7.5 pounds/hr/sq ft

PCBase = Production Capacity base

= custom or if unknown, use 25/6 = 4.17 pounds/hr/sq ft

PreheatRateENERGYSTAR = preheat energy rate high efficiency

= custom or if unknown, use 60000/6 = 10000 btu/h/sq ft

PreheatRateBase = preheat energy rate baseline

= custom or if unknown, use 84000/6 = 14000 btu/h/sq ft

IdleENERGYSTAR = Idle energy rate

= custom or if unknown, use 15900/6 = 2650 btu/h/sq ft

IdleBase = Idle energy rate

= custom or if unknown, use 21000/6 = 3500 btu/h/sq ft

EFOOD = ASTM energy to food

= 475 btu/pound

For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 38 percent or greater and an idle energy rate of 2,650 Btu/h per square foot of cooking surface or less and an Idle Energy Consumption Rate < 2,600 Btu/h per square foot of cooking surface would save.

ΔDailyIdleEnergy =[3500 * 3 * 2 * (12 - 100/(25/6* 3 * 2)) – (1* 15/60))]- [(2650 * 3 * 2 * (12 - (100/(45/6 * 3 * 2)) – (1* 15/60)))]

= 11258 Btu

ΔDailyPreheatEnergy = (1 * 15 / 60 * 14,000 * 3 * 2) – (1* 15/60 * 10000 * 3 * 2)

= 6000 btu

ΔDailyCookingEnergy = (100 * 475/ 0.32) - (100 * 475/ 0.38)

=23438 btu

ΔTherms = (11258 + 6000 + 23438) * 365.25 /100000

=149 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESGR-V03-190101

REVIEW DEADLINE: 1/1/2023

4.2.9 ENERGY STAR Hot Food Holding Cabinets

DESCRIPTION

This measure applies to electric ENERGY STAR hot food holding cabinets (HFHC) 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 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[91]

DEEMED MEASURE COST

The incremental capital cost for this measure is[92]

HFHC Size	Incremental Cost
Full Size (20 cubic feet)	$1200
¾ Size (12 cubic feet)	$1800
½ Size (8 cubic feet)	$1500

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[93]:

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

[91] Lifetime from ENERGY STAR Commercial Kitchen Equipment Calculator, Hot Food Holding Cabinet Calculations, which cites reference as "FSTC research on available models, 2009"

[92] Measure cost from ENERGY STAR Commercial Kitchen Equipment Calculator, which cites reference as "EPA research on available models using AutoQuotes, 2010"

[93] 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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values depending on HFHC size[94]

Cabinet Size	Savings (kWh)
Full Size HFHC	9308
¾ Size HFHC	3942
½ Size HFHC	2628

ΔkWh = HFHCBaselinekWh – HFHCENERGYSTARkWh

Where:

HFHCBaselinekWh = PowerBaseline* HOURSday * Days/1000

PowerBaseline = Custom, otherwise

Cabinet Size	Power (W)
Full Size HFHC	2500
¾ Size HFHC	1200
½ Size HFHC	800

HOURSday = Average Daily Operation

= custom or if unknown, use 15 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

HFHCENERGYSTARkWh = PowerENERGYSTAR* HOURSday * Days/1000

PowerENERGYSTAR = Custom, otherwise

Cabinet Size	Power (W)
Full Size HFHC	800
¾ Size HFHC	480
½ Size HFHC	320

HOURSday = Average Daily Operation

= custom or if unknown, use 15 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

[94] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

For example, if a full size HFHC is installed the measure would save:

ΔkWh = (PowerBaseline* HOURSday * Days)/1000 – (PowerENERGYSTAR* HOURSday * Days)/1000

= (2500*15*365.25)/1000 – (800*15*365.25)/1000

= 9,314 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where: Hours = Hoursday *Days

For example, if a full size HFHC is installed in a cafeteria the measure would save:

= 9,314 kWh / (15*365.25)* .39

=0 .66 kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESHH-V03-190101

REVIEW DEADLINE: 1/1/2023

4.2.10 ENERGY STAR Ice Maker

Description

This measure relates to the installation of a new ENERGY STAR qualified commercial ice machine. The ENERGY STAR label applied to air-cooled, cube-type machines including ice-making head, self-contained, and remote-condensing units. This measure excludes flake and nugget type ice machines. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

This measure was developed to be applicable to the following program types: TOS and 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 new commercial ice machine meeting the minimum ENERGY STAR efficiency level standards.

ENERGY STAR Requirements (Version 3.0, Effective January 28, 2018)

ENERGY STAR Requirements for Air-Cooled Batch-Type Ice Makers			
Equipment Type	**Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)**	**ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)**	**Potable Water Use (gal/100 lbs ice)**
IMH	H < 300	≤ 9.20 - 0.01134H	≤ 20.0
	300 ≤ H < 800	≤ 6.49 - 0.0023H	
	800 ≤ H < 1500	≤ 5.11 - 0.00058H	
	1500 ≤ H ≤ 4000	≤ 4.24	
RCU	H < 988	≤ 7.17 – 0.00308H	≤ 20.0
	988 ≤ H ≤ 4000	≤ 4.13	
SCU	H < 110	≤ 12.57 - 0.0399H	≤ 25.0
	110 ≤ H < 200	≤ 10.56 - 0.0215H	
	200 ≤ H ≤ 4000	≤ 6.25	
ENERGY STAR Requirements for Air-Cooled Continuous-Type Ice Makers			
Equipment Type	**Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)**	**ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)**	**Potable Water Use (gal/100 lbs ice)**
IMH	H < 310	≤ 7.90 – 0.005409H	≤ 15.0
	310 ≤ H < 820	≤ 7.08 – 0.002752H	
	820 ≤ H ≤ 4000	≤ 4.82	
RCU	H < 800	≤ 7.76 – 0.00464H	≤ 15.0
	800 ≤ H ≤ 4000	≤ 4.05	
SCU	H < 200	≤ 12.37 – 0.0261H	≤ 15.0
	200 ≤ H < 700	≤ 8.24 – 0.005429H	
	700 ≤ H ≤ 4000	≤ 4.44	

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a commercial ice machine meeting federal equipment standards established January 1, 2010.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 9 years[95].

Deemed Measure Cost

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is $0 for Batch-Type and $222 for Continuous-Type ice makers.[96]

Loadshape

Loadshape C23 - Commercial Refrigeration

Coincidence Factor

The Summer Peak Coincidence Factor is assumed to equal 0.937

Algorithm

Calculation of Savings

Electric Energy Savings

$\Delta kWH = [(kWh_{base} – kWh_{ee}) / 100] * (DC * H) * 365.25$

Where:

kWh_{base} = maximum kWh consumption per 100 pounds of ice for the baseline equipment

= calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.

kWh_{ee} = maximum kWh consumption per 100 pounds of ice for the efficient equipment

= calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.

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			

[95] Based on DOE Technical Support Document, 2014 as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[96] Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2016.

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh_{Base}	kWh_{ESTAR}
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 = conversion factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice.

DC = Duty Cycle of the ice machine

= 0.57[97]

H = Harvest Rate (pounds of ice made per day)

= Actual installed

365.35 = days per year

> For example a batch ice machine with an ice making head producing 450 pounds of ice would save
>
> ΔkWH = [(5.9 – 5.5) / 100] * (0.57 * 450) * 365.25
>
> = 440 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / (HOURS * DC) * CF

Where:

HOURS = annual operating hours

= 8766[98]

CF = 0.937

[97]Duty cycle varies considerably from one installation to the next. TRM assumptions from Vermont, Wisconsin, and New York vary from 40 to 57%, whereas the ENERGY STAR Commercial Ice Machine Savings Calculator assumes a value of 75%. A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). Furthermore, a report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). The value of 57% was utilized since it appears to represent a high quality data source.

[98]Unit is assumed to be connected to power 24 hours per day, 365.25 days per year.

For example an ice machine with an ice making head producing 450 pounds of ice would save

$$\Delta kW = 440/(8766 * 0.57) * .937$$
$$= 0.083 \text{ kW}$$

NATURAL GAS ENERGY 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[99] indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESIM-V02-190101

REVIEW DEADLINE: 1/1/2024

[99] AHRI Certification Directory, Automatic Commercial Ice Makers, Accessed on 7/7/10.

4.2.11 High Efficiency Pre-Rinse Spray Valve

Description

Pre-rise valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water thereby reducing water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

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

Definition of Efficient Equipment

To qualify for this measure, the new or replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less.

Definition of Baseline Equipment

The baseline equipment will vary based on the delivery method and is defined below:

Time of Sale	Retrofit, Direct Install
The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.	The baseline equipment is assumed to be an existing pre-rinse spray valve with a flow rate of 1.9 gallons per minute.[100] If existing pre-rinse spray valve flow rate is unknown, then existing pre-rinse spray valve must have been installed prior to 2006. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. However, field data shows that not all nozzles in use have been replaced with the newer flow rate nozzle. Products predating this standard can use up to five gallons per minute

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 5 years[101]

Deemed Measure Cost

When available, the actual cost of the measure (including labor where applicable) should be used. If unknown, a default value of $92.90[102] may be assumed.

Loadshape

Loadshape C01 - Commercial Electric Cooking

---

[100] Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively." from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007)

[101] Reference 2010 Ohio Technical Reference Manual, Act on Energy Business Program Technical Reference Manual Rev05, and Federal Energy Management Program (2004), "How to Buy a Low-Flow Pre-Rinse Spray Valve."

[102] Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100).

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS (NOTE WATER SAVINGS MUST FIRST BE CALCULATED)

ΔkWH = ΔWater (gallons) * 8.33 * 1 * (Tout - Tin) * (1/EFF_Elec) /3,412 * FLAG

Where:

ΔWater (gallons) = amount of water saved as calculated below

8.33 = specific mass in pounds of one gallon of water (lbm/gal)

1 = Specific heat of water: 1 Btu/lbm/°F

Tout = Water Heater Outlet Water Temperature

= custom, otherwise assume Tin + 70°F temperature rise from Tin[103]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[104]

EFF_Elec = Efficiency of electric water heater supplying hot water to pre-rinse spray valve

=custom, otherwise assume 97%[105]

Flag = 1 if electric or 0 if gas

EXAMPLE

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water saves annually :

ΔkWH = 30,326x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.97) /3,412 x 1

= 5,343kWh

Retrofit: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water equals:

ΔkWH = 47,175 x 8.33 x 1 x ((70+ 54.1) - 54.1) x (1/.97) /3,412 x 1

=8311 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

[103]If unknown, assume a 70 degree temperature rise from Tin per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies

[104]August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.

[105]This efficiency value is based on IECC 2012/2015 performance requirement for electric resistant water heaters rounded without the slight adjustment allowing for reduction based on size of storage tank.

ΔkWh_{water} = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[106]

EXAMPLE

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria equals

ΔWater (gallons) = (1.6 – 1.06) * 60 * 3 * 312

= 30,326 gal/yr

ΔkWh_{water} = 30,326/1,000,000*5,010

= 152 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms = ΔWater (gallons) * 8.33 * 1 * (Tout - Tin) * (1/EFF_Gas) /100,000 * (1 – FLAG)

Where (new variables only):

EFF_Gas = Efficiency of gas water heater supplying hot water to pre-rinse spray valve

= custom, otherwise assume 80%[107]

EXAMPLE

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:

ΔTherms = 30,326 x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.80)/100,000 x (1-0)

= 221 Therms

Retrofit: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a busy large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:

ΔTherms = 47,175 x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.80)/100,000 x (1-0)

=344 Therms

WATER IMPACT CALCULATION[108]

ΔWater (gallons) = (FLObase - FLOeff) * 60 * HOURSday * DAYSyear

Where:

FLObase = Base case flow in gallons per minute, or custom (Gal/min)

---

[106] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[107] IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[108] In order to calculate energy savings, water savings must first be calculated

Time of Sale	Retrofit, Direct Install
1.6 gal/min[109]	1.9 gal/min[110]

FLOeff = Efficient case flow in gallons per minute or custom (Gal/min)

Time of Sale	Retrofit, Direct Install
1.06 gal/min[111]	1.06 gal/min[112]

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise[113]:

Application	Hours/day
Small, quick- service restaurants	1
Medium-sized casual dining restaurants	1.5
Large institutional establishments with cafeteria	3

DAYSyear = Days per year pre-rinse spray valve is used at the site, custom, otherwise 312 days/yr based on assumed 6 days/wk x 52 wk/yr = 312 day/yr.

EXAMPLE

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria equals

= (1.6 – 1.06) * 60 * 3 * 312

= 30,326 gal/yr

Retrofit: For example, a new spray nozzle with 106 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria equals

= (1.9 – 1.06) * 60 * 3 * 312

= 47,175 gal/yr

---

[109] The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. Federal Energy Management Program: Purchasing Specifications for Low-Flow Pre-Rinse Spray Valves , Office of Energy Efficiency & Renewable Energy

[110] Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively." from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007)

[111] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[112] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[113] Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05.

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-FSE-SPRY-V05-190101

Review Deadline: 1/1/2023

4.2.12 Infrared Charbroiler

DESCRIPTION

This measure applies to natural gas fired charbroilers that utilize infrared burners installed in a commercial kitchen

This measure was developed to be aptplicable 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 charbroiler with infrared burners.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas charbroiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[114]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2173[115]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 707 therms based on default values.[116]

$$\Delta Therms = \frac{(\Delta PreheatEnergy + \ \Delta CookingEnergy) * Days}{100{,}000}$$

$$\Delta \text{PreheatEnergy} = \ (PreheatRate_{Base} - PreheatRate_{EE}) * Preheats * \frac{PreheatTime}{60}$$

[114] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment

[115] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

[116] Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment, Section 4: Broilers

$$\Delta \text{CookingEnergy} = (InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)$$

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[117]

100,000 = Btu to therms 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[118]

60 = Minutes to hours conversion factor

$InputRate_{Base}$ = Input energy rate of baseline charbroiler

= 140,000 Btu/hr

$InputRate_{EE}$ = Input energy rate of infrared charbroiler

= Custom or if unknown, use 105,000 Btu/hr

Duty = Duty cycle of charbroiler (%)

= Custom or if unknown, use 80%[119]

Hours = Average daily hours of operation

= Custom or if unknown, use 8 hours per day

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-IRCB-V02-180101

REVIEW DEADLINE: 1/1/2024

---

[117]Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3
[118]Typical preheat time from FSTC Broiler Technology Assessment.
[119] Duty cycle from FSTC Broiler Technology Assessment, Table 4.3

4.2.13 Infrared Rotisserie Oven

DESCRIPTION

This measure applies to natural gas fired high efficiency rotisserie ovens utilizing infrared burners 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 rotisserie oven with infrared burners.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas rotisserie oven without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[120]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2665[121]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 599 therms, based on default values.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100{,}000}$$

Where:

$InputRate_{Base}$ = Energy input rate of baseline rotisserie oven (Btu/hr)

[120] Lifecycle determined from Food Service Technology Center Gas Oven Life-Cycle Cost Calculator.

[121] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

	= Custom of if unknown, use 90,000 Btu/hr[122]
$InputRate_{EE}$	= Energy input rate of infrared rotisserie oven (Btu/hr)
	= Custom of if unknown, use 50,000 Btu/hr[123]
Duty	= Duty cycle of rotisserie oven (%)
	= Custom or if unknown, use 60%[124]
Hours	= Typical operating hours of rotisserie oven
	= Custom or if unknown, use 2,496 hours[125]
100,000	= Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-IROV-V02-180101

REVIEW DEADLINE: 1/1/2024

[122] Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Section 7: Ovens, Table 7.2

[123] Infrared energy input rate calculated based on efficient energy input rate of 50,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 45%. Efficiencies and rates derived from FSTC Gas Rotisserie Oven Test Reports and FSTC Oven Technology Assessment.

[124] Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2

[125] 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

4.2.14 Infrared Salamander Broiler

Description

This measure applies to natural gas fired high efficiency salamander broilers utilizing infrared burners 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 salamander broiler with infrared burners

Definition of Baseline Equipment

The baseline equipment is an existing natural gas salamander broiler without infrared burners

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[126]

Deemed Measure Cost

The incremental capital cost for this measure is $1000[127]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 240 therms, based on defaults.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100,000}$$

Where:

[126] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

[127] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

$InputRate_{Base}$	= Rated energy input rate of baseline salamander broiler (Btu/hr)
	= 38,500 Btu/hr[128]
$InputRate_{EE}$	= Rated energy input rate of infrared salamander broiler (Btu/hr)
	= Custom or if unknown, use 24,750 Btu/hr[129]
Duty	= Duty cycle of salamander broiler (%)
	= Custom or if unknown, use 70%[130]
Hours	= Typical operating hours of salamander broiler
	= Custom or if unknown, use 2,496 hours[131]
100,000	= Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-IRBL-V02-180101

REVIEW DEADLINE: 1/1/2024

[128] Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Section 4: Broilers, Table 4.3
[129] 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%
[130] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3
[131] 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

4.2.15 Infrared Upright Broiler

Description

This measure applies to natural gas fired high efficiency upright broilers utilizing infrared burners 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 upright broiler with infrared burners.

Definition of Baseline Equipment

The baseline equipment is an existing natural gas upright broiler without infrared burners.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[132]

Deemed Measure Cost

The incremental capital cost for this measure is $4400[133]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 943 therms based on default values.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100{,}000}$$

Where:

[132] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

[133] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

$InputRate_{Base}$ = Rated energy input rate of baseline upright broiler (Btu/hr)

= 144,000 Btu/hr[134]

$InputRate_{EE}$ = Rated energy input rate of infrared upright broiler (Btu/hr)

= Custom or if unknown, use 90,000 Btu/hr[135]

Duty = Duty cycle of upright broiler (%)

= Custom or if unknown, use 70%[136]

Hours = Typical operating hours of upright broiler

= Custom or if unknown, use 2,496 hours[137]

100,000 = Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-IRUB-V02-180101

REVIEW DEADLINE: 1/1/2024

[134] Baseline energy input rate calculated based on efficient energy input rate of 90,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 40%

[135] Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Section 4.0: Broiler, Table 4.3

[136] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

[137] 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

4.2.16 Kitchen Demand Ventilation Controls

DESCRIPTION

Installation of commercial kitchen demand ventilation controls that vary the ventilation based on cooking load and/or time of day.

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 control system that varies the exhaust rate of kitchen ventilation (exhaust and/or makeup air fans) based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a new temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed accordingly.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is kitchen ventilation that has constant speed ventilation motor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[138]

DEEMED MEASURE COST

The incremental capital cost for this measure is[139]

Measure Category	Incremental Cost $/HP of fan
DVC Control Retrofit	$1,988
DVC Control New	$1,000

LOADSHAPE

Loadshape C23 - Commercial Ventilation

COINCIDENCE FACTOR

The measure has deemed peak kW savings therefore a coincidence factor does not apply

Algorithm

CALCULATION OF SAVINGS

Annual energy use was based on monitoring results from five different types of sites, as summarized in PG&E Food Service Equipment work paper.

ELECTRIC ENERGY SAVINGS

kWh savings are assumed to be 4966 kWh per horsepower of the fan[140]

[138] PG&E Workpaper: Commercial Kitchen Demand Ventilation Controls-Electric, 2004 - 2005

[139] Ibid.

[140] Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

kW savings are assumed to be 0.68 kW per horsepower of the fan[141]

NATURAL GAS ENERGY SAVINGS

ΔTherms = CFM * HP* Annual Heating Load /(Eff(heat) * 100,000)

Where:

CFM = the average airflow reduction with ventilation controls per hood

= 430 cfm/HP[142]

HP = actual if known, otherwise assume 7.75 HP[143]

Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air, Btu/cfm dependent on location[144]:

Zone	Annual Heating Load, Btu/cfm
1 (Rockford)	154,000
2-(Chicago)	144,000
3 (Springfield)	132,000
4-(Belleville)	102,000
5-(Marion)	104,000

Eff(heat) = Heating Efficiency

= actual if known, otherwise assume 80%[145]

100,000 = conversion from Btu to Therm

EXAMPLE

For example, a kitchen hood in Rockford, IL with a 7.75 HP ventilation motor

ΔTherms = 430 * 7.75*154,000 / (0.80 * 100,000)

= 6,415 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[141] Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

[142] Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

[143] Average of units in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009.

[144] Food Service Technology Center Outside Air Load Calculator, with inputs of one cfm, and hours from Commercial Kitchen Demand Ventilation Controls (Average 17.8 hours a day 4.45 am to 10.30 pm). Savings for Rockford, Chicago, and Springfield were obtained from the calculator; values for Belleview and Marion were obtained by using the average savings per HDD from the other values.

[145] Work Paper WPRRSGNGRO301 CLEAResult"Boiler Tune-Up" which cites Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0, PA Consulting, KEMA, March 22, 2010

MEASURE CODE: CI-FSE-VENT-V03-160601

REVIEW DEADLINE: 1/1/2021

4.2.17 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 paste 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[146].

Deemed Measure Cost

The incremental capital cost for this measure is $2400[147].

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

The annual natural gas energy savings from this measure is a deemed value equaling 1380 Therms[148].

Water Impact Descriptions and Calculation

N/A

[146]See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.
[147]Ibid.
[148] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-PCOK-V02-180101

REVIEW DEADLINE: 1/1/2024

4.2.18 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 ≥ 50% utilizing ASTM standard 2093

Definition of Baseline Equipment

The baseline equipment is an existing natural gas rack oven – double oven with a baking efficiency < 50%.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[149]

Deemed Measure Cost

The incremental capital cost for this measure is $3000.[150]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

Custom calculation below, otherwise use deemed value of 1930 therms based on default values.[151]

$$\Delta Therms = InputRate * (BakingEfficiency_{EE} - BakingEfficiency_{Base}) * Duty * Hours * \frac{1}{100{,}000}$$

Where:

[149] Lifecycle determined from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment

[150] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

[151] 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.

InputRate	= Input energy rate of rack oven – double oven
	= Custom or if unknown, 275,000 Btu/hr[152]
$BakingEfficiency_{EE}$	= Baking efficiency of energy efficiency rack oven – double oven
	= Custom or if unknown, use 55%[153]
$BakingEfficiency_{Base}$	= Baking efficiency of baseline rack oven – double oven
	= Custom or if unknown, 30%
Duty	= Duty cycle of double rack oven (%)
	= Custom or if unknown, use 75%[154]
Hours	= Average daily hours of operation
	= Custom or if unknown, use 3,744 hours[155]
100,000	= Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE CI-FSE-RKOV-VO2-180101

REVIEW DEADLINE: 1/1/2024

[152] Median rated energy input for rack ovens from FSTC Oven Technology Assessment, Section 7: Ovens.
[153] Average baking efficiency of double rack oven from FSTC Gas Double Rack Oven Test Reports.
[154] Duty cycle from FSTC Gas Double Rack Oven Test Reports on various double rack ovens.
[155] 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.

4.2.19 ENERGY STAR Electric Convection Oven

Description

Commercial convection ovens that are ENERGY STAR certified have higher heavy load cooking efficiencies, and lower idle energy rates, making them on average about 20 percent more efficient than standard models. Energy savings estimates are for ovens using full size (18" x 36") sheet pans.

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 efficient equipment is assumed to be an ENERGY STAR qualified electric convection oven.

Definition of Baseline Equipment

The baseline equipment is assumed to be a standard convection oven with a heavy load efficiency of 65%.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[156]

Deemed Measure Cost

The incremental cost for this measure is assumed to be $800 for half size units and $1000 for full size[157]

Loadshape

Loadshape C01 - Commercial Electric Cooking

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[158]:

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
Unknown	0.41

[156] Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.

[157] Based on data from the Regional Technical Forum for the Northwest Council (Commercial Cooking Convection Oven Calculator, UES Measure Workbook) using actual list prices for 23 units from 2012, see "ComCookingConvectionOven_v2_0.xlsm".

[158]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 1985Unknown is an average of other location types.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = kWH_{base} - kWh_{eff}$

$kWh = [(LB * E_{FOOD}/EFF) + (IDLE * (HOURS_{DAY} – LB/PC – PRE_{TIME}/60)) + PRE_{ENERGY}] * DAYS$

Where:

kWH_{base} = the annual energy usage of the baseline equipment calculated using baseline values

kWH_{eff} = the annual energy usage of the efficient equipment calculated using efficient values

$HOURS_{DAY}$ = daily operating hours

= Actual, defaults:

Type of Food Service	$HOURS_{DAY}$ [159]
Fast Food, limited menu	4
Fast Food, expanded menu	5
Pizza	8
Full Service, limited menu	8
Full Service, expanded menu	7
Cafeteria	6
Unknown	6
Custom	Varies

DAYS = Days per year of operation

= Actual, default = 365[160]

PRE_{TIME} = Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on
= 15 min/day[161]

E_{FOOD} = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food

= 0.0732[162]

LB = pounds of food cooked per day (lb/day)

= Actual, default = 100[163]

EFF = Heavy load cooking energy efficiency (%). See table below.

IDLE = Idle energy rate. See table below.

PC = Production capacity (lbs/hr). See table below.

PRE_{ENERGY} = Preheat energy (kWh/day). See table below.

[159] Ibid.
[160] Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.
[161] Food Service Technology Center (2002). *Commercial Cooking Appliance Technology Assessment*. Prepared by Don Fisher. Chapter 7: Ovens
[162] American Society for Testing and Materials. Industry standard for Commercial Ovens
[163] Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.

Performance Metrics: Baseline and Efficient Values

Metric	Baseline Model [164]	Energy Efficient Model [165]
PRE_{ENERGY} (kWh)	1.5	1
IDLE (kW)	2	Actual, default = 1.0
EFF	65%	Actual, default = 74%
PC (lb/hr)	70	Actual, default = 79

EXAMPLE

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

kWH_{base} = [(100 * 0.0732/0.65) + (2 * (6 – 100/70 – 15/60)) + 1.5] * 365

= 7,813 kWh

kWh_{eff} = [(100 * 0.0732/0.74) + (1 * (6 – 100/79 – 15/60)) + 1.0] * 365

= 5,612 kWh

ΔkWh = kWH_{base} - kWh_{eff}

= 7,813 – 5,612

= 2200 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / (HOURS_{DAY} * DAYS)) * CF$$

Where:

ΔkWh = Annual energy savings (kWh)

CF = Summer Peak Coincidence Factor for measure is provided below for different building type[166]:

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
Unknown	0.41

[164] Ibid.

[165] Average ratings of units on ENERGY STAR qualified list as of 10/2014. Preheat energy is not provided so default is provided based on FSTC life cycle cost calculator.

[166] Minnesota 2012 Technical Reference Manual, version 1.3, Commercial Food Service - Electric Oven and Range, page 138. Unknown is an average of other location types

EXAMPLE

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

$$\Delta kW = (2200 / (6 * 365)) * 0.41$$
$$= 0.41$$

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE CI-FSE-ECON-V02-190101

REVIEW DEADLINE: 1/1/2022

4.3 Hot Water

4.3.1 Storage Water Heater

Description

This measure is for upgrading from minimum code to a high efficiency storage-type water heater. Storage water heaters are used to supply hot water for a variety of commercial building types. Storage capacities vary greatly depending on the application. Large consumers of hot water include (but not limited to) industries, hotels/motels and restaurants.

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 minimum specifications of the high efficiency equipment should be defined by the programs.

Definition of Baseline Equipment

The baseline condition is assumed to be a new standard water heater of same type as existing, meeting the Federal Standard for ≤75,000 Btuh units and IECC 2015 for all others. If existing type is unknown, assume Gas Storage Water Heater.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

Equipment Type	Sub Category	Federal Standard – Uniform Energy Factor[167]
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.6483 – (0.0017 * Rated Storage Volume in Gallons)
	>55 gallon tanks	0.7897 – (0.0004 * Rated Storage Volume in Gallons)
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	0.6002 – (0.0011 * Rated Storage Volume in Gallons)
Electric Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.9307 – (0.0002 * Rated Storage Volume in Gallons)
	>55 gallon tanks [168]	2.1171 – (0.0011 * Rated Storage Volume in Gallons)
Electric Water Heaters > 75,000 Btu/h	≤2 gal	0.91
	> 12kW and ≤58.6 kW and ≤2 gal	0.80

V= Rated volume in gallons, Vm = measured volume in gallons.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 Years[169]

Deemed Measure Cost

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available[170]:

---

[167] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

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

[169] DEER 08, EUL_Summary_10-1-08.xls.

[170] Cost information is based upon data from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. See “NR HW Heater_WA017_MCS Results Matrix - Volume I.xls” for more information.

Equipment Type	Category	Install Cost	Incremental Cost
Gas Storage Water Heaters ≤ 75,000 Btu/h, ≤55 Gallons	Baseline	$616	N/A
	Efficient	$1,055	$440
Gas Storage Water Heaters > 75,000 Btu/h	0.80 Et	$4,886	N/A
	0.83 Et	$5,106	$220
	0.84 Et	$5,299	$413
	0.85 Et	$5,415	$529
	0.86 Et	$5,532	$646
	0.87 Et	$5,648	$762
	0.88 Et	$5,765	$879
	0.89 Et	$5,882	$996
	0.90 Et	$6,021	$1,135

For electric water heaters the incremental capital cost for this measure is assumed to be[171]

Tank Size	Incremental Cost
50 gallons	$1050
80 gallons	$1050
100 gallons	$1950

LOADSHAPE

For electric hot water heaters, use Loadshape C02 - Non-Residential Electric DHW.

COINCIDENCE FACTOR

The coincidence factor is assumed to be 0.925 [172].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings are calculated for electric storage water heaters per the equations given below.

Electric units ≤12 kW:

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

Where:

T_{OUT} = Tank temperature

= 125°F

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

= 54°F[173]

[171] Act on Energy Commercial Technical Reference Manual, Table 9.6.1-4

[172] Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads,

[173] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

$HotWaterUse_{Gallon}$ = 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:[174]

Building Type[175]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	622
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multi-Family	894

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

   Where:

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

   = Actual

   Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[176]

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

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

[176] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL

Building Type[177]	Consumption/1,000 sq.ft.
Convenience	4,594
Education	7,285
Grocery	697
Health	24,540
Large Office	1,818
Large Retail	1,354
Lodging	29,548
Other Commercial	3,941
Restaurant	44,439
Small Office	1,540
Small Retail	6,111
Warehouse	1,239
Nursing	30,503
Multi-Family	15,434

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

= 8.33 lbs/gal

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

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

Equipment Type	Sub Category	Federal Standard – Uniform Energy Factor [178]
Electric Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.9307 – (0.0002 * Rated Storage Volume in Gallons)
	>55 gallon tanks [179]	2.1171 – (0.0011 * Rated Storage Volume in Gallons)
Electric Water Heaters > 75,000 Btu/h	≤2 gal	0.91
	> 12kW and ≤58.6 kW and ≤2 gal	0.80

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

= Actual

3412 = Converts Btu to kWh

For example, for a 200,000 Btu/h, 150 gallon, 90% UEF storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft^2 restaurant:

ΔkWh = ((125 – 54) * ((1,500/1,000) * 44,439) * 8.33 * 1 * (1/0.8 - 1/0.9))/3412

= 1,605 kWh

Electric units > 12kW:

White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

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

[178] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

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

$$\Delta kWh = \frac{\left((T_{out} - T_{air}) * V * \gamma Water * 1 * \left(SL_{elecbase} - SL_{eff}\right)\right) * 8766}{3412}$$

T_{air} = Ambient Air Temperature

= 70°F

V = Rated tank volume in gallons

= Actual

$SL_{elecbase}$ = Standby loss of electric baseline unit (%/hr)

= 0.30 + 27/V

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

8766 = Hours per year

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

SLbase = 0.3 + (27 / 100)

= 0.57%/hr

ΔkWh = (((125 – 70) * 100 * 8.33 * 1 * (0.57- 0.5)) * 8766)/3412

= 8,239 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

Hours = Full load hours of water heater

= 6461 [180]

CF = Summer Peak Coincidence Factor for measure

= 0.925 [181]

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

ΔkW = 8,239 / 6,461 * 0.925

= 1.18 kW

NATURAL GAS ENERGY SAVINGS

Natural gas energy savings are calculated for natural gas storage water heaters per the equations given below.

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

Where:

100,000 = Converts Btu to Therms

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

[180] Full load hours assumption based on Wh/Max W Ratio from Itron eShape data for Missouri, calibrated to Illinois loads,

[181] Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads,

Equipment Type	Sub Category	Federal Standard – Uniform Energy Factor [182]
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.6483 – (0.0017 * Rated Storage Volume in Gallons)
	>55 gallon tanks	0.7897 – (0.0004 * Rated Storage Volume in Gallons)
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	0.6002 – (0.0011 * Rated Storage Volume in Gallons)

Additional Standby Loss Savings

Gas Storage Water Heaters >75,000 Btu/h can claim additional savings due to lower standby losses.

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

Where:

$SL_{gasbase}$ = Standby loss of gas baseline unit (Btu/h)

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

Q =Nameplate input rating in Btu/h

V = Rated volume in gallons

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

8766 = Hours per year

For example, for a 200,000 Btu/h, 150 gallon, 90% UEF storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft^2 restaurant:

ΔTherms = ((125 – 54) * ((1,500/1,000) * 44,439) * 8.33 * 1 * (1/0.8 - 1/0.9))/100,000

= 54.8 Therms

$\Delta Therms_{Standby}$ = (((200000/800 + 110 * √150) – 1029) * 8766)/100,000

= 49.8 Therms

ΔThermsTotal = 54.8 + 49.8

= 104.6 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HWE-STWH-V03-190101

REVIEW DEADLINE: 1/1/2022

[182] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

4.3.2 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, or motel. Health care-specific inputs are defined for Laminar Flow Restrictor (LFR) devices. For multifamily or senior housing, the residential low flow faucet aerator 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, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. For LFR devices, the installed equipment must be a device rated at 2.2 GPM 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 bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more. For LFR devices, the baseline condition is assumed to be no aerator at all, due to the contamination risk caused by faucet aerators in health care facilities and the baseline flow rate is assumed to be 3.74 GPM[183]. Note if flow rates are measured, for example through a Direct Install program, then actual baseline flow rates should be used as opposed to the deemed values.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[184]

DEEMED MEASURE COST

The full install cost (including labor) for this measure is $8[185] or program actual. For LFRs, The incremental cost is $14.27[186] or program actual.

LOADSHAPE

Loadshape C02 - Commercial Electric DHW

COINCIDENCE FACTOR

The coincidence factor for this measure is dependent on building type as presented below.

---

183 Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

184 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

185 Direct-install price per faucet assumes cost of aerator and install time. (2011, Market research average of $3 and assess and install time of $5 (20min @ $15/hr)

186 Direct install price per faucet assumes cost of LFR ($7.27) and install time ($7) (Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015).

Algorithm

'CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

NOTE THESE SAVINGS ARE *PER* FAUCET RETROFITTED[187].

ΔkWh = %ElectricDHW * ((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%

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

= 1.39[188] or custom based on metering studies[189] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[190]

Baseline for LFRs[191]: = 3.74 * 0.83 = 3.10

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

= 0.94[192] or custom based on metering studies[193] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[194]

For LFRs[195]: = 2.2 * 0.95 = 2.09

[187] 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.

[188] DeOreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[189] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[190] 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.

[191] Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

[192] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

[193] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[194] 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.

[195] Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

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[196] (A)	Unit	Estimated % hot water from Faucets [197] (B)	Multiplier [198] (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	9,581
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365	15,768
Retail	2	employee	100%	5	employees per faucet	365	3,650
Grocery	2	employee	100%	5	employees per faucet	365	3,650
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365	16,425
Motel	20	room	25%	1	faucet per room	365	1,825
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)

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= 0.0795 kWh/gal for Bath, 0.0969 kWh/gal for Kitchen, 0.139 kWh/gal for LFRs, 0.0919 kWh/gal for unknown

8.33 = Specific weight of water (lbs/gallon)

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

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[199], 110F for health care facilities[200]

SupplyTemp = Assumed temperature of water entering building

= 54.1°F [201]

---

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

[197] Estimated based on data provided in Appendix E; "Waste Not, Want Not: The Potential for Urban Water Conservation in California", Pacific Institute, November 2003.

[198] Based on review of the Illinois 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.

[199] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

[200] Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015

[201] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

RE_electric = Recovery efficiency of electric water heater

= 98% [202]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below[203]

Selection	ISR
Direct Install - Deemed	0.95

EXAMPLE

For example, a direct installed kitchen faucet in a large office with electric DHW:

ΔkWh = 1 * ((1.39 – 0.94)/1.39) * 11,250 * 0.0969 * 0.95

= 335.3 kWh

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

ΔkWh = 1 * ((1.39 – 0.94)/1.39) * 3,000 * 0.0795 * 0.95

= 73.4 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[204]

EXAMPLE

For example, a direct installed faucet in a large office:

ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 11,250 * 0.95

= 3,640 gallons

ΔkWh_{water} = 3,640/1,000,000*5,010

= 18 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh / Hours) * CF

Where:

ΔkWh = calculated value above on a per faucet basis.Note do not include the secondary savings in this calculation.

---

[202] Electric water heaters have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory.

[203] ComEd Energy Efficiency/Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program, December 21, 2010, Table 3-8.

[204] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

Hours = Annual electric DHW recovery hours for faucet use

= (Usage * 0.545[205])/GPH

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

Building Type	Annual Recovery Hours
Small Office	24
Large Office	109
Fast Food Rest	93
Sit-Down Rest	153
Retail	36
Grocery	36
Warehouse	24
Elementary School	29
Jr High/High School	88
Health	160
Motel	18
Hotel	12
Other	49

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 85.9F temp rise (140-54.1), 98% recovery efficiency, and typical 12kW electric resistance storage tank.

= 56

CF = Coincidence Factor for electric load reduction

= Dependent on building type[206]

Building Type	Coincidence Factor
Small Office	0.0064
Large Office	0.0288
Fast Food Rest	0.0084
Sit-Down Rest	0.0184
Retail	0.0043
Grocery	0.0043
Warehouse	0.0064
Elementary School	0.0096
Jr High/High School	0.0288
Health	0.0144
Motel	0.0006
Hotel	0.0004
Other	0.0128

[205] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90°F mixed faucet water.

[206] Calculated as follows: Assumptions for percentage of usage during peak period (1-5pm) 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 you will see savings during the peak period is calculated as the number of hours of recovery during peak divided by 260. See 'C&I Faucet Aerator.xls' for details.

EXAMPLE

For example, a direct installed kitchen faucet in a large office with electric DHW:

ΔkW = 335.3/109 * 0.0288

= 0.0886 kW

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

ΔkW = 73.4/29 * 0.0096

= 0.0243 kW

Fossil Fuel Impact Descriptions and Calculation

ΔTherms = %FossilDHW * ((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%

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

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

= 0.00397 Therm/gal for Bath, 0.00484 Therm/gal for Kitchen, 0.00695 Therm/gal for LFRs, 0.00459 Therm/gal for unknown

Where:

RE_gas = Recovery efficiency of gas water heater

` = 67% [207]

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

Other variables as defined above.

EXAMPLE

For example, a direct installed kitchen faucet in a large office with gas DHW:

ΔTherms = 1 * ((1.39 – 0.94)/1.39) * 11,250 * 0.00484 * 0.95

= 16.7 Therms

For example, a direct installed bathroom faucet in an Elementary School with gas DHW:

ΔTherms = 1 * ((1.39 – 0.94)/1.39) * 3,000 * 0.00397 * 0.95

= 3.66 Therms

Water Impact Descriptions and Calculation

ΔWater (gallons) = ((GPM_base - GPM_low)/GPM_base) * Usage * ISR

[207] 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 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

Variables as defined above

EXAMPLE
For example, a direct installed faucet in a large office:
ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 11,250 * 0.95
= 3,640 gallons
For example, a direct installed faucet in a Elementary School:
ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 3,000 * 0.95
= 971 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES USED FOR GPM ASSUMPTIONS

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	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.

MEASURE CODE: CI-HWE-LFFA-V08-190101

REVIEW DEADLINE: 1/1/2023

4.3.3 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, restaurant, or small motel. 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 2.0 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.[208]

DEEMED MEASURE COST

The full install cost (including labor) for this measure is $12[209] or program actual.

LOADSHAPE

Loadshape C02 - Commercial Electric DHW

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.78%[210].

Algorithm

CALCULATION OF SAVINGS [211]

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

ΔkWh =

%ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * NSPD * 365.25) * EPG_electric * ISR

---

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

[209] Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and assess and install time of $5 (20min @ $15/hr)

[210] Calculated as follows: Assume 11% showers take place during peak hours (as sourced from "Analysis of Water Use in New Single Family Homes, Aquacraft Water Engineering and Management, January 2011). 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% * 369 = 7.23 hours of recovery during peak period. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7,23/260 = 0..0278

[211]Based on excel spreadsheet 120911.xls …on SharePoint

Where:

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

= 1 if electric DHW, 0 if fuel DHW, if unknown assume 16% [212]

GPM_base = Flow rate of the baseline showerhead

= 2.67 for Direct-install programs[213]

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual[214]

L_base = Shower length in minutes with baseline showerhead

= 8.20 min[215]

L_low = Shower length in minutes with low-flow showerhead

= 8.20 min[216]

365.25 = Days per year, on average.

NSPD = Estimated number of showers taken per day for one showerhead

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (105 – 54.1)) / (0.98 * 3412)

= 0.127 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 105°F [217]

SupplyTemp = Assumed temperature of water entering house

= 54.1°F [218]

[212] Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009 (RECS)

[213] Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above.

[214] Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

[215] Representative value from sources 1, 2, 3, 4, 5, and 6 (See Source Table at end of measure section)

[216] Set equal to L_base.

[217] Shower temperature cited from SBW Consulting, Evaluation for the Bonneville Power Authority, 1994.

[218] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

RE_electric = Recovery efficiency of electric water heater

= 98% [219]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

Selection	ISR[220]
Direct Install - Deemed	0.98

EXAMPLE

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

ΔkWh = 1 * ((2.67*8.20)- (1.5*8.20)) * 3*365.25) *0.127 * 0.98

= 1308.4 kWh

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[221]

EXAMPLE

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

ΔWater (gallons) = ((2.67 * 8.20)-(1.5 * 8.20)) * 3 * 365.25 * 0.98

= 10,302 gallons

ΔkWh_{water} = 10,302/1,000,000*5,010

= 52 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

---

[219] Electric water heaters have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory.

[220] Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

[221] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) *NSPD * 365.25) * 0.773[222] / GPH

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[223]

EXAMPLE

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

ΔkW = (1308.4 / 674.1)*0.0278

= 0.054 kW

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * NSPD* 365.25) * EPG_gas * ISR

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	84%[224]

EPG_gas = Energy per gallon of Hot water supplied by gas

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

= 0.0063 Therm/gal

Where:

RE_gas = Recovery efficiency of gas water heater

[222] 77.3% is the proportion of hot 120F water mixed with 54.1°F supply water to give 105°F shower water

[223] Calculated as follows: Assume 11% showers take place during peak hours (as sourced from “Analysis of Water Use in New Single Family Homes, Aquacraft Water Engineering and Management, January 2011). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365.25 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF 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 7.23/260 = 0.0278

[224] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

= 67% [225]

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

Other variables as defined above.

EXAMPLE

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

ΔTherms = 1.0 * ((2.67 *8.2) – (1.5 * 8.2)) * 3 * 365.25 * 0.0063 * 0.98

= 64.9 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * NSPD * 365.25 * ISR

Variables as defined above

EXAMPLE

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

ΔWater (gallons) = ((2.67 * 8.20)-(1.5 * 8.20)) * 3 * 365.25 * 0.98

= 10,302 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	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.

[225] 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 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

MEASURE CODE: CI-HWE-LFSH-V05-190101

REVIEW DEADLINE: 1/1/2020

4.3.4 Commercial Pool Covers

DESCRIPTION

This measure refers to the installation of covers on commercial use pools that are heated with gas-fired equipment located either indoors or outdoors. 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 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. 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 can be used for pools that (1) currently do not have pool covers, (2) have pool covers that are past the useful life of the existing cover, or (3) have pool covers that are past their warranty period and have failed.

DEFINITION OF EFFICIENT EQUIPMENT

For indoor pools, the efficient case is the installation of an indoor pool cover with a 5 year warranty on an indoor pool that operates all year.

For outdoor pools, the efficient case is the installation of an outdoor pool cover with a 5 year warranty on an outdoor pool that is open through the summer season.

DEFINITION OF BASELINE EQUIPMENT

For indoor pools, the base case is an uncovered indoor pool that operates all year.

For outdoor pools, the base case is an outdoor pool that is uncovered and is open through the summer season.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The useful life of this measure is assumed to be 6 years [226]

DEEMED MEASURE COST

The table below shows the costs for the various options and cover sizes. Since this measure covers a mix of various sizes, the average cost of these options is taken to be the incremental measure cost. [227].

Cover Size	Edge Style	
	Hemmed (indoor)	Weighted (outdoor)
1000-1,999 sq. ft.	$2.19	$2.24
2,000-2,999 sq. ft.	$2.01	$2.06
3,000+ sq. ft.	$1.80	$1.83
Average	$2.00	$2.04

LOADSHAPE

N/A

[226] 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

[227] Pool Cover Costs: Lincoln Commercial Pool Equipment online catalog. Accessed 8/26/11.

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ supply}$$

Where

$E_{water\ supply}$ = Water Supply Energy Factor (kWh/Million Gallons)

= 2,571[228]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

The calculations are based on modeling runs using RSPEC! Energy Smart Pools Software that was created by the U.S. Department of Energy. [229]

$$\Delta Therms = SavingFactor \times Size\ of\ Pool$$

Where

Savings factor = dependant on pool location and listed in table below[230]

Location	Therm / sq-ft
Indoor	2.61
Outdoor	1.01

Size of Pool = custom input

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = WaterSavingFactor \times Size\ of\ Pool$$

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below.[231].

[228] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'. Note since the water loss associated with this measure is due to evaporation and does not discharge into the wastewater system, only the water supply factor is used here.

[229] Full method and supporting information found in reference document: IL TRM - Business Pool Covers WorkPaper.docx. Note that the savings estimates are based upon Chicago weather data.

[230] Business Pool Covers.xlsx

[231] Ibid.

Location	Annual Savings Gal / sq-ft
Indoor	15.28
Outdoor	8.94

Size of Pool = Custom input

DEEMED O&M COST ADJUSTMENT CALCULATION

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

MEASURE CODE: CI-HWE-PLCV-V02-190101

REVIEW DEADLINE: 1/1/2020

4.3.5 Tankless Water Heater

DESCRIPTION

This measure covers the installation of on-demand or instantaneous tankless water heaters. Tankless water heaters function similar to standard hot water heaters except they do not have a storage tank. When there is a call for hot water, the water is heated instantaneously as it passes through the heating element and then proceeds to the user or appliance calling for hot water. Tankless water heaters achieve savings by eliminating the standby losses that occur in stand-alone or tank-type water heaters and by being more efficient than the baseline storage hot water heater.

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

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

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

DEFINITION OF EFFICIENT EQUIPMENT

Electric	Gas
To qualify for this measure, the tankless water heater shall be a new electric powered tankless hot water heater with an energy factor greater than or equal to 0.98 with an output greater than or equal to 5 GPM output at 70° F temperature rise.	To qualify for this measure, the tankless water heater shall meet or exceed the efficiency requirements for tankless hot water heaters mandated by the International Energy Conservation Code (IECC) 2012/2015/2018, Table C404.2.

DEFINITION OF BASELINE EQUIPMENT

Electric	Gas
The baseline condition is assumed to be an electric commercial-grade tanked water heater 50 or more gallon storage capacity with an energy factor less than or equal to 0.9 or the water heater is five or more years old.	The baseline condition is assumed to be a gas-fired tank-type water heater meeting the efficiency requirements mandated by the International Energy conservation Code (IECC) 2012/2015/2018, Table C404.2. The Federal Standard applies to units with input ≤75,000 Btu/hr, consistent with the baseline definitions of 4.3.1 Storage Water Heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Electric	Gas
The expected measure life is assumed to be 5 years[232].	The expected measure life is assumed to be 20 years[233]

DEEMED MEASURE COST

The incremental capital cost for an electric tankless heater this measure is assumed to be[234]

Output (gpm) at delta T 70	Incremental Cost
5	$1050
10	$1050
15	$1950

[232] Ohio Technical Reference Manual 8/2/2010 referencing CenterPoint Energy-Triennial CIP/DSM Plan 2010-2012 Report; Additional reference stating >20 years is soured from the US DOE Energy Savers for Tankless or Demand-Type Water Heaters.
[233] Ibid.
[234] Act on Energy Technical Reference Manual, Table 9.6.2-3

The incremental capital cost for a gas fired tankless heater is as follows:

Program	Capital Cost, $ per unit
Retrofit	$3,255[235]
Time of Sale or New Construction	$2,526[236]

DEEMED O&M COST ADJUSTMENTS

$100[237]

LOADSHAPE

Loadshape C02 - Commercial Electric DHW

COINCIDENCE FACTOR

The measure has deemed kW savings therefor a coincidence factor is not applied

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS [238]

The annual electric savings from an electric tankless heater is a deemed value and assumed to be:

Output (gpm) at delta T 70	Savings (kWh)
5.0	2,992
10.0	7,905
15.0	12,879

SUMMER COINCIDENT PEAK DEMAND SAVINGS[239]

The annual kW savings from an electric tankless heater is a deemed value and assumed to be:

Output (gpm) at delta T 70	Savings (kW)
5.0	0.34
10.0	0.90
15.0	1.47

[235] Based on AOE historical average installation data of 42 tankless gas hot water heaters
[236]Minnesota Center for Energy and Environment, Low contractor estimate used to reflect less labor required in new construction of venting.
[237] Water heaters (WH) require annual maintenance. There are different levels of effort for annual maintenance depending if the unit is gas or electric, tanked or tankless. Electric and gas tank water heater manufacturers recommend an annual tank drain to clear sediments. Also recommended are "periodic" inspections by qualified service professionals of operating controls, heating element and wiring for electric WHs and thermostat, burner, relief valve internal flue-way and venting systems for gas WHs. Tankless WH require annual maintenance by licensed professionals to clean control compartments, burners, venting system and heat exchangers. This information is from WH manufacturer product brochures including GE, Rennai, Rheem, Takagi and Kenmore. References for incremental O&M costs were not found. Therefore the incremental cost of the additional annual maintenance for tankless WH is estimated at $100.
[238] Act on Energy Technical Reference Manual, Table 9.6.2-3
[239] Ibid.

NATURAL GAS SAVINGS

ΔTherms =[[Wgal x 8.33 x 1 x (Tout - Tin) x [(1/Eff base) - (1/Eff ee)]]/100,000] +[[(SL x 8,766)/Eff base]] / 100,000 Btu/Therms]

Where:

Wgal = Annual water use for equipment in gallons

= custom, otherwise assume 21,915 gallons [240]

8.33 lbm/gal = weight in pounds of one gallon of water

1 Btu/lbm°F = Specific heat of water: 1 Btu/lbm/°F

8,766 hr/yr = hours a year

Tout = Unmixed Outlet Water Temperature

= custom, otherwise assume 130 °F[241]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[242]

Eff base = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et); see table below[243]

Input Btu/hr of existing, tanked water heater	Eff base	Units
Size: ≤ 75,000 Btu/hr, ≥20 gal and ≤55 gal	0.675 -0.0015*Tank Volume	Energy Factor
Size: ≤ 75,000 Btu/hr, >55 gal and ≤100 gal	0.8012 -0.00078*Tank Volume	Energy Factor
Size: >75,000 Btu/hr and ≤ 155,000 Btu/hr	80%	Thermal Efficiency
Size: >155,000 Btu/hr	80%	Thermal Efficiency

Where:

Tank Volume = custom input, if unknown assume 60 gallons for Size: ≤ 75,000 Btu/hr

Please note: Units in base case must match units in efficient case. If Energy Factor used in base case, Energy Factor to be used in efficient case. If Themal Efficiency is used in base case, Thermal Efficiency must be used in efficient case.

Eff ee = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (Eff t)

[240] 21,915 gallons is an estimate of 60 gal/day for 365.25 days/yr. If building type is known, reference 2007 ASHRAE Handbook HVAC Applications p. 49.14 Table 7 Hot Water Demands and Use for Various Types of Buildings to help estimate hot water consumption.

[241] Based on 2010 Ohio Techical Reference Manual and NAHB Research Center, (2002) Performance Comparison of Residential hot Water Systems. Prepared for National Renewable Energy Laboratory, Golden, Colorado.

[242] August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.

[243] International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment. Units less than or equal to 75,000 Btu/hr input are governed by the most recent Code of Federal Regulation rulings, consistent with baseline definitions of 4.3.1 Storage Water Heater.

= custom input, if unknown assume 0.84[244]

SL = Stand-by Loss in Base Case Btu/hr

= custom input based on formula in table below, if unknown assume unit size in table below[245]

Input Btu/h of new, tankless water heater	Standby Loss (SL)
Size: ≤ 75,000 Btu/hr	0
Size: >75,000 Btu/hr	(Input rating/800)+(110*√Tank Volume))*

**Note: IECC2018 does not specify standby performance.*

Where:

Tank Volume = custom input, if unknown assume, 60 gallons for <75,000 Btu/hr, 75 gallons for >75,000 Btu/hr and ≤ 155,000 Btu/hr and 150 for Size >155,000 Btu/hr

Input Rating = nameplate Btu/hr rating of water heater

EXAMPLE

For example, a 75,000 Btu/hr tankless unit using 21,915 gal/yr with outlet temperature at 130.0 and inlet temperature at 54.1, replacing a baseline unit with 0.8 thermal efficiency and standby losses of 1008.3 btu/hr:

ΔTherms =[[(21,915 x 8.33x 1 x (130 – 54.1) x [(1/.8) - (1/.84)]/100,000] +[(1008.3 x 8,766)/.8]] / 100,000

=115 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed O&M cost adjustment for a gas fired tankless heater is $100

REFERENCE TABLES

Minimum Performance Water Heating Equipment[246]

[244] Specifications of energy efficient tankless water heater. Reference Consortium for Energy Efficiency (CEE) which maintains a list of high efficiency tankless water heaters which currently have Energy Factors up to .96. Ameren currently requires minimum .82 energy factor.

[245] Stand-by loss is provided in 2012/2015 IECC, Table C404.2, Minimum Performance of Water-Heating Equipment

[246] International Energy Conservation Code (IECC)2012/2015

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Water heaters, electric	≤ 12 kW	Resistance	0.97 - 0.00132 V, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance	1.73 V + 155 SL, Btu/h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00132 V, EF	DOE 10 CFR Part 430
Storage water heaters, gas	[redacted]			
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h[c]	≥ 4,000 (Btu/h)/gal and < 2 gal	0.62 - 0.0019 V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal	0.59 - 0.0019 V, EF	DOE 10 CFR Part 430
	≥ 105,000 Btu/h	< 4,000 Btu/h/gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	ANSI Z21.10.3
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019 V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Hot water supply boilers, oil	> 300,000 Btu/h and < 12,500,000 Btu/h	> 4,000 Btu/h/gal and > 10 gal	78% E_t $(Q/800 + 110\sqrt{V})$ SL, Btu/h	
Pool heaters, gas and oil	All	—	78% E_t	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 $(h \cdot ft^2 \cdot °F)/Btu$	(none)

For SI: °C = [(°F) - 32]/1.8, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, 1 British thermal unit per hour per gallon = 0.078 W/L.

a. Energy factor (EF) and thermal efficiency (E_t) are minimum requirements. In the EF equation, V is the rated volume in gallons.

b. Standby loss (SL) is the maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, Q is the nameplate input rate in Btu/h. In the SL equation for electric water heaters, V is the rated volume in gallons. In the SL equation for oil and gas water heaters and boilers, V is the rated volume in gallons.

c. Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

IECC 2018 :

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Water heaters, electric	≤ 12 kW[d]	Tabletop[e], ≥ 20 gallons and ≤ 120 gallons	0.93 - 0.00132*V*, EF	DOE 10 CFR Part 430
		Resistance ≥ 20 gallons and ≤ 55 gallons	0.960 - 0.0003*V*, EF	
		Grid-enabled[f] > 75 gallons and ≤ 120 gallons	1.061 - 0.00168V, EF	
	> 12 kW	Resistance	$(0.3 + 27/V_m)$, %/h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump > 55 gallons and ≤ 120 gallons	2.057 - 0.00113V, EF	DOE 10 CFR Part 430
Storage water heaters, gas	[redacted]			
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h[c]	≥ 4,000 (Btu/h)/gal and < 2 gal	0.82 - 0.00 19V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t	
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal and ≤ 50 gallons	0.68 - 0.0019V, EF	DOE 10 CFR Part 430
	≥ 105,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	ANSI Z21.10.3
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	78% E_t	
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal and ≤ 50 gallons	0.68 - 0.0019V, EF	DOE 10 CFR Part 430
	≥ 105,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	ANSI Z21.10.3
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	78% E_t	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t	
Hot water supply boilers, oil	> 300,000 Btu/h and < 12,500,000 Btu/h	> 4,000 Btu/h/gal and > 10 gal	78% E_t	
Pool heaters, gas and oil	All	—	82% E_t	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 (h • ft² • °F)/Btu	(none)

MEASURE CODE: CI-HWE-TKWH-V04-190101

REVIEW DEADLINE: 1/1/2022

4.3.6 Ozone Laundry

Description

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The system generates ozone (O_3), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) will reduce the amount of chemicals, detergents, and hot water needed to wash linens. Using ozone also reduces the total amount of water consumed, saving even more in energy.

Natural gas energy savings will be achieved at the hot water heater/boiler as they will be required to produce less hot water to wash each load of laundry. The decrease in hot water usage will increase cold water usage, but overall water usage at the facility will decrease.

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. The increased usage associated with operating the ozone system should also be accounted for when determining total kWh impact. Data reviewed for this measure characterization indicated that pumping savings should be accounted for, but washer savings and ozone generator consumption are comparatively so small that they can be ignored.

The reduced washer cycle length may decrease the dampness of the clothes when they move to the dryer. This can result in shorter runtimes which result in gas and electrical savings. However, at this time, there is inconclusive evidence that energy savings are achieved from reduced dryer runtimes so the resulting dryer effects are not included in this analysis. Additionally, there would be challenges verifying that dryer savings will be achieved throughout the life of the equipment.

This incentive only applies to the following facilities with on-premise laundry operations:

- Hotels/motels
- Fitness and recreational sports centers.
- Healthcare (excluding hospitals)
- Assisted living facilities

Ozone laundry system(s) could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries), however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.)-capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

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

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The ozone laundry system(s) must transfer ozone into the water through:

- Venturi Injection
- Bubble Diffusion
- Additional applications may be considered upon program review and approval on a case by case basis

Definition of Baseline Equipment

The base case equipment is a conventional washing machine system with no ozone generator installed. The washing machines are provided hot water from a gas-fired boiler.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure equipment effective useful life (EUL) is estimated at 10 years based on typical lifetime of the ozone generator's corona discharge unit.[247]

DEEMED MEASURE COST

The actual measure costs should be used if available. If not a deemed value of $79.84 / lbs capacity should be used[248].

LOADSHAPE

Loadshape C53 – Flat

COINCIDENCE FACTOR

Past project documentation and data collection is not sufficient to determine a coincidence factor for this measure. Value should continue to be studied and monitored through additional studies due to limited data points used for this determination

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. There is also an increased usage associated with operating the ozone system. Data reviewed for this measure characterization indicated that while pumping savings is significant and should be accounted for, washer savings and ozone generator consumption are negligible, counter each other out and are well within the margin of error so these are not included to simplify the characterization[249].

$$\Delta kWh_{PUMP} = HP * HP_{CONVERSION} * Hours * \%water\_savings$$

Where:

ΔkWh_{PUMP} = Electric savings from reduced pumping load

HP = Brake horsepower of boiler feed water pump;

= Actual or use 5 HP if unknown[250]

$HP_{CONVERSION}$ = Conversion from Horsepower to Kilowatt

= 0.746

Hours = Actual associated boiler feed water pump hours

[247] Aligned with other national energy efficiency programs and confirmed with national vendors

[248] Average costs per unit of capacity were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2 and RSMeans Mechanical Cost Data, 31st Annual Edition (2008)

[249] Washer savings were reviewed but were considered negligible and not included in the algorithm (0.00082 kWh / lbs-capacity, determined through site analysis through Nicor Emerging Technology Program (ETP) and confirmed with national vendors). Note that washer savings from Nicor's site analysis are smaller than those reported in a WI Focus on Energy case study (0.23kWh/100lbs, Hampton Inn Brookfield, November 2010). Electric impact of operating ozone generator (0.0021 kWh / lbs-capacity same source as washer savings) was also considered negligible and not included in calculations. Values should continue to be studied and monitored through additional studies due to limited data points used for this determination.

[250] Assumed average horsepower for boilers connected to applicable washer

= 800 hours if unknown[251]

%water_savings = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.

= 25%[252]

Using defaults above:

ΔkWh_{PUMP} = 5 * 0.746 * 800 * 0.25

= 746 kWh

Default per lb capacity: = ΔkWh_{PUMP} / lb capacity

Where:

Lbs-Capacity = Average Capacity in lbs of washer

=254.38[253]

ΔkWh_{PUMP} / lb capacity = 746/254.38

= 2.93 kWh/lb-capacity

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

ΔkWh_{water} = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[254]

Deemed savings using defaults:

ΔkWh_{water} = 464,946/1,000,000*5,010

= 2,329 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Past project documentation and data collection is not sufficient to determine summer coincident peak demand savings for this measure. Value should continue to be studied and monitored through additional studies due to

[251] Engineered estimate provided by CLEAResult review of Nicor custom projects. Machines spent approximately 7 minutes per hour filling with water and were in operation approximately 20 hours per day. Total pump time therefore estimated as 7/60 * 20 * 365 = 852 hours, and rounded down conservatively to 800 hours.

[252] Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

[253] Average lbs-capacity per project site was generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2

[254] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

limited data points used for this determination. In absence of site-specific data, the summer coincident peak demand savings should be assumed to be zero.

ΔkW = 0

NATURAL GAS SAVINGS

ΔTherm = $Therm_{Baseline}$ * %hot_water_savings

Where:

ΔTherm = Gas savings resulting from a reduction in hot water use, in therm.

$Therm_{Baseline}$ = Annual Baseline Gas Consumption

= WHE * WUtiliz * WUsage_hot

Where:

WHE = water heating energy: energy required to heat the hot water used

= 0.00885 therm/gallon[255]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[256], approximately equivalent to 13 cycles/day

WUsage_hot = hot water usage factor: how much hot water a typical conventional washing machine utilizes, normalized per pounds of clothes washed

= 1.19 gallons/lbs laundry[257]

Using defaults above:

$Therm_{Baseline}$ = 0.00885 * 916,150 * 1.19

= 9,648 therms

Default per lb capacity:

$Therm_{Baseline}$ / lb capacity = 9,648 / 254.38

= 37.9 therms / lb-capacity

%hot_water_savings = hot water reduction factor: how much more efficient an ozone injection washing machine is, compared to a typical conventional washing machine, as a rate of hot water reduction

= 81%[258]

---

[255] Assuming boiler efficiency is the regulated minimum efficiency (80%), per Title 20 Appliance Standard of the California Energy Regulations (October 2007). The incoming municipal water temperature is assumed to be 55 °F with an average hot water supply temperature of 140°F, based on default test procedures on clothes washers set by the Department of Energy's Office of Energy Efficiency and Renewable Energy (Federal Register, Vol. 52, No. 166). Enthalpies for these temperatures (107 btu/lbs at 140F, 23.07 btu/lbs at 55F) were obtained from ASHRAE Fundamentals

[256] Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects

[257] Average hot water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. summarizes data gathered from several NRR-DR projects:

[258] Average hot water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 5 summarizes data gathered from

Savings using defaults above:

ΔTherm = $Therm_{Baseline}$ * %hot_water_savings

= 9648 * 0.81

= 7,815 therms

Default per lb capacity:

ΔTherm / lb-capacity = 7815 / 254.38

= 30.7 therms / lb-capacity

WATER IMPACT DESCRIPTIONS AND CALCULATION

The water savings calculations listed here account for the combination of hot and cold water used. Savings calculations for this measure were based on the reduction in total water use from implementing an ozone washing system to the base case. There are three main components in obtaining this value:

ΔWater (gallons) = WUsage * WUtiliz * %water_savings

Where:

ΔWater (gallons) = reduction in total water use from implementing an ozone washing system to the base case

WUsage = water usage factor: how efficiently a typical conventional washing machine utilized hot and cold water normalized per unit of clothes washed

= 2.03 gallons/lbs laundry[259]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[260], approximately equivalent to 13 cycles/day

%water_savings = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.

= 25%[261]

Savings using defaults above:

ΔGallons = WUsage * WUtiliz * %water_savings

= 2.03 * 916,150 * 0.25

= 464,946 gallons

Default per lb capacity:

---

several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

[259] Average water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. summarizes data gathered from several NRR-DR projects

[260] Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects

[261] Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

Δ Gallons / lb-capacity = 464,946 / 254.38

= 1,828 gallons / lb-capacity

DEEMED O&M COST ADJUSTMENT CALCULATION

Maintenance is required for the following components annually:[262]

- Ozone Generator: filter replacement, check valve replacement, fuse replacement, reaction chamber inspection/cleaning, reaction chamber o-ring replacement
- Air Preparation – Heat Regenerative: replacement of two medias
- Air Preparation – Oxygen Concentrators: filter replacement, pressure relief valve replacement, compressor rebuild
- Venturi Injector: check valve replacement

Maintenance is expected to cost $0.79 / lbs capacity.

REFERENCES

1 "Lodging Report", December 2008, California Travel & Tourism Commission, http://tourism.visitcalifornia.com/media/uploads/files/editor/Research/CaliforniaTourism_200812.pdf

2 "Health, United States, 2008" Table 120, U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, http://www.cdc.gov/nchs/data/hus/hus08.pdf#120

3 Fourth Quarter 2008 Facts and Fictures, California Department of Corrections & Rehabilitation (CDCR), http://www.cdcr.ca.gov/Divisions_Boards/Adult_Operations/docs/Fourth_Quarter_2008_Facts_and_Figures.pdf

4 Jail Profile Survey (2008), California Department of Corrections & Rehabilitation (CDCR), http://www.cdcr.ca.gov/Divisions_Boards/CSA/FSO/Docs/2008_4th_Qtr_JPS_full_report.pdf

5 DEER2011_NTGR_2012-05-16.xls from DEER Database for Energy-Efficient Resources; Version 2011 4.01

Under: DEER2011 Update Documentation linked at: DEER2011 Update Net-To-Gross table Cells: T56 and U56

6 The Benefits of Ozone in Hospitality On-Premise Laundry Operations, PG&E Emerging Technologies Program, Application Assessment Report #0802, April 2009.

7 Federal Register, Vol. 52, No. 166

8 2009 ASHRAE Handbook – Fundamentals, Thermodynamic Properties of Water at Saturation, Section 1.1 (Table 3), 2009

9 Table 2 through 6: Excel file summarizing data collected from existing ozone laundry projects that received incentives under the NRR-DR program

MEASURE CODE CI-HWE-OZLD-V02-190101

REVIEW DEADLINE: 1/1/2020

[262] Confirmed through communications with national vendors and available references, via an online forum (The Ozone Laundry Blog – The Importance of Maintenance)

4.3.7 Multifamily Central Domestic Hot Water Plants

DESCRIPTION

This measure covers multifamily central domestic hot water (DHW) plants with thermal efficiencies greater than or equal to 88%. This measure is applicable to any combination of boilers and storage tanks provided the thermal efficiency of the boilers is greater than 88%. Plants providing other than solely DHW are not applicable to this measure.

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

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

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler(s) must have a Thermal Efficiency of 88% or greater and supply domestic hot water to multi-family buildings.

DEFINITION OF BASELINE EQUIPMENT

For TOS the baseline boiler is assumed to have a Thermal Efficiency of 80%.[263]

For Early Replacement the savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit as above and efficient unit consumption for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic hot water boilers is 15 years.[264]

DEEMED MEASURE COST

TOS: The actual install cost should be used for the efficient case, minus the baseline cost assumption provided below:

Capacity Range	Baseline Installed Cost per kBtuh[265]
<300kBtuh	$65 per kBTUh
300 – 2500 kBtuh	$38 per kBTUh
>2500 kBtuh	$32 per kBTUh

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[263] International Energy Conservation Code (IECC) 2012/2015/2018, Table C404.2, Minimum Performance of Water-Heating Equipment

[264] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.

[265] Baseline install costs are based on data from the “2010-2012 WO017 Ex Ante Measure Cost Study”, Itron, California Public Utilities Commission. The data is provided in a file named “MCS Results Matrix – Volume I”.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

There are no anticipated electrical savings from this measure.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Time of Sale:

ΔTherms = Hot Water Savings + Standby Loss Savings

= [(MFHH * #Units * GPD * Days/yr * ɣWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

Early Replacment[266]:

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

= [(MFHH * #Units * GPD * Days/yr * ɣWater * (Tout – Tin) * (1/Eff_exist – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_exist – 1/Eff_ee)) / 100,000]

ΔTherms for remaining measure life (next 10 years):

= [(MFHH * #Units * GPD * Days/yr * ɣWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

Where:

MFHH = number of people in Multi-Family House Hold

= Actual. If unknown assume 2.1 persons/unit[267]

#Units = Number of units served by hot water boiler

= Actual

GPD = Gallons of hot water used per person per day

= Actual. If unknown assume 17.6 gallons per person per day[268]

Days/yr = 365.25

ɣWater = Specific Weight of Water

= 8.33 gal/lb

Tout = tank temperature of hot water

= 125°F or custom

[266] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

[267] Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

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

Tin = Incoming water temperature from well or municiple system

= 54°F[269]

Eff_base = thermal efficiency of base unit

= 80%[270]

Eff_ee = thermal efficiency of efficient unit complying with this measure

= Actual. If unknown assume 88%

Eff_exist = thermal efficiency of existing unit

= Actual. If unknown assume 73%[271]

SL = Standby Loss[272]

= (Input rating / 800) + (110 * √Tank Volume). Note: IECC2018 does not specify standby loss performance.

Input rating = Name plate input capacity in Btuh

Tank Volume = Rated volume of the tank in gallons

Hours / yr = 8766 hours

100,000 = btu/therm

[269] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

[270] IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[271] Based upon DCEO data provided 10/2014; average age adjusted efficiency of existing units replaced through the program. Efficiency age adjustment of 0.5% per year based upon NREL "Building America Performance Analysis Procedures for Existing Homes".

[272] Stand-by loss is provided in IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

EXAMPLES

Time of Sale:

For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units.

ΔTherms = Hot Water Savings + Standby Loss Savings

= [(MFHH * #Units * GPD * Days/yr * γWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

=[(2.1 * 50 * 17.6 * 8.33 * 365.25 * 1.0 * (125-54) * (1/0.8 – 1/0.88)) / 100000] + [((150000/800 + (110 * √1000)) * 8766 * (1/0.8 – 1/0.88)) / 100000]

= 454 + 37

= 490 therms

Early Replacement:

For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units replaces a working unit with unknown efficiency.

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

=[(2.1 * 50 * 17.6 * 8.33 * 365.25 * 1.0 * (125-54) * (1/0.73 – 1/0.88)) / 100000] + [((150000/800 + (110 * √1000)) * 8766 * (1/0.73 – 1/0.88)) / 100000]

= 932 + 75

= 1007 therms

ΔTherms for remaining measure life (next 10 years):

= 454 + 37 (as above)

= 490 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HWE-MDHW-V03-190101

REVIEW DEADLINE: 1/1/2023

4.3.8 Controls for Central Domestic Hot Water

Description

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The base case for this measure category are existing, un-controlled Recirculation Pumps on gas-fired Central Domestic Hot Water Systems.

Deemed Lifetime of Efficient Equipment

The effective useful life is 15 years[273].

Deemed Measure Cost

The average cost of the demand controller circulation kit is $1,608 with an installation cost of $400 for a total measure cost of $2,008.[274]

Loadshape

Loadshape C02 - Non-Residential Electric DHW

Coincidence Factor

N/A

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Deemed at 656 kWh[275].

---

[273] 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.

[274] The incremental costs were averaged based on the following multi-family and dormitory 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.

[275] This value is the average kWh saved per pump based on results from Multi-Family buildings studied in Nicor Gas Emerging Technology Program study and Southern California Gas' study in multiple dormitory buildings. Note this value does not reflect

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Gas savings for this measure can be calculated by using site specific boiler size and boiler usage information or deemed values are provided based on number of rooms for Dormitories and number of apartments for Multi-Family buildings[276].

$$\Delta Therms = Boiler\ Input\ Capacity * (t_{normal\ occ} * R_{normal\ occ} + t_{low\ occ} * R_{low\ occ}) / 100{,}000$$

Where:

Boiler Input Capacity = Input capacity of the Domestic Hot Water boiler in BTU/hr.

= If the facility uses the same boiler for space heat and domestic hot water, estimate the boiler input capacity for only domestic hot water loads. If this cannot be estimated, use 22.75%[277] of total boiler input capacity for Multi-Family Buildings and 16.48%[278] of total boiler input capacity for Dormitories, as domestic hot water load.

= If unknown capcity use 4,938 BTU/hr per room for Dormitories[279] and 12,493 BTU/hr per apartment for Multi-Family Buildings[280]

$t_{normal\ occ}$ = Total operating hours of domestic hot water burner, when the facility has normal occupancy. If unknown, assume 1,688 hours for Dormitories[281] and 2,089 hours for Multi-Family buildings[282].

$t_{low\ occ}$ = Total operating hours of domestic hot water burner, when the facility has low occupancy[283]. If unknown, assume 520 hours for Dormitories and 0 hours for Multi-Family buildings.

---

savings from electric units but electrical savings from gas-fired units. See 'CDHW Controls Summary Calculations.xlsx' for more information.

276 See 'CDHW Controls Summary Calculations.xlsx' for more information.

277 This is an average number based on Residential Energy Consumption Survey (2009) data and Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for buildings with more than 5 apartments in Illinois and Nursing Home and Assisted Living facilties in Midwest.

278 This is based on Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for Education facilities in East North Central.

279 This is based on studies done in multiple university dormitory buildings in the California region, for Southern California Gas' PREPS Program, 2012. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 7, and assumes 1 to 2 students per dorm room based on typical dorm room layouts. This source provides the source for dormitory assumptions of Boiler Input Capacity, $t_{low\ occ}$, $R_{normal\ occ}$ and $R_{low\ occ}$,

280 This is based on studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program by Gas Technology Institute. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 9, and assumes 2.1 persons per apartment as per ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012 by Navigant. This source provides the source for dormitory assumptions of Boiler Input Capacity, $t_{low\ occ}$, $R_{normal\ occ}$ and $R_{low\ occ}$,

281 Based on results of studies performed in multiple university dormitory buildings in the California region, for Southern California Gas' PREPS Program, 2012.

282 Based on results of the studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program:

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

283 Low occupancy periods for dormitory buildings can be assumed as vacation day or holiday occupancy.

$R_{normal\ occ}$ = Reduction(%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during normal occupancy period.

= 22.44% for Dormitories

= 24.02% for Multi-Family Buildings

$R_{low\ occ}$ = Reduction(%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during low occupancy period.

= 44.57% for Dormitories

= 0% for Multi-Family Buildings

Based on defaults above:

ΔTherms = 30.1 * number of rooms (for Dormitories)

= 62.7 * number of apartments (for Multi-Family buildings)

EXAMPLE

For example, a dormitory building has a 400,000 BTU/hr boiler whose burner operates for an estimated 580 hours during vacation months and 1,300 hours during regular occupancy months. Savings from installing central domestic hot water controls in this building are -

ΔTherms = 400,000 BTU/hr * (1,300 * 0.2244 + 580 * 0.4457) / 100,000

= 2,200.9 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HWE-CDHW-V02-180101

REVIEW DEADLINE: 1/1/2022

4.3.9 Heat Recovery Grease Trap Filter

Description

A heat recovery grease trap filter combines grease filters and a heat exchanger to recover heat leaving kitchen hoods. As a direct replacement for conventional hood mounted filters in commercial kitchens, they are plumbed to the domestic hot water system to provide preheating energy to incoming water.

This measure was developed to be applicable to the following program types: TOS and RF. If applied to other program types, the measure savings should be verified. For NC projects, this measure may be applicable if code requirements are otherwise satisfied.

Definition of Efficient Equipment

Grease filters with heat exchangers carrying domestic hot water in kitchen exhaust air ducts.

Definition of Baseline Equipment

Kitchen exhaust air duct with constant air flow[284] and no heat recovery.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.285

Deemed Measure Cost

Full installation costs, including plumbing materials, labor and any associated contols, should be used for screening purposes.

Loadshape

Loadshape C01 - Commercial Electric Cooking

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[286]:

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	0.36
Unknown	0.40

[284] Savings methodology factors are for a constant speed fan.
[285] Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment.
[286]Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For electric hot water heaters:

$$\Delta kWh = [(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb.°F * (\Delta T/filter * Qty\_Filter) * 0.00293] / (\eta_{HeaterElec})$$

Where:

Meal/Day = Average number of meals served per day. If not directly available, see Table 1.

HW/Meal = Hot water required per meal

= 3 gal/meal[287]

Days/Year = Number of days kitchen operates per year. If not directly available, see Table 1.

Lbs/gal = weight of water

= 8.3 lbs/gal

BTU/lb.°F = Specific heat of water

= 1.0

ΔT/filter = Temperature difference of domestic water across each filter

= 5.8°F/filter[288]

Qty_Filter = Number of heat recovery grease trap filters installed. If not directly available, see Table 1.

Commercial Kitchen Load based on Building Type

Building Type	Meals/Day[289]	Assumed days/Year	Number of Filters[290]
Primary School	400	312	2
Secondary School	600	312	3
Quick Service Restaurant	800	312	5
Full Service Restaurant	780	312	4
Large Hotel	780	356	4
Hospital	800	356	4

$\eta_{HeaterElec}$ = Efficiency of the Electric water heater.

[287] Average dishwashing and faucet water usage taken from Chapter 8, Table 8.3.3 Normalized Annual End Uses of Water in Select Restaurants in Western United States.

[288] Average value based on case studies. Northwinds Sailing, Inc. and North Shore Sustainable Energy, LLC. *Angry Trout Café Kitchen Exhaust Heat Recovery.* Minnesota Department of Commerce, Division of Energy Resources, 2012.

[289] Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

[290] Each filter is 20 X 20 inches.

= Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

Hours = Hours of operation of kitchen exhaust air fan. If not directly available use:

Building Type	Kitchen Exhaust Fan Annual Operating Hours[291]
Primary School	4,056
Secondary School	4,056
Quick Service Restaurant	5,616
Full Service Restaurant	5,616
Large Hotel	5,340
Hospital	3,916

CF = Summer Peak Coincidence Factor for measure[292]:

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	0.36
Unknown	0.40

NATURAL GAS SAVINGS

For natural gas hot water heaters:

ΔTherm = [(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb .°F * (ΔT/filter * Qty_Filter] / ($\eta_{HeaterGas}$ * 100,000)

Where:

$\eta_{HeaterGas}$ = Efficiency of the Gas water heater. If not directly available, use:

= Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

Other variables as above

[291] Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

[292] Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls.

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M savings may result from reduced filter and hood cleaning frequencies. More research should be done to understand any potential savings and the associated value.

MEASURE CODE: CI-HWE-GRTF-V01-160601

REVIEW DEADLINE: 1/1/2024

4.3.10 DHW Boiler Tune-up

Description

Domestic hot water (DHW) boilers provide hot water for bathrooms, kitchens, tubs and other applicances. Several commercial and industrial facilities such as multi-family buildings, lodging and restaurants have a separate hot water boiler serving DHW loads. Unlike space heating boilers, DHW boilers operate year round, which means they have a greater need to be properly maintained and tuned up.

This measure calculates savings for tuning up a DHW boiler to improve its efficiency and reduce its consumption. A boiler tune-up involves cleaning/inspecting burners, burner nozzles and combustion chambers, adjusting air flow and burner gas input to reduce stack temperatures, and checking venting and safety controls. A pre- and post- tune up combustion efficiency ticket (from combustion analyzer) can be used to confirm the improvement in boiler efficiency.

Boilers that serve only a DHW load are eligible for 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

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[293] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

Definition of Baseline Equipment

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months.

[293] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years.[294]

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr per tune-up.[295]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = ((T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{water} * 1 * (1/Eff_{before} – 1/Eff_{after}))/100,000$$

Where:

T_{OUT} = Hot water storage tank temperature

= 125°F

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

= 54°F[296]

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

= Actual if possible to provide reasonable custom estimate. If not, the following methods are provided to develop an estimate[297]:

1. Consumption per usable storage tank capacity

= Capacity * Consumption/cap

[294] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

[295] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

[296] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy

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

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:

Building Type[298]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	622
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multi-Family	894

2. Consumption per unit area by building type

= (Area/1000) * Consumption/1,000 sq.ft.

Where:

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

= Actual

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

Building Type	Consumption/1,000 sq.ft.
Convenience	4,594
Education	7,285
Grocery	697
Health	24,540
Large Office	1,818
Large Retail	1,354
Lodging	29,548
Other Commercial	3,941
Restaurant	44,439
Small Office	1,540
Small Retail	6,111
Warehouse	1,239
Nursing	30,503
Multi-Family	15,434

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

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

= 8.33 lbs/gal

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

Eff_{before} = Efficiency of the boiler before tune-up

Eff_{after} = Efficiency of the boiler after tune-up

100,000 = Converts Btu to therms

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the year and take readings at a consistent firing rate for pre and post tune-up.

EXAMPLE

Tune up of a DHW Boiler heating a 100 gallon storage tank in a nursing home, measuring 80% AFUE prior to tune up and 82.2% AFUE after.

$\Delta Therms = ((T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{water} * 1 * (1/Eff_{before} – 1/Eff_{after}))/100,000$

$= ((125 - 54) * (100 * 672) * 8.33 * 1 * (1/0.8 – 1/0.822))/100,000$

= 13.3 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HWE-DBTU-V01-180101

REVIEW DEADLINE: 1/1/2024

4.4 HVAC End Use

Many of the commercial HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure.

To calculate the updated EFLHs by building type and climate zone provided below, a TAC Subcommittee utilized building energy models originally developed for ComEd[299], applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant[300], the EFLH calculation was finalized by the Subcommittee to be 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 calculation keeps EFLH independent of modeled systems efficiency (which is utilized in the TRM savings calculation) and buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings. See "EFLH Description 2015-02-11.doc" for further explanation.

The building characteristics can be found in the reference table named "EFLH Building Descriptions Updated 2014-11-21.xlsx".

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.

Building Type	Heating EFLH					Model Source
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)	
Assembly	1,787	1,831	1,635	1,089	1,669	eQuest
Assisted Living	1,683	1,646	1,446	1,063	1,277	eQuest
College	1,530	1,430	1,276	709	849	eQuest
Convenience Store	1,481	1,368	1,214	871	973	eQuest
Elementary School	1,781	1,736	1,531	1,057	1,283	eQuest
Garage	985	969	852	680	752	eQuest
Grocery	1,608	1,602	1,404	876	1,047	eQuest
Healthcare Clinic	1,579	1,620	1,414	963	1,019	eQuest
High School	1,845	1,857	1,666	1,187	1,388	eQuest
Hospital - CAV no econ[301]	1,764	1,818	1,549	1,332	1,512	eQuest
Hospital - CAV econ[302]	1,788	1,853	1,580	1,369	1,555	eQuest
Hospital - VAV econ[303]	731	695	522	314	340	eQuest
Hospital - FCU	1,325	1,512	1,232	1,448	1,946	eQuest
Hotel/Motel	1,761	1,712	1,544	1,056	1,290	eQuest
Hotel/Motel - Common	1,601	1,626	1,548	1,260	1,323	eQuest
Hotel/Motel - Guest	1,758	1,702	1,521	1,018	1,252	eQuest
Manufacturing Facility	1,048	1,013	939	567	634	eQuest
MF - High Rise	1,526	1,506	1,373	1,169	1,172	eQuest
MF - High Rise - Common	1,815	1,762	1,580	1,089	1,406	eQuest
MF - High Rise - Residential	1,475	1,464	1,330	1,152	1,123	eQuest
MF - Mid Rise	1,742	1,704	1,498	1,208	1,429	OpenStudio
Movie Theater	1,916	1,905	1,718	1,288	1,538	eQuest

[299] A full description of the ComEd model development is found in "ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010"
[300] "Estimates of Heating Equivalent Full-Load Hours (EFLH) for the Illinois Technical Reference Manual (TRM)", Memorandum, Navigant
[301] Based on model with single duct reheat system with a fixed outdoor air volume.
[302] Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors.
[303] Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors.

Building Type	Heating EFLH					Model Source
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)	
Office - High Rise - CAV no econ	2,020	2,050	1,869	1,252	1,363	eQuest
Office - High Rise - CAV econ	2,089	2,132	1,960	1,351	1,487	eQuest
Office - High Rise - VAV econ	1,528	1,558	1,284	759	846	eQuest
Office - High Rise - FCU	1,118	1,102	952	505	530	eQuest
Office - Low Rise	1,428	1,425	1,132	692	793	eQuest
Office - Mid Rise	1,683	1,538	1,319	1,313	1,206	OpenStudio
Religious Building	1,603	1,504	1,440	1,054	1,205	eQuest
Restaurant	1,350	1,354	1,216	920	1,091	eQuest
Retail - Department Store	1,123	979	852	697	689	OpenStudio
Retail - Strip Mall	1,332	1,233	1,090	751	810	eQuest
Warehouse	1,338	1,098	976	771	810	OpenStudio
Unknown	1,553	1,539	1,369	982	1,139	n/a

Equivalent Full Load Hours for Cooling ($EFLH_{cooling}$) :

Building Type	Cooling EFLH					Model Source
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)	
Assembly	725	796	937	1,183	932	eQuest
Assisted Living	1,475	1,457	1,773	2,110	1,811	eQuest
College	475	481	662	746	806	eQuest
Convenience Store	1,088	1,067	1,368	1,541	1,371	eQuest
Elementary School	725	764	905	1,142	956	eQuest
Garage	934	974	1,226	1,582	1,383	eQuest
Grocery	1,033	1,000	1,236	1,499	1,286	eQuest
Healthcare Clinic	1,282	1,305	1,519	1,767	1,571	eQuest
High School	675	721	840	1,060	920	eQuest
Hospital - CAV no econ	4,166	4,275	4,319	4,692	4,445	eQuest
Hospital - CAV econ	1,751	1,814	2,120	2,411	2,112	eQuest
Hospital - VAV econ	1,531	1,592	1,853	2,163	1,876	eQuest
Hospital - FCU	3,245	3,291	3,451	4,128	3,806	eQuest
Hotel/Motel	1,233	1,186	1,436	1,274	1,616	eQuest
Hotel/Motel - Common	2,186	2,103	2,344	1,391	2,651	eQuest
Hotel/Motel - Guest	1,042	1,019	1,269	1,216	1,418	eQuest
Manufacturing Facility	1,010	1,055	1,209	1,453	1,273	eQuest
MF - High Rise	921	845	1,048	1,779	1,099	eQuest
MF - High Rise - Common	914	839	1,055	2,893	1,132	eQuest
MF - High Rise - Residential	899	831	1,011	1,569	1,055	eQuest
MF - Mid Rise	694	747	927	983	961	OpenStudio
Movie Theater	876	745	1,036	1,178	1,010	eQuest
Office - High Rise - CAV no econ	1,688	1,708	1,811	1,865	1,725	eQuest
Office - High Rise - CAV econ	1,454	1,452	1,551	1,568	1,416	eQuest
Office - High Rise - VAV econ	875	919	1,057	1,275	1,077	eQuest
Office - High Rise - FCU	1,117	1,170	1,277	1,642	1,412	eQuest
Office - Low Rise	949	1,010	1,182	1,452	1,281	eQuest
Office - Mid Rise	907	909	1083	1057	1060	OpenStudio
Religious Building	861	817	967	1,159	1,067	eQuest

Building Type	Cooling EFLH					Model Source
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)	
Restaurant	1,074	1,134	1,279	1,627	1,325	eQuest
Retail - Department Store	884	885	1076	1195	1108	OpenStudio
Retail - Strip Mall	950	919	1,149	1,351	1,215	eQuest
Warehouse	287	308	400	467	448	OpenStudio
Unknown	1,215	1,221	1,408	1,670	1,480	n/a

4.4.1 Air Conditioner Tune-up

Description

An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space

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 least 3 tons and preapproved by program. The measure requires 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

A copy of contractor invoices that detail the work performed to identify tune-up items, as well as additional labor and parts to improve/repair air conditioner performance must be submitted to the program

Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be an AC system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 3 years.[304]

Deemed Measure Cost

The incremental capital cost for this measure is $35[305] per ton.

Loadshape

Loadshape C03 - Commercial Cooling

Coincidence Factor

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [306]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

---

[304] 3 years is given for "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils". DEER2014 EUL Table.

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

[306] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8% [307]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWH = (kBtu/hr) * [(1/EERbefore) – (1/EERafter)] * EFLH

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio[308] of the baseline equipment prior to tune-up

=Actual

EERafter = Energy Efficiency Ratio of the baseline equipment after to tune-up

=Actual

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

ΔkWh = (kBtu/hr) / EERbefore * EFLH * %Savings

Where:

%Savings = Deemed percent savings per Tune-Up component. These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed (totals provided below)[309]

Tune-Up Component	% savings
Condenser Cleaning	6.10%
Evaporator Cleaning	0.22%
Refrig. Charge Off. <=20%	0.68%
Refrig. Charge Off. >20%	8.44%
Combined (Refrig. Charge Off. <=20%)	7.00%

[307] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[308] 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. Generally, this requires that the outside air temperature is at least 60°F, and that the unit runs with all stages of cooling enabled for 10 to 15 minutes prior to making measurements. For more information, please see "IL TRM_Normalizing to AHRI Conditions Method".

[309] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

Tune-Up Component	% savings
Combined (Refrig. Charge Off. >20%)	14.76%

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives a tune-up that includes both condenser and evaporator cleaning:

ΔkWh = (5*12) / 12 * 1,392 * 6.32%

= 440 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW_{SSP} = (kBtu/hr * (1/EERbefore - 1/EERafter)) * CF_{SSP}

ΔkW_{PJM} = (kBtu/hr * (1/ EERbefore - 1/EERafter)) * CF_{PJM}

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [310]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [311]

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

ΔkW = (kBtu/hr) / EERbefore * %Savings * CF

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ACTU-V05-180101

REVIEW DEADLINE: 1/1/2021

[310] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[311] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

4.4.2 Space Heating Boiler Tune-up

DESCRIPTION

This measure is for a non-residential 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.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[312] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years[313]

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr[314] per tune-up

[312] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[313] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[314]Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms =(Capacity * EFLH * (((Effbefore + Ei)/ Effbefore) – 1)) / 100,000

Where:

Capacity = Boiler gas input size (Btu/hr)

= custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Effbefore = Efficiency of the boiler before the tune-up

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

Ei = Efficiency Improvement of the boiler tune-up measure

100,000 = Converts Btu to therms

EXAMPLE

For example, a 1050 kBtu boiler in a Chicago high rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

Δtherms = (1,050,000 * 2050 * ((0.82 + 0.018)/ 0.82 – 1)) /100,000

= 473 Therms

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-BLRT-V06-160601

REVIEW DEADLINE: 1/1/2022

4.4.3 Process Boiler Tune-up

DESCRIPTION

This measure is for a non-residential boiler for process loads. For space heating, see measure 4.4.2. 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.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[315] by approved technician, as specified below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as reQuested by on-site personnel

DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years[316]

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr[317] per tune-up

[315] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[316] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[317] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = ((Ngi * 8766 * UF)/100) * (1 - (Eff_{pre}/Eff_{measured}))$$

Where:

Ngi = Boiler gas input size (kBtu/hr)

= custom

UF = Utilization Factor

= 41.9%[318] or custom

Eff_{pre} = Boiler Combustion Efficiency Before Tune-Up

= Actual

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

$Eff_{measured}$ = Boiler Combustion Efficiency After Tune-Up

= Actual

100 =converstion from kBtu to therms

8766 = hours a year

EXAMPLE

For example, a 80% 1050 kBtu boiler is tuned-up resulting in final efficiency of 81.3%:

Δtherms =((1050 * 8766*0.419)/100) * (1- (0.80/0.813))

= 617 therms

[318] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PBTU-V05-160601

REVIEW DEADLINE: 1/1/2022

4.4.4 Boiler Lockout/Reset Controls

DESCRIPTION

This measure relates to improving combustion efficiency by adding controls to non-residential building heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. Energy is saved by increasing the temperature difference between the water temperature entering the boiler in the boiler's heat exchanger and the boiler's burner flame temperature. The flame temperature remains the same while the water temperature leaving the boiler decreases with the decrease in heating load due to an increase in outside air temperature. A lockout temperature is also set to prevent the boiler from turning on when it is above a certain temperature outdoors.

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

Natural gas customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse linear fashion with outdoor air temperature. Boiler lockout temperatures should be set to 55 °F at this time as well, to turn the boiler off when the temperature goes above a certain setpoint.

DEFINITION OF BASELINE EQUIPMENT

Existing boiler without boiler reset controls, any size with constant hot water flow.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 20 years[319]

DEEMED MEASURE COST

The cost of this measure is $612[320]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[319]CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

[320] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

NATURAL GAS ENERGY SAVINGS

ΔTherms = Binput * SF * EFLH /(100)

Where:

Binput = Boiler Input Capacity (kBtu/hr)

= custom

SF = Savings factor

= 8%[321] or custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

100 = conversion from kBtu to therms

EXAMPLE

For example, a 800 kBtu/hr boiler at a restaurant in Rockford, IL

ΔTherms = 800 * 0.08 * 1,350 / (100)

= 864 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-BLRC-V03-150601

REVIEW DEADLINE: 1/1/2021

[321] Savings factor is the estimate of annual gas consumption that is saved due to adding boiler reset controls. The CLEAResultuses a boiler tuneup savings value derived from Xcel Energy "DSM Biennial Plan-Technical Assumptions," Colorado. Focus on Energy uses 8%, citing multiple sources. Vermont Energy Investment Corporation's boiler reset savings estimates for custom projects further indicate 8% savings estimate is better reflection of actual expected savings.

4.4.5 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[322]

Deemed Measure Cost

The incremental capital cost for a unit heater is $676[323]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

The annual natural gas energy savings from this measure is a deemed value equaling 266 Therms.

[322] DEER 2008

[323] ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

MEASURE CODE: CI-HVC-CUHT-V01-190101

REVIEW DEADLINE: 1/1/2022

4.4.6 Electric Chiller

DESCRIPTION

This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs).

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements within Table 403.2.3(7) of either the 2012 or the 2015 IECC (applicable from 01/01/2016), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 23 years [324].

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below.

Equipment Type	Size Category	Incremental Cost ($/ton)
Air cooled, electrically operated	All capacities	$127/ton [325]
Water cooled, electrically operated, positive displacement (reciprocating)	All capacities	$22/ton [326]
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	< 150 tons	$351/ton [327]
	>= 150 tons and < 300 tons	$127/ton
	>= 300 tons	$87/ton

LOADSHAPE

Loadshape C03 - Commercial Cooling

---

[324] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
(http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

[325] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008. Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from DEER2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

[326] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation"

[327] Incremental costs for water-cooled, electrically operated, positive displacement (rotary screw and scroll) from the "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, May 2014 (submitted to CPUC). The data is provided in a file named "MCS Results Matrix – Volume I".

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [328]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [329]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWH = TONS * ((IPLVbase) – (IPLVee)) * EFLH

Where:

TONS = chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)

= Actual installed

IPLVbase = efficiency of baseline equipment expressed as Integrated Part Load Value(kW/ton). Chiller units are dependent on chiller type. See Chiller Units, Convertion Values and Baseline Efficiency Values by Chiller Type and Capacity in the Reference Tables section.

IPLVee[330] = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[331]

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

> For example, a 100 ton air-cooled electrically operated chiller with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) ,in a low-rise office building in Rockford with a building permit dated on 1/1/2015 would save:
>
> ΔkWH = 100 * ((0.96) – (0.86)) * 949
>
> = 9,490 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW_{SSP} = TONS * ((PEbase) – (PEee)) * CF_{SSP}

---

[328] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[329] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[330] 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.

[331] Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRI online Certification Directory.

ΔkW_{PJM} = TONS * ((PEbase) – (PEee)) * CF_{PJM}

Where:

PEbase = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)

PEee = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)

= Actual installed

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%

For example, a 100 ton air-cooled electrically operated chiller with a peak efficiency of 1.05 kW/ton and a baseline peak efficiency of 1.2 kW/ton would save:

ΔkW_{SSP} = 100 * (1.2 – 1.05) * 0.913

= 13.7 kW

NATURAL GAS ENERGY 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	Unit
Air cooled, electrically operated	EER
Water cooled, electrically operated, positive displacement (reciprocating)	kW/ton
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	kW/ton

In order to convert chiller equipment ratings to IPLV the following relationships are provided

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS:
WATER CHILLING PACKAGES[a]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010[b]				TEST PROCEDURE[c]
					PATH A		PATH B		
			FULL LOAD	IPLV	FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA	NA	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA	NA	

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.
NA = Not applicable, not to be used for compliance; NR = No requirement.

a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.

b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.

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

2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.2.3(7)
WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS[a, b, d]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015 Path A	BEFORE 1/1/2015 Path B	AS OF 1/1/2015 Path A	AS OF 1/1/2015 Path B	TEST PROCEDURE[c]
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.680 FL	≤ 0.718 FL	≤ 0.660 FL	≤ 0.680 FL	
			≤ 0.580 IPLV	≤ 0.540 IPLV	≤ 0.540 IPLV	≤ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

2018 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[e]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≥ 0.680 FL	≥ 0.718 FL	≥ 0.660 FL	≥ 0.680 FL	
			≥ 0.580 IPLV	≥ 0.540 IPLV	≥ 0.540 IPLV	≥ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

MEASURE CODE: CI-HVC-CHIL-V06-190101

REVIEW DEADLINE: 1/1/2022

4.4.7 ENERGY STAR and CEE Super Efficient Room Air Conditioner

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE Super Efficient minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:[332]

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR CEER, with louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th><th>CEE Super Efficient CEER</th></tr>
<tr><td>< 8,000</td><td>11.0</td><td>10.0</td><td>12.1</td><td>11.0</td><td>12.7</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">10.9</td><td>9.6</td><td rowspan="2">12.0</td><td>10.6</td><td rowspan="2">12.5</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td>10.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>9.3</td><td>11.8</td><td>10.2</td><td>12.3</td></tr>
<tr><td>20,000 to 27,999</td><td>9.4</td><td rowspan="2">9.4</td><td>10.3</td><td rowspan="2">10.3</td><td>10.8</td></tr>
<tr><td>>= 28,000</td><td>9.0</td><td>9.9</td><td>10.4</td></tr>
</table>

Casement	Federal Standard (CEER)	ENERGY STAR (CEER)
Casement-only	9.5	10.5
Casement-slider	10.4	11.4

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEER, with louvered sides	Federal Standard CEER, without louvered sides	ENERGY STAR CEER, with louvered sides	ENERGY STAR CEER, without louvered sides
< 14,000	N/A	9.3	N/A	10.2
>= 14,000	N/A	8.7	N/A	9.6
< 20,000	9.8	N/A	10.8	N/A
>= 20,000	9.3	N/A	10.2	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.

[332] Federal Baselines defined by Code of Federal Regulations §430.32(d). ENERGY STAR specification defined by Version 4.0 Room Air Conditioners. CEE specification defined by Room Air Conditioner Specification effective January 31, 2017.
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.

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years.[333]

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE Super Efficient unit.[334]

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [335]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [336]

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

$$\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$$

Where:

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

333 Energy Star Room Air Conditioner Savings Calculator, Life Cycle Cost Estimate for ENERGY STAR Qualified Room Air Conditioners

334 Based on field study conducted by Efficiency Vermont

335 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

336 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

= dependent on location:[337]

Zone	FLHRoomAC
1 (Rockford)	253
2-(Chicago)	254
3 (Springfield)	310
4-(Belleville)	391
5-(Marion)	254

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr [338]

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR or CEE Super Efficient 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 Rockford:

$\Delta kWH_{ENERGY\ STAR}$ = (253 * 8500 * (1/10.9 – 1/12.0)) / 1000

= 18.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Btu/H * ((1/CEERbase - 1/CEERee))/1000) * CF

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [339]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[340]

Other variable as defined above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford during system peak

$\Delta kW_{ENERGY\ STAR}$ = (8500 * (1/10.9 – 1/12.0)) / 1000 * 0.913

= 0.065 kW

[337] Full load hours for room AC is significantly lower than for central AC. 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 (detailed in the Energy Star Room Air Conditioner Savings Calculator) is 31%. This ratio has been applied to the FLH from the unitary and split system air conditioning measure.

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

[339] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[340] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ESRA-V02-190101

REVIEW DEADLINE: 1/1/2022

4.4.8 Guest Room Energy Management (PTAC & PTHP)

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 the guest room's set temperatures and control the HVAC unit for various occupancy modes.

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 default setting for controlled units differs by at least 5 degrees from the operating set point. Theoretically, the control system may also be tied into other electric loads, such as lighting and plug loads to shut them off when occupancy is not sensed. This measure bases savings on improved HVAC controls. If system is connected to lighting and plug loads, additional savings would be realized. 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 heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Two possible baselines exist based on whether housekeeping staff are directed to set-back (or turn off) thermostats when rooms are not rented.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for GREM is 15 years[341].

DEEMED MEASURE COST

$260/unit

The IMC documented for this measure is $260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM[342].

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

A coincidence factor is not used in the determination of coincident peak kW savings.

Algorithm

CALCULATION OF SAVINGS

Below are the annual kWh savings per installed EMS for different sizes and types of HVAC units. The savings are achieved based on GREM's ability to automatically adjust the guest room's set temperatures and control the HVAC

[341] DEER 2008 value for energy management systems
[342] This value was extracted from Smart Ideas projects in PY1 and PY2.

unit to maintain set temperatures for various occupancy modes. Note that care should be taken in selecting a value consistent with actual baseline conditions (e.g. whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented). Different values are provided for Motels and Hotels since significant differences in shell performance, number of external walls per room and typical heating and cooling efficiencies result in significantly different savings estimates. Energy savings estimates are derived using a prototypical EnergyPlus simulation of a motel and a hotel[343]. Model outputs are normalized to the installed capacity and reported here as kWh/Ton, coincident peak kW/Ton and Therms/Ton.

ELECTRIC ENERGY SAVINGS

Motel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	744
		No Housekeeping Setback	1,786
	PTAC w/ Gas Heating	Housekeeping Setback	63
		No Housekeeping Setback	155
	PTHP	Housekeeping Setback	385
		No Housekeeping Setback	986
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	506
		No Housekeeping Setback	1,582
	PTAC w/ Gas Heating	Housekeeping Setback	51
		No Housekeeping Setback	163
	PTHP	Housekeeping Setback	211
		No Housekeeping Setback	798
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	462
		No Housekeeping Setback	1,382
	PTAC w/ Gas Heating	Housekeeping Setback	65
		No Housekeeping Setback	198
	PTHP	Housekeeping Setback	202
		No Housekeeping Setback	736
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	559
		No Housekeeping Setback	1,877
	PTAC w/ Gas Heating	Housekeeping Setback	85
		No Housekeeping Setback	287
	PTHP	Housekeeping Setback	260
		No Housekeeping Setback	1,023
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	388
		No Housekeeping Setback	1,339
	PTAC w/ Gas Heating	Housekeeping Setback	81
		No Housekeeping Setback	274
	PTHP	Housekeeping Setback	174
		No Housekeeping Setback	682

[343] For motels, see S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013 and spreadsheet summarizing the results: 'GREM Savings Summary_IL TRM_1_22_14.xlsx'. In 2014 the hotel models were also run to compile results, rather than by applying adjustment factors to the motel results as had been done in V3.0 of the TRM. The updated values can be found in 'GREM Savings Summary (Hotel)_IL TRM_10_16_14.xls'.

Hotel Electric Energy Savings			
Climate Zone City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	204
		No Housekeeping Setback	345
	PTAC w/ Gas Heating	Housekeeping Setback	121
		No Housekeeping Setback	197
	PTHP	Housekeeping Setback	152
		No Housekeeping Setback	253
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	177
		No Housekeeping Setback	296
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	94
		No Housekeeping Setback	148
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	188
		No Housekeeping Setback	342
	PTAC w/ Gas Heating	Housekeeping Setback	119
		No Housekeeping Setback	195
	PTHP	Housekeeping Setback	145
		No Housekeeping Setback	250
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	161
		No Housekeeping Setback	294
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	92
		No Housekeeping Setback	147
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	182
		No Housekeeping Setback	291
	PTAC w/ Gas Heating	Housekeeping Setback	123
		No Housekeeping Setback	197
	PTHP	Housekeeping Setback	145
		No Housekeeping Setback	233
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	153
		No Housekeeping Setback	240
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	94
		No Housekeeping Setback	146
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	182
		No Housekeeping Setback	308
	PTAC w/ Gas Heating	Housekeeping Setback	125
		No Housekeeping Setback	199
	PTHP	Housekeeping Setback	146
		No Housekeeping Setback	240
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	152
		No Housekeeping Setback	255
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	95
		No Housekeeping Setback	147
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	171
		No Housekeeping Setback	295
	PTAC w/ Gas Heating	Housekeeping Setback	122
		No Housekeeping Setback	199
	PTHP	Housekeeping Setback	140
		No Housekeeping Setback	235
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	141

Hotel Electric Energy Savings			
Climate Zone City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
		No Housekeeping Setback	243
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	92
		No Housekeeping Setback	146

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Motel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.17
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.06
		No Housekeeping Setback	0.17
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
	PTAC w/ Gas Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
	PTHP	Housekeeping Setback	0.07
		No Housekeeping Setback	0.17
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
	PTAC w/ Gas Heating	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
	PTHP	Housekeeping Setback	0.10
		No Housekeeping Setback	0.28
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.21
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.21
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.21

Hotel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
1 (Rockford)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
2 (Chicago)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.07
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.07
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
3 (Springfield)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.07
4 (Belleville)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
5 (Marion-Williamson)	PTAC w/ Electric Resistance Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTAC w/ Gas Heating	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11
	PTHP	Housekeeping Setback	0.08
		No Housekeeping Setback	0.11

Hotel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
	Central Hot Water Fan Coil w/ Electric Resistance Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	0.05
		No Housekeeping Setback	0.08

Natural Gas Energy Savings

For PTACs with gas heating:

Motel Natural Gas Energy Savings		
Climate Zone (City based upon)	Baseline	Gas Savings (Therms/Ton)
1 (Rockford)	Housekeeping Setback	30
	No Housekeeping Setback	71
2 (Chicago)	Housekeeping Setback	20
	No Housekeeping Setback	62
3 (Springfield)	Housekeeping Setback	17
	No Housekeeping Setback	52
4 (Belleville)	Housekeeping Setback	21
	No Housekeeping Setback	70
5 (Marion-Williamson)	Housekeeping Setback	13
	No Housekeeping Setback	47

Hotel Natural Gas Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Gas Savings (Therms/Ton)
1 (Rockford)	PTAC w/ Gas Heating	Housekeeping Setback	3.6
		No Housekeeping Setback	6.4
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	3.6
		No Housekeeping Setback	6.4
2 (Chicago)	PTAC w/ Gas Heating	Housekeeping Setback	3.0
		No Housekeeping Setback	6.5
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	3.0
		No Housekeeping Setback	6.5
3 (Springfield)	PTAC w/ Gas Heating	Housekeeping Setback	2.6
		No Housekeeping Setback	4.1
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	2.6
		No Housekeeping Setback	4.1
4 (Belleville)	PTAC w/ Gas Heating	Housekeeping Setback	2.5
		No Housekeeping Setback	4.8
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	2.5
		No Housekeeping Setback	4.8
5 (Marion-Williamson)	PTAC w/ Gas Heating	Housekeeping Setback	2.1
		No Housekeeping Setback	4.2
	Central Hot Water Fan Coil w/ Gas Heating	Housekeeping Setback	2.1

Hotel Natural Gas Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Gas Savings (Therms/Ton)
		No Housekeeping Setback	4.2

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-GREM-V05-150601

REVIEW DEADLINE: 1/1/2022

4.4.9 Air and Water Source 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 or water source, heat pump system that exceeds the baseline and meets program requirements.

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 heat pump system that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date unknown assume current Code minimum). The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Note: IECC 2018 is scheduled to become effective March 1, 2019 will become baseline for all New Construction permits from that date.

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[344].

Deemed Measure Cost

For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.[345] The incremental cost for all other equipment types should be determined on a site-specific basis.

Loadshape

Loadshape C05 - Commercial Electric Heating and Cooling

Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [346]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

[344] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[345] Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.
[346] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8% [347]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = ($kBtu/hr_{cool}$) * [(1/SEERbase) – (1/SEERee)] * $EFLH_{cool}$

Annual kWh $Savings_{heat}$ = ($kBtu/hr_{heat}$) * [(1/HSPFbase) – (1/HSPFee)] * $EFLH_{heat}$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = ($kBtu/hr_{cool}$) * [(1/EERbase) – (1/EERee)] * $EFLH_{cool}$

Annual kWh $Savings_{heat}$ = ($kBtu/hr_{heat}$)/3.412 * [(1/COPbase) – (1/COPee)] * $EFLH_{heat}$

Where:

$kBtu/hr_{cool}$ = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

SEERbase =Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment.

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

HSPFbase = Heating Seasonal Performance Factor of the baseline equipment

= HSPF from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

HSPFee = Heating Seasonal Performance Factor of the energy efficient equipment.

= Actual installed. If rating is COP, HSPF = COP * 3.413

$EFLH_{heat}$ = heating mode equivalent full load hours are provided in section 4.4 HVAC End Use.

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[348]

$$EER = (-0.02 * SEER^2) + (1.12 * SEER)$$

[347] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[348] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the conversion from SEER to EER as provided above.

= Actual installed

$kBtu/hr_{heat}$ = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPbase = coefficient of performance of the baseline equipment

= COP from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). If rating is HSPF, COP = HSPF / 3.413

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed. If rating is HSPF, COP = HSPF / 3.413

Code of Federal Redulations (baseline effective 1/1/2019):

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

Minimum Efficiency Requirements: 2012 IECC (baseline effective 1/1/2013)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	AHRI 210/240
			Single Packaged	13.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System	13.0 SEER	
			Single Packaged	13.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	

(continued)

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

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

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

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

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

Minimum Efficiency Requirements: 2015 IECC (baseline effective 1/1/2016)

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 Before 1/1/2016	MINIMUM EFFICIENCY As of 1/1/2016	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	13.0 SEER[c]	14.0 SEER[c]	AHRI 210/240
			Single Package	13.0 SEER[c]	14.0 SEER[c]	
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	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 SEER	11.0 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	11.0 EER 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.8 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	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	14.1 EER	ISO 13256-1
Water to Water: WaterLoop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	12.1 EER	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	7.7 HSPF[c]	8.2 HSPF[c]	AHRI 210/240
		—	Single Package	7.7 HSPF[c]	8.0 HSPF[c]	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	7.4 HSPF	
		—	Single Package	7.4 HSPF	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	6.8 HSPF	
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	3.3 COP	AHRI 340/360
			17°F db/15°F wb outdoor air	2.25 COP	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP	3.2 COP	
			17°F db/15°F wb outdoor air	2.05 COP	2.05 COP	
Water to Air: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	4.3 COP	ISO 13256-1
Water to Air: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	3.7 COP	
Brine to Air: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	3.2 COP	
Water to Water: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	3.7 COP	ISO 13256-2
Water to Water: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	3.1 COP	
Brine to Water: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.
a. Chapter 6 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.
c. Minimum efficiency as of January 1, 2015.

Minimum Efficiency Requirements: 2018 IECC (baseline effective 3/1/2019 for New Construction measures)

TABLE C403.3.2(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	14.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 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 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	ISO 13256-1
Water to Water: Water Loop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	

IECC2018 Table C403.3.2(2) continued from previous page:

Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	8.2 HSPF	AHRI 210/240
		—	Single Package	8.0 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	
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°Fdb/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°Fdb/15°F wb outdoor air	2.05 COP	
Water to Air: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	ISO 13256-1
Water to Air: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	
Brine to Air: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	
Water to Water: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
Water to Water: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	
Brine to Water: Ground Loop (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 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled heat pumps less than 65,000 Btu/h are regulated by NAECA. SEER and HSPF values are those set by NAECA.

For example a 5 ton cooling unit with 60 kbtu heating, an efficient SEER of 16, and an efficient HSPF of 9.5, at a restaurant in Chicago with a building permit dated after 1/1/2016 saves:

ΔkWh = [(60) * [(1/14) – (1/16)] * 1134] + [(60) * [(1/8.2) – (1/9.5)] * 1354]

= 1963.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = $((kBtu/hr_{cool}) * (1/EERbase – 1/EERee)) *CF$

Where CF value is chosen between:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [349]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [350]

349 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

350 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

For example a 5 ton cooling unit with 60 kbtu heating, an efficient EER of 12.5 with a building permit dated after 1/1/2016 saves:

$$\Delta kW = (60 * (1/11 - 1/12.5)) * 0.913$$

$$= 0.598 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-HPSY-V06-190101

REVIEW DEADLINE: 1/1/2022

4.4.10 High Efficiency Boiler

DESCRIPTION

To qualify for this measure the installed equipment must be replacement of an existing boiler at the end of its service life, in a commercial or multifamily space with a high efficiency, gas-fired steam or hot water boiler. High efficiency boilers achieve gas savings through the utilization 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 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

To qualify for this measure the installed equipment must be a boiler used 80% or more for space heating, not process, and boiler AFUE, TE (thermal efficiency), or Ec (combustion efficiency) rating must be rated greater than or equal to 85% for hot water boilers and 81% for steam boilers.

DEFINITION OF BASELINE EQUIPMENT

Dependent on when the unit is installed and whether the unit is hot water or steam. The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/hr and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/hr.

Note: a new Federal Standard, applicable only to gas-fired, natural draft steam packaged boilers, becomes effective March 2, 2022.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years[351]

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below[352]

Measure Tier	Incr. Cost, per unit
ENERGY STAR® Minimum	$1,470
AFUE 90%	$2,400
AFUE 95%	$3,370
AFUE ≥ 96%	$4,340
Boilers > 300,000 Btu/hr with TE (thermal efficiency) rating	Custom

LOADSHAPE

N/A

[351] The technical support documents for federal residential appliance standards, per the US DOE Office of Energy Efficiency & Renewable Energy, 10 CFR 431.97(c). Note that this value is below the 20 years used by CA's DEER and the range of 20-40 year estimate made by the Consortium for Energy Efficiency in 2010

[352] Average of low and high incremental cost based on Nicor Gas program data for non-condensing and condensing boilers. Nicor Gas Energy Efficiency Plan 2011 - 2014, May 27, 2011 $1,470 for ≤ 300,000 Btu/hr for non-condensing hydronic boilers >85% AFUE & $3,365 for condensing boilers > 90% AFUE. The exception is $4,340 for AFUE ≥ 96% AFUE which was obtained from extrapolation above the size range that Nicor Gas Energy Efficiency Plan provided for incremental cost.

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms = EFLH * Capacity * ((EfficiencyRating(actual) - EfficiencyRating(base)/ EfficiencyRating(base)) / 100,000

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

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

= custom Boiler input capacity in Btu/hr

EfficiencyRating(base) = Baseline Boiler Efficiency Rating, dependant on year and boiler type.

Hot water boiler baseline:

Year	Efficiency
Hot Water <300,000 Btu/hr < June 1, 2013[353]	80% AFUE
Hot Water <300,000 Btu/hr ≥ June 1, 2013	82% AFUE
Hot Water ≥300,000 & ≤2,500,000 Btu/hr	80% TE
Hot Water >2,500,000 Btu/hr	82% Ec

Steam boiler baseline:

Year	Efficiency
Steam <300,000 Btu/hr < June 1, 2013[354]	75% AFUE
Steam <300,000 Btu/hr ≥June 1, 2013	80% AFUE
Steam - all except natural draft ≥300,000 & ≤2,500,000 Btu/hr	79% TE
Steam - natural draft ≥300,000 & ≤2,500,000 Btu/hr	77% TE
Steam - all except natural draft >2,500,000 Btu/hr	79% TE
Steam - natural draft >2,500,000 Btu/hr	77% TE

EfficiencyRating(actual) = Efficent Boiler Efficiency Rating

=actual value, specified to one significant digit (i.e., 95.7%)

353 The Federal baseline for boilers <300,000 btu/hr changes from 80% to 82% in September 2012. To prevent a change in baseline mid-program, the increase in efficiency is delayed until June 2013 when a new program year starts.

354 Ibid.

EXAMPLE

For example, a 150,000 btu/hr water boiler meeting AFUE 90% in Rockford at a high rise office building , in the year 2012

ΔTherms = 2,089* 150,000 * (0.90-0.80)/0.80) / 100,000 Btu/Therm

= 392 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-BOIL-V06-190101

REVIEW DEADLINE: 1/1/2021

4.4.11 High Efficiency Furnace

Description

This measure covers the installation of a high efficiency gas furnace in lieu of a standard efficiency gas furnace in a commercial or industrial space. High efficiency 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

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

Time of sale:

a. The installation of a new high efficiency, gas-fired condensing furnace in a commercial location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system.

Early replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$528)[355].
- All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

- If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
- If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a furnace with input energy less than 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating and fan electrical efficiency exceeding the program requirements:

Definition of Baseline Equipment

Time of Sale: Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. As discussed above we estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%

Note: a new Federal Standard will become effective January 1, 2023 and be applicable to all gas furnaces.

[355] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

DEFINITION OF MEASURE LIFE

The expected measure life is assumed to be 16.5 years[356]

Remaining life of existing equipment is assumed to be 5.5 years[357].

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below[358]:

AFUE	Installation Cost	Incremental Install Cost
80%	$2011	n/a
90%	$2641	$630
91%	$2727	$716
92%	$2813	$802
93%	$3049	$1,038
94%	$3286	$1,275
95%	$3522	$1,511
96%	$3758	$1,747

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 5.5 years) of replacing existing equipment with a new baseline unit is assumed to be $2876[359]. This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

Where:

Heating Savings = Brushless DC motor or Electronically commutated motor (ECM)
= 418 kWh[360]

Cooling Savings = Brushless DC motor or electronically commutated motor (ECM) savings during cooling season

356 Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010.
357 Assumed to be one third of effective useful life
358 Based on data from Appendix E of the US DOE Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
359 $2641 inflated using 1.91% rate.
360 To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.

If air conditioning = 263 kWh

If no air conditioning = 175 kWh

If unknown (weighted average)= 241 kWh[361]

Shoulder Season Savings = Brushless DC motor or electronically commutated motor (ECM) savings during shoulder seasons

= 51 kWh

EXAMPLE

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

= 418 +241 + 51

= 710 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

For units that have evaporator coils and condensing units and are cooling in the summer in addition to heating in the winter the summer coincident peak demand savings should be calculated. If the unit is not equipment with coils or condensing units, the summer peak demand savings will not apply.

ΔkW = (CoolingSavings/HOURSyear) * CF

Where:

HOURSyear = Actual hours per year if known, otherwise use hours from Table below for building type[362].

Building Type	HOURSyear	Model source
Assembly	2150	eQuest
Assisted Living	4373	eQuest
College	1605	eQuest
Convenience Store	2084	eQuest
Elementary School	3276	eQuest
Garage	2102	eQuest
Grocery	2096	eQuest
Healthcare Clinic	1987	eQuest
High School	3141	eQuest
Hospital - VAV econ	2788	eQuest
Hospital - CAV econ	2881	eQuest
Hospital - CAV no econ	8760	eQuest
Hospital - FCU	8729	eQuest
Manufacturing Facility	2805	eQuest
MF - High Rise	4237	eQuest
MF - Mid Rise	2899	eQuest
Hotel/Motel – Guest	4479	eQuest
Hotel/Motel - Common	8712	eQuest
Movie Theater	2120	eQuest

[361] The weighted average value is based on assumption that 75% of buildings installing BPM furnace blower motors have Central AC.

[362] Hours per year are estimated using the eQuest models as the total number of hours the cooling system is operating for each building type.

Building Type	HOURSyear	Model source
Office - High Rise - VAV econ	2038	eQuest
Office - High Rise - CAV econ	4849	eQuest
Office - High Rise - CAV no econ	5682	eQuest
Office - High Rise - FCU	3069	eQuest
Office - Low Rise	2481	eQuest
Office - Mid Rise	3036	OpenStudio
Religious Building	2830	eQuest
Restaurant	3350	eQuest
Retail - Department Store	2528	eQuest
Retail - Strip Mall	2266	eQuest
Warehouse	770	eQuest
Unknown	2718	n/a

CF =Summer Peak Coincidence Factor for measure is provided below for different building types[363]:

HVAC Pumps	CF
Assembly	48.3%
Assisted Living	52.9%
College	14.2%
Convenience Store	57.1%
Elementary School	33.3%
Garage	61.9%
Grocery	47.5%
Healthcare Clinic	61.9%
High School	28.8%
Hospital - VAV econ	57.6%
Hospital - CAV econ	61.5%
Hospital - CAV no econ	64.8%
Hospital - FCU	60.9%
Manufacturing Facility	43.3%
MF - High Rise - Common	43.7%
MF - Mid Rise	24.3%
Hotel/Motel - Guest	62.9%
Hotel/Motel - Common	64.6%
Movie Theater	41.9%
Office - High Rise - VAV econ	43.2%
Office - High Rise - CAV econ	48.3%
Office - High Rise - CAV no econ	50.3%
Office - High Rise - FCU	46.2%
Office - Low Rise	47.4%
Office - Mid Rise	42.8%
Religious Building	43.3%
Restaurant	48.8%
Retail - Department Store	50.5%
Retail - Strip Mall	52.8%
Warehouse	22.5%
Unknown	42.4%

[363] Coincidence Factors are estimated using the eQuest models.

EXAMPLE

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

ΔkW = (241 / 2481) * 0.474

= 0.05 kW

NATURAL GAS ENERGY SAVINGS

Time of Sale:

ΔTherms = EFLH * Capacity * ((AFUE(eff) – AFUE(base))/AFUE(base))/ 100,000 Btu/Therm

Early replacement[364]:

ΔTherms for remaining life of existing unit (1st 5.5 years):

ΔTherms = EFLH * Capacity * ((AFUE(eff) – AFUE(exist))/ AFUE(exist)) / 100,000 Btu/Therm

ΔTherms for remaining measure life (next 11 years):

ΔTherms = EFLH * Capacity * ((AFUE(eff) - AFUE(base))/AFUE(base)) / 100,000 Btu/Therm

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

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

= custom Furnace input capacity in Btu/hr

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4 AFUE% [365].

AFUE(base) = Baseline Furnace Annual Fuel Utilization Efficiency Rating

Dependent on program type as listed below[366]:

Program Year	AFUE(base)
Time of Sale	80%
Early Replacement	90%

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating.

= Actual. If Unknown, assume 95%[367]

[364] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

[365] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

[366] Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

[367]Minimum ENERGY STAR efficiency after 2.1.2012.

EXAMPLE

ΔTherms = 1428 * 150,000 * ((0.92-0.80)/0.80)/ 100,000

= 321 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-FRNC-V08-190101

REVIEW DEADLINE: 1/1/2022

4.4.12 Infrared Heaters (all sizes), Low Intensity

DESCRIPTION

This measure applies to natural gas fired low-intensity infrared heaters with an electric ignition that use non-conditioned air for combustion

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 heater with an electric ignition that uses non-conditioned air for combustion

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard natural gas fired heater warm air heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[368]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1716[369]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

The annual natural gas energy savings from this measure is a deemed value equaling 451 Therms[370]

[368]ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

[369]Ibid.

[370]Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011. These deemed values should be compared to PY evaluation and revised as necessary.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-IRHT-V01-190101

REVIEW DEADLINE: 1/1/2022

4.4.13 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 equipment that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years. [371]

Remaining life of existing equipment is assumed to be 3 years[372]

Deemed Measure Cost

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[373]

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[374].

[371] Based on 2015 DOE Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[372]Standard assumption of one third of effective useful life.
[373] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation
[374] Based on DCEO – IL PHA Efficient Living Program data.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton[375]. This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [376]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [377]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

ENERGY SAVINGS

Time of Sale:

PTAC ΔkWh[378] = Annual kWh $Savings_{cool}$

PTHP ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * EFLH_{cool}$

Annual kWh $Savings_{heat}$ = $(kBtu/hr_{heat})/3.412 * [(1/COPbase) – (1/COPee)] * EFLH_{heat}$

Early Replacement:

ΔkWh for remaining life of existing unit (1st 5years) = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool}) * [(1/EERexist) – (1/EERee)] * EFLH_{cool}$

Annual kWh $Savings_{heat}$ = $(kBtu/hr_{heat})/3.412 * [(1/COPexist) – (1/COPee)] * EFLH_{heat}$

ΔkWh for remaining measure life (next 10 years) = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * EFLH_{cool}$

---

[375] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

[376] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[377] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[378] There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COPbase and COPee would be 1.0.

Annual kWh $Savings_{heat}$ = $(kBtu/hr_{heat})/3.412 * [(1/COPbase) – (1/COPee)] * EFLH_{heat}$

Where:

$kBtu/hr_{cool}$ = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use:

$EFLH_{heat}$ = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

EERexist = Energy Efficiency Ratio of the existing equipment

= Actual. If unknown assume 8.1 EER[379]

EERbase = Energy Efficiency Ratio of the baseline equipment; see the table below for values.

= Based on applicable Code on date of equipment purchase(if unknown assume current Code

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

Equipment Type	IECC 2012 Minimum Efficiency (baseline effective 1/1/2013)	IECC 2015/2018 Minimum Efficiency (baseline effective 1/1/2016)	Federal Regulations Minimum Efficiency (baseline effective 1/1/2019)
PTAC (Cooling mode) New Construction	13.8 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER Compliance date: 1/1/2017
PTAC (Cooling mode) Replacements	10.9 – (0.213 x Cap/1000) EER	10.9 – (0.213 x Cap/1000) EER	10.9 – (0.213 x Cap/1000) EER Compliance date: 10/7/2010
PTHP (Cooling mode) New Construction	14.0 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER Complainace date: 10/8/2012
PTHP (Cooling mode) Replacements	10.8 – (0.213 x Cap/1000) EER	10.8 – (0.213 x Cap/1000) EER	10.8 – (0.213 x Cap/1000) EER Compliance date: 10/7/2010
PTHP (Heating mode) New Construction	3.2 – (0.026 x Cap/1000) COP	3.2 – (0.026 x Cap/1000) COP	3.7 – (0.052 x Cap/1000) COP Compliance date: 10/8/2012
PTHP (Heating mode) Replacements	2.9 – (0.026 x Cap/1000) COP	2.9 – (0.026 x Cap/1000) COP	2.9 – (0.026 x Cap/1000) COP Compliance date: 10/7/2010

[379] Estimated using the 2000 IECC building energy code, for equipment up until year 2003, p107, and assuming a 1 ton unit; EER = 10 – (0.16 * 12,000/1,000) = 8.1.

Table notes: "Cap" = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS", Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the following conversion from SEER to EER for calculation of peak savings[380]: EER = (-0.02 * $SEER^2$) + (1.12 * SEER)

= Actual installed

$kBtu/hr_{heat}$ = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPexist = coefficient of performance of the existing equipment

= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP[381] for PTHPs.

COPbase = coefficient of performance of the baseline equipment; see table above for values.

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed

EXAMPLE:

Time of Sale (assuming new construction baseline):

For example a 1 ton PTAC with an efficient EER of 12 at a guest hotel in Rockford with a building permit dated before 1/1/2016 saves:

= [(12) * [(1/10.4) – (1/12)] * 1,042

= 160 kWh

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

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

ΔkWh for remaining life of existing unit (1^{st} 5years)

= (12 * (1/8.1 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)

= 502 + 4,122

= 4,624 kWh

ΔkWh for remaining measure life (next 10 years)

= (12 * (1/8.3 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)

= 465 + 4,122

= 34,587 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

[380] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[381] Estimated using the 2000 IECC building energy code, for equipment up until year 2003, p107, and assuming a 1 ton unit; COP = 2.9 – (0.026 * 12,000/1,000) = 2.6

$\Delta kW = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] *CF$

Early Replacement:

ΔkW for remaining life of existing unit (1st 5years) $= (kBtu/hr_{cool}) * [(1/EERexist) – (1/EERee)] *CF$

ΔkW for remaining measure life (next 10 years) $= (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] *CF$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [382]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [383]

EXAMPLE

Time of Sale:

For example a 1 ton replacement cooling unit with no heating with an efficient EER of 12 saves:

$\Delta kW_{SSP} = (12 * (1/10.4 – 1/12) *0.913$

$= 0.14$ kW

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 replacing a PTAC unit with unknown efficiency saves:

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

$\Delta kW_{SSP} = 12 * (1/8.1 – 1/12) * 0.913$

$= 0.44$ kW

ΔkW for remaining measure life (next 10 years):

$\Delta kW_{SSP} = 12 * (1/8.3 – 1/12) * 0.913$

$= 0.41$ kW

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-HVC-PTAC-V09-190101

Review Deadline: 1/1/2022

[382] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[383] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

4.4.14 Pipe Insulation

Description

This measure provides rebates for installation of ≥1" or ≥2" fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all non-residential installations.

Default per linear foot 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")
- Domestic hot water
- 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.[384]

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.[385]

---

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

[385] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means[386] pricing reference materials may be used.[387] The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

	Insulation Thickness	
	1 Inch (Indoor)	2 Inches (Outdoor)
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.10.0156	220719.10.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	$9.40	$13.90
Jacket Cost per foot	$4.57	$7.30
Total Cost per foot	**$13.97**	**$21.20**

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Δtherms per foot[388] $= [((Q_{base} – Q_{eff}) * EFLH) / (100{,}000 * \eta Boiler)] * TRF$

= [Modeled or provided by tables below] * TRF

Δtherms $= (L_{sp} + L_{oc,i}) * \Delta therms\ per\ foot$

Where:

EFLH = Equivalent Full Load Hours for Heating

= Actual or defaults by building type provided in Section 4.4, HVAC end use

For year round recirculation or domestic hot water:

= 8,766

For heating season recirculation, hours with the outside air temperature below 55°F:

[386] RS Means 2008. Mechanical Cost Data, pages 106 to 119

[387] RS Means 2010: "for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting"

[388] This value comes from the reference table "Savings Summary by Building Type and System Type." The formula and the input tables in this section document assumptions used in calculation spreadsheet "Pipe Insulation Savings 2013-11-12.xlsx"

Zone	Hours
Zone 1 (Rockford)	5,039
Zone 2 (Chicago)	4,963
Zone 3 (Springfield)	4,495
Zone 4 (Belleville/	4,021
Zone 5 (Marion)	4,150
Zone 1 (Rockford)	5,039

Q_{base} = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

Q_{eff} = Heat Loss from Insulated Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000 = conversion factor (1 therm = 100,000 Btu)

ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe

= Actual or if unknown use default values given below:

= 81.9% for water boilers [389]

= 80.7% for steam boilers, except multifamily low-pressure [390]

= 64.8% for multifamily low-pressure steam boilers [391]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [392]

= 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.[393]

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

[389] Average efficiencies of units from the California Energy Commission (CEC).
[390] Ibid.
[391] Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993.
[392] 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.
[393] 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

L_{sp} = Length of straight pipe to be insulated (linear foot)

= actual installed ((linear foot)

$L_{oc,I}$ = Total equivalent length of the other components (valves and tees) of pipe to be insulated

= Actual installed (linear foot). See table "Equivalent Length of Other Components – Elbows and Tees" for equivalent lengths.

The heat loss estimates (Q_{base} and Q_{eff}) were developed using the 3E Plus v4.0 software program.[394] The energy savings analysis is based on adding 1-inch (indoor) or 2-inch (outdoor) thick insulation around bare pipe. The thermal conductivity of pipe insulation varies by material and temperature rating; to obtain a typical value, a range of materials allowed for this measure were averaged. For insulation materials not in the table below, use 3E Plusv4.0 software to calculate Q_{base} and $Q_{eff.}$

Insulation Type	Conductivity (Btu.in / hr.ft^2.ºF @ 75F)	Max temp (ºF)
Polyethylene foam	0.25	200
Flexible polyurethane-based foam	0.27	200
Fiberglass	0.31	250
Melamine foam	0.26	350
Flexible silicon foam	0.40	392
Calcium silicate	0.40	1200
Cellular glass	0.31	400
Average conductivity of all these materials (Btu.in / hr.ft^2.ºF @ 75ºF)	0.31	

The pipe fluid temperature assumption used depends upon both the system type and whether there is outdoor reset controls:

System Type	Fluid temperature assumption (°F)
Hot Water space heating with outdoor reset - Non recirculation	145
Hot Water space heating without outdoor reset - Non recirculation	170
Hot Water space heating with outdoor reset – Recirculation heating season only	145
Hot Water space heating without outdoor reset – Recirculation heating season only	170
Hot Water space heating with outdoor reset – Recirculation year round	130
Hot Water space heating without outdoor reset – Recirculation year round	170
Domestic Hot Water	125
Low Pressure Steam	225
High Pressure Steam	312

394 3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association).

	Indoor Insulation, Hot Water	Indoor Insulation, Low Pressure Steam	Indoor Insulation, High Pressure Steam	Domestic Hot Water	Outdoor Insulation, Hot Water	Outdoor Insulation, Low Pressure Steam	Outdoor Insulation, High Pressure Steam
Insulation thickness (inch)	1	1	1	1	2	2	2
Temperature, Fluid in Pipe (ºF)	170 (w/o reset) 145 (w/ reset heat) 130 (w/reset year)	225	312	125	170 (w/o reset) 145 (w/ reset heat) 130 (w/reset year)	225	312
Av. steam pressure (psig)	n/a	10.9	82.8	n/a	n/a	10.9	82.8
Operating Time (hrs/yr)	2,746 (non-recirc) 5,039 (recirc heating season) 8,760 (recirc year round)						
Ambient Temperature (ºF)[395]	75	75	75	75	48.6	48.6	48.6
Wind speed (mph)[396]	0	0	0	0	9.4	9.4	9.4
Pipe parameters							
Pipe material	Copper	Steel	Steel	Copper	Copper	Steel	Steel
Pipe size for Heat Loss Calc	2”	2”	2”	2”	2”	2”	2”
Outer Diameter, Pipe, actual	2.38”	2.38”	2.38”	2.38”	2.38”	2.38”	2.38”
Heat Loss, Bare Pipe (from 3EPlus) (Btu/hr.ft)	114 (w/o reset) 78 (w/ reset heat) 58 (w/reset year)	232	432	52	460 (w/o reset) 363 (w/ reset heat) 306 (w/reset year)	710	1101
Insulation parameters							
Outer diameter, insulation	4.38”	4.38”	4.38”	4.38”	4.38”	4.38”	4.38”
Average Heat Loss, Insulation (from 3EPlus) (Btu/hr.ft)	24 (w/o reset) 17 (w/ reset heat) 13 (w/reset year)	40	70	13.25	21 (w/o reset) 16 (w/ reset heat) 13 (w/reset year)	32	52
Annual Energy Savings							
Boiler / Water Heater efficiency	81.9%	80.7% (64.8% for MF)	80.7%	67%	81.9%	80.7% (64.8% for MF)	80.7%
Annual Gas Use, Base Case (therms/yr/ft)	3.8 (w/o reset) 4.8 (w/ reset heat) 6.2 (w/reset year)	7.9 (non recirc) 14.5 (recirc heat) 25.2 (recirc year)	14.7 (non recirc) 27.0 (recirc heat) 46.9 (recirc year)	6.76	15.4 (w/o reset) 22.5 (w/ reset heat) 32.7 (w/reset year)	24.1 (non recirc) 44.3 (recirc heat) 77.0 (recirc year)	37.5 (non recirc) 68.7 (recirc heat) 119.5 (recirc year)
Annual Gas Use, Measure case (therms/yr/ft)	0.8 (w/o reset) 1.1 (w/ reset heat) 1.4 (w/reset year)	1.4 (non recirc) 2.5 (recirc heat) 4.4 (recirc year)	2.4 (non recirc) 4.4 (recirc heat) 7.6 (recirc year)	1.73	0.7 (w/o reset) 1.0 (w/ reset heat) 1.4 (w/reset year)	1.1 (non recirc) 2.0 (recirc heat) 3.4 (recirc year)	1.8 (non recirc) 3.2 (recirc heat) 5.6 (recirc year)
Annual Gas Savings (therms/yr/ft)	3.0 (w/o reset) 3.7 (w/ reset heat) 4.8 (w/reset year)	6.5 (non recirc) 12.0 (recirc heat) 20.8 (recirc year)	12.3 (non recirc) 22.6 (recirc heat) 39.3 (recirc year)	5.0	14.7 (w/o reset) 21.4 (w/ reset heat) 31.3 (w/reset year)	23.1 (non recirc) 42.3 (recirc heat) 73.6 (recirc year)	35.7 (non recirc) 65.5 (recirc heat) 113.9 (recirc year)

Heat = heating season only, year = year round

[395] DOE Weather Data, TMY3 (Typical Meteorological Year), developed by NREL for the average ambient temperature for Aurora, IL. Ibid.
[396] Ibid.

Values below must be multiplied by the appropriate Thermal Regain Factor (TRF). All variables were the same except for hours of operation in the calculation of the default savings per foot for the various building types and applications as presented in the table below:

Savings Summary for Indoor pipe insulation by System Type and Building Type (Δtherms per foot) (continues for 3.5 pages)

			Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
Location	System Type	Building Type	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Indoor	Hot Water Space Heating with outdoor reset – non-recirculation	Assembly	1.32	1.36	1.21	0.81	1.24
		Assisted Living	1.25	1.22	1.07	0.79	0.95
		College	1.13	1.06	0.95	0.53	0.63
		Convenience Store	1.10	1.01	0.90	0.65	0.72
		Elementary School	1.32	1.29	1.13	0.78	0.95
		Garage	0.73	0.72	0.63	0.50	0.56
		Grocery	1.19	1.19	1.04	0.65	0.78
		Healthcare Clinic	1.17	1.20	1.05	0.71	0.75
		High School	1.37	1.38	1.23	0.88	1.03
		Hospital - CAV no econ	1.31	1.35	1.15	0.99	1.12
		Hospital - CAV econ	1.33	1.37	1.17	1.01	1.15
		Hospital - VAV econ	0.54	0.51	0.39	0.23	0.25
		Hospital - FCU	0.98	1.12	0.91	1.07	1.44
		Hotel/Motel	1.31	1.27	1.14	0.78	0.96
		Hotel/Motel - Common	1.19	1.21	1.15	0.93	0.98
		Hotel/Motel - Guest	1.30	1.26	1.13	0.75	0.93
		Manufacturing Facility	0.78	0.75	0.70	0.42	0.47
		MF - High Rise	1.13	1.12	1.02	0.87	0.87
		MF - High Rise - Common	1.35	1.31	1.17	0.81	1.04
		MF - High Rise - Residential	1.09	1.08	0.99	0.85	0.83
		MF - Mid Rise	1.23	1.25	1.07	0.79	0.90
		Movie Theater	1.35	1.33	1.24	0.94	1.12
		Office - High Rise - CAV no econ	1.50	1.52	1.38	0.93	1.01
		Office - High Rise - CAV econ	1.55	1.58	1.45	1.00	1.10
		Office - High Rise - VAV econ	1.13	1.15	0.95	0.56	0.63
		Office - High Rise - FCU	0.83	0.82	0.71	0.37	0.39
		Office - Low Rise	1.06	1.06	0.84	0.51	0.59
		Office - Mid Rise	1.17	1.18	0.99	0.63	0.70
		Religious Building	1.19	1.11	1.07	0.78	0.89
		Restaurant	1.00	1.00	0.90	0.68	0.81
		Retail - Department Store	1.03	0.95	0.89	0.58	0.66
		Retail - Strip Mall	0.99	0.91	0.81	0.56	0.60
		Warehouse	1.08	1.01	1.04	0.65	0.80
		Unknown	1.15	1.14	1.01	0.73	0.84
	Hot Water Space Heating without outdoor reset – non-recirculation	Assembly	1.96	2.00	1.79	1.19	1.83
		Assisted Living	1.84	1.80	1.58	1.16	1.40
		College	1.67	1.56	1.40	0.78	0.93
		Convenience Store	1.62	1.50	1.33	0.95	1.06
		Elementary School	1.95	1.90	1.68	1.16	1.40
		Garage	1.08	1.06	0.93	0.74	0.82

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Grocery	1.76	1.75	1.54	0.96	1.15
		Healthcare Clinic	1.73	1.77	1.55	1.05	1.11
		High School	2.02	2.03	1.82	1.30	1.52
		Hospital - CAV no econ	1.93	1.99	1.69	1.46	1.65
		Hospital - CAV econ	1.96	2.03	1.73	1.50	1.70
		Hospital - VAV econ	0.80	0.76	0.57	0.34	0.37
		Hospital - FCU	1.45	1.65	1.35	1.58	2.13
		Hotel/Motel	1.93	1.87	1.69	1.16	1.41
		Hotel/Motel - Common	1.75	1.78	1.69	1.38	1.45
		Hotel/Motel - Guest	1.92	1.86	1.66	1.11	1.37
		Manufacturing Facility	1.15	1.11	1.03	0.62	0.69
		MF - High Rise	1.67	1.65	1.50	1.28	1.28
		MF - High Rise - Common	1.99	1.93	1.73	1.19	1.54
		MF - High Rise - Residential	1.61	1.60	1.46	1.26	1.23
		MF - Mid Rise	1.82	1.84	1.59	1.17	1.33
		Movie Theater	1.99	1.96	1.83	1.39	1.66
		Office - High Rise - CAV no econ	2.21	2.24	2.04	1.37	1.49
		Office - High Rise - CAV econ	2.29	2.33	2.14	1.48	1.63
		Office - High Rise - VAV econ	1.67	1.70	1.40	0.83	0.93
		Office - High Rise - FCU	1.22	1.21	1.04	0.55	0.58
		Office - Low Rise	1.56	1.56	1.24	0.76	0.87
		Office - Mid Rise	1.73	1.74	1.47	0.94	1.04
		Religious Building	1.75	1.65	1.58	1.15	1.32
		Restaurant	1.48	1.48	1.33	1.01	1.19
		Retail - Department Store	1.52	1.40	1.31	0.85	0.97
		Retail - Strip Mall	1.46	1.35	1.19	0.82	0.89
		Warehouse	1.59	1.49	1.53	0.96	1.18
		Unknown	1.70	1.68	1.50	1.07	1.25
	Hot Water with outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	3.73	3.68	3.33	2.98	3.08
	Hot Water w/o outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	5.51	5.43	4.92	4.40	4.54
	Hot Water with outdoor reset	All buildings, Recirculation year round (All hours)	4.79	4.79	4.79	4.79	4.79
	Hot Water w/o outdoor reset	All buildings, Recirculation year round (All hours)	9.58	9.58	9.58	9.58	9.58
	Domestic Hot Water	DHW circulation loop	5.02	5.02	5.02	5.02	5.02
	LP Steam – non-recirculation	Assembly	4.25	4.36	3.89	2.59	3.97
		Assisted Living	4.01	3.92	3.44	2.53	3.04
		College	3.64	3.40	3.04	1.69	2.02
		Convenience Store	3.52	3.26	2.89	2.07	2.32
		Elementary School	4.24	4.13	3.64	2.52	3.05
		Garage	2.34	2.31	2.03	1.62	1.79
		Grocery	3.83	3.81	3.34	2.08	2.49
		Healthcare Clinic	3.76	3.85	3.36	2.29	2.42

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		High School	4.39	4.42	3.96	2.82	3.30
		Hospital - CAV no econ	4.20	4.33	3.69	3.17	3.60
		Hospital - CAV econ	4.25	4.41	3.76	3.26	3.70
		Hospital - VAV econ	1.74	1.65	1.24	0.75	0.81
		Hospital - FCU	3.15	3.60	2.93	3.44	4.63
		Hotel/Motel	4.19	4.07	3.67	2.51	3.07
		Hotel/Motel - Common	3.81	3.87	3.68	3.00	3.15
		Hotel/Motel - Guest	4.18	4.05	3.62	2.42	2.98
		Manufacturing Facility	2.49	2.41	2.23	1.35	1.51
		MF - High Rise	4.52	4.46	4.07	3.46	3.47
		MF - High Rise - Common	5.38	5.22	4.68	3.23	4.17
		MF - High Rise - Residential	4.37	4.34	3.94	3.41	3.33
		MF - Mid Rise	4.94	4.99	4.30	3.16	3.60
		Movie Theater	4.33	4.26	3.98	3.03	3.61
		Office - High Rise - CAV no econ	4.81	4.88	4.45	2.98	3.24
		Office - High Rise - CAV econ	4.97	5.07	4.66	3.21	3.54
		Office - High Rise - VAV econ	3.64	3.71	3.06	1.81	2.01
		Office - High Rise - FCU	2.66	2.62	2.27	1.20	1.26
		Office - Low Rise	3.40	3.39	2.69	1.65	1.89
		Office - Mid Rise	3.77	3.78	3.19	2.03	2.26
		Religious Building	3.82	3.58	3.43	2.51	2.87
		Restaurant	3.21	3.22	2.89	2.19	2.60
		Retail - Department Store	3.31	3.04	2.86	1.86	2.12
		Retail - Strip Mall	3.17	2.94	2.59	1.79	1.93
		Warehouse	3.46	3.23	3.33	2.08	2.56
		Unknown	3.70	3.66	3.26	2.34	2.71
	LP Steam	All buildings, Recirculation heating season only (Hours below 55F)	11.99	11.81	10.70	9.57	9.88
	LP Steam	All buildings, Recirculation year round (All hours)	20.84	20.84	20.84	20.84	20.84
	HP Steam – non-recirculation	Assembly	8.02	8.22	7.34	4.89	7.49
		Assisted Living	7.56	7.39	6.49	4.77	5.73
		College	6.87	6.42	5.73	3.18	3.81
		Convenience Store	6.65	6.14	5.45	3.91	4.37
		Elementary School	8.00	7.79	6.87	4.75	5.76
		Garage	4.42	4.35	3.82	3.05	3.38
		Grocery	7.22	7.19	6.30	3.93	4.70
		Healthcare Clinic	7.09	7.27	6.35	4.32	4.57
		High School	8.28	8.34	7.48	5.33	6.23
		Hospital - CAV no econ	7.92	8.16	6.95	5.98	6.79
		Hospital - CAV econ	8.03	8.32	7.09	6.14	6.98
		Hospital - VAV econ	3.28	3.12	2.35	1.41	1.53
		Hospital - FCU	5.95	6.79	5.53	6.50	8.73
		Hotel/Motel	7.91	7.69	6.93	4.74	5.79
		Hotel/Motel - Common	7.18	7.30	6.95	5.65	5.94
		Hotel/Motel - Guest	7.89	7.64	6.83	4.57	5.62

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Manufacturing Facility	4.70	4.55	4.22	2.55	2.84
		MF - High Rise	6.85	6.76	6.16	5.25	5.26
		MF - High Rise - Common	8.15	7.91	7.09	4.89	6.31
		MF - High Rise - Residential	6.62	6.57	5.97	5.17	5.04
		MF - Mid Rise	7.48	7.57	6.51	4.79	5.46
		Movie Theater	8.16	8.04	7.52	5.71	6.80
		Office - High Rise - CAV no econ	9.07	9.20	8.39	5.62	6.12
		Office - High Rise - CAV econ	9.38	9.57	8.80	6.06	6.67
		Office - High Rise - VAV econ	6.86	6.99	5.76	3.41	3.80
		Office - High Rise - FCU	5.02	4.95	4.27	2.27	2.38
		Office - Low Rise	6.41	6.40	5.08	3.11	3.56
		Office - Mid Rise	7.12	7.12	6.03	3.84	4.27
		Religious Building	7.20	6.75	6.46	4.73	5.41
		Restaurant	6.06	6.08	5.46	4.13	4.90
		Retail - Department Store	6.25	5.74	5.39	3.51	4.00
		Retail - Strip Mall	5.98	5.54	4.89	3.37	3.63
		Warehouse	6.53	6.09	6.29	3.93	4.84
		Unknown	6.97	6.91	6.14	4.41	5.11
	HP Steam	All buildings, Recirculation heating season only (Hours below 55F)	22.62	22.28	20.18	18.05	18.63
	HP Steam	All buildings, Recirculation year round (All hours)	39.32	39.32	39.32	39.32	39.32

Savings Summary for Outdoor pipe insulation by System Type and Building Type (Δtherms per foot) (continues for 3.5 pages)

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Outdoor	Hot Water Space Heating with outdoor reset – non-recirculation	Assembly	7.58	7.77	6.94	4.62	7.08
		Assisted Living	7.14	6.98	6.13	4.51	5.42
		College	6.49	6.07	5.41	3.01	3.60
		Convenience Store	6.28	5.80	5.15	3.70	4.13
		Elementary School	7.56	7.36	6.50	4.49	5.44
		Garage	4.18	4.11	3.61	2.88	3.19
		Grocery	6.82	6.80	5.96	3.72	4.44
		Healthcare Clinic	6.70	6.87	6.00	4.09	4.32
		High School	7.83	7.88	7.07	5.03	5.89
		Hospital - CAV no econ	7.49	7.71	6.57	5.65	6.41
		Hospital - CAV econ	7.59	7.86	6.70	5.81	6.60
		Hospital - VAV econ	3.10	2.95	2.22	1.33	1.44
		Hospital - FCU	5.62	6.42	5.23	6.14	8.26
		Hotel/Motel	7.47	7.26	6.55	4.48	5.47
		Hotel/Motel - Common	6.79	6.90	6.57	5.34	5.61
		Hotel/Motel - Guest	7.46	7.22	6.45	4.32	5.31

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Manufacturing Facility	4.45	4.30	3.98	2.41	2.69
		MF - High Rise	6.48	6.39	5.83	4.96	4.97
		MF - High Rise - Common	7.70	7.48	6.70	4.62	5.96
		MF - High Rise - Residential	6.26	6.21	5.64	4.89	4.77
		MF - Mid Rise	7.07	7.15	6.15	4.53	5.16
		Movie Theater	7.71	7.60	7.10	5.40	6.43
		Office - High Rise - CAV no econ	8.57	8.70	7.93	5.31	5.78
		Office - High Rise - CAV econ	8.86	9.04	8.32	5.73	6.31
		Office - High Rise - VAV econ	6.48	6.61	5.45	3.22	3.59
		Office - High Rise - FCU	4.75	4.67	4.04	2.14	2.25
		Office - Low Rise	6.06	6.05	4.80	2.94	3.36
		Office - Mid Rise	6.73	6.73	5.70	3.63	4.03
		Religious Building	6.80	6.38	6.11	4.47	5.11
		Restaurant	5.73	5.75	5.16	3.90	4.63
		Retail - Department Store	5.91	5.42	5.09	3.31	3.78
		Retail - Strip Mall	5.65	5.23	4.62	3.19	3.44
		Warehouse	6.18	5.76	5.94	3.71	4.57
		Unknown	6.59	6.53	5.81	4.17	4.83
	Hot Water Space Heating without outdoor reset – non-recirculation	Assembly	9.59	9.83	8.77	5.85	8.96
		Assisted Living	9.04	8.83	7.76	5.70	6.86
		College	8.21	7.68	6.85	3.80	4.56
		Convenience Store	7.95	7.34	6.52	4.68	5.22
		Elementary School	9.56	9.32	8.22	5.68	6.89
		Garage	5.28	5.20	4.57	3.65	4.04
		Grocery	8.63	8.60	7.54	4.70	5.62
		Healthcare Clinic	8.47	8.70	7.59	5.17	5.47
		High School	9.90	9.97	8.94	6.37	7.45
		Hospital - CAV no econ	9.47	9.76	8.31	7.15	8.11
		Hospital - CAV econ	9.60	9.95	8.48	7.35	8.34
		Hospital - VAV econ	3.93	3.73	2.80	1.68	1.82
		Hospital - FCU	7.11	8.12	6.61	7.77	10.45
		Hotel/Motel	9.45	9.19	8.29	5.67	6.92
		Hotel/Motel - Common	8.59	8.73	8.31	6.76	7.10
		Hotel/Motel - Guest	9.44	9.13	8.16	5.47	6.72
		Manufacturing Facility	5.63	5.44	5.04	3.05	3.40
		MF - High Rise	8.19	8.08	7.37	6.27	6.29
		MF - High Rise - Common	9.74	9.46	8.48	5.85	7.54
		MF - High Rise - Residential	7.92	7.86	7.14	6.18	6.03
		MF - Mid Rise	8.94	9.05	7.78	5.73	6.53
		Movie Theater	9.76	9.61	8.99	6.83	8.14
		Office - High Rise - CAV no econ	10.84	11.01	10.03	6.72	7.32
		Office - High Rise - CAV econ	11.21	11.44	10.52	7.25	7.98
		Office - High Rise - VAV econ	8.20	8.36	6.89	4.07	4.54
		Office - High Rise - FCU	6.00	5.91	5.11	2.71	2.84
		Office - Low Rise	7.67	7.65	6.08	3.72	4.25
		Office - Mid Rise	8.51	8.52	7.21	4.59	5.10

			Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam)				
Location	System Type	Building Type	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Religious Building	8.61	8.07	7.73	5.66	6.47
		Restaurant	7.25	7.27	6.53	4.94	5.85
		Retail - Department Store	7.47	6.86	6.44	4.19	4.78
		Retail - Strip Mall	7.15	6.62	5.85	4.03	4.35
		Warehouse	7.81	7.29	7.52	4.69	5.78
		Unknown	8.34	8.26	7.35	5.27	6.11
	Hot Water with outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	21.38	21.06	19.07	17.06	17.61
	Hot Water without outdoor reset	All buildings, Recirculation heating season only (Hours below 55F)	27.05	26.64	24.13	21.58	22.28
	Hot Water with outdoor reset	All buildings, Recirculation year round (All hours)	31.30	31.30	31.30	31.30	31.30
	Hot Water without outdoor reset	All buildings, Recirculation year round (All hours)	47.02	47.02	47.02	47.02	47.02
	LP Steam – non-recirculation	Assembly	15.01	15.38	13.73	9.15	14.02
		Assisted Living	14.14	13.82	12.15	8.93	10.73
		College	12.85	12.01	10.72	5.95	7.13
		Convenience Store	12.44	11.49	10.20	7.32	8.17
		Elementary School	14.96	14.58	12.86	8.88	10.78
		Garage	8.27	8.14	7.15	5.71	6.32
		Grocery	13.51	13.46	11.80	7.36	8.79
		Healthcare Clinic	13.26	13.61	11.88	8.09	8.56
		High School	15.50	15.60	13.99	9.97	11.66
		Hospital - CAV no econ	14.82	15.27	13.01	11.19	12.70
		Hospital - CAV econ	15.02	15.57	13.27	11.50	13.06
		Hospital - VAV econ	6.14	5.84	4.39	2.64	2.85
		Hospital - FCU	11.13	12.71	10.35	12.16	16.35
		Hotel/Motel	14.80	14.38	12.97	8.87	10.84
		Hotel/Motel - Common	13.45	13.66	13.00	10.58	11.12
		Hotel/Motel - Guest	14.77	14.29	12.78	8.56	10.52
		Manufacturing Facility	8.80	8.51	7.89	4.77	5.32
		MF - High Rise	15.97	15.76	14.37	12.23	12.26
		MF - High Rise - Common	18.99	18.44	16.53	11.39	14.71
		MF - High Rise - Residential	15.43	15.31	13.92	12.05	11.75
		MF - Mid Rise	17.43	17.63	15.17	11.16	12.72
		Movie Theater	15.27	15.05	14.07	10.69	12.73
		Office - High Rise - CAV no econ	16.97	17.22	15.70	10.51	11.45
		Office - High Rise - CAV econ	17.55	17.91	16.47	11.35	12.49
		Office - High Rise - VAV econ	12.83	13.09	10.79	6.37	7.11
		Office - High Rise - FCU	9.40	9.26	8.00	4.25	4.45
		Office - Low Rise	12.00	11.97	9.51	5.82	6.66
		Office - Mid Rise	13.32	13.33	11.28	7.18	7.98
		Religious Building	13.47	12.64	12.10	8.86	10.13
		Restaurant	11.34	11.38	10.21	7.73	9.16
		Retail - Department Store	11.69	10.74	10.08	6.56	7.48
		Retail - Strip Mall	11.19	10.36	9.15	6.31	6.80
		Warehouse	12.23	11.40	11.77	7.35	9.05

Location	System Type	Building Type	Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
		Unknown	13.05	12.93	11.50	8.25	9.57
	LP Steam	All buildings, Recirculation heating season only (Hours below 55F)	42.33	41.69	37.76	33.78	34.86
	LP Steam	All buildings, Recirculation year round (All hours)	73.59	73.59	73.59	73.59	73.59
	HP Steam – non-recirculation	Assembly	23.24	23.81	21.26	14.16	21.70
		Assisted Living	21.89	21.40	18.80	13.82	16.61
		College	19.90	18.60	16.60	9.22	11.04
		Convenience Store	19.26	17.79	15.79	11.33	12.65
		Elementary School	23.16	22.57	19.91	13.75	16.69
		Garage	12.80	12.60	11.08	8.84	9.78
		Grocery	20.91	20.83	18.26	11.39	13.61
		Healthcare Clinic	20.53	21.07	18.39	12.53	13.25
		High School	23.99	24.15	21.66	15.43	18.05
		Hospital - CAV no econ	22.94	23.64	20.14	17.32	19.66
		Hospital - CAV econ	23.25	24.10	20.54	17.80	20.22
		Hospital - VAV econ	9.51	9.03	6.79	4.08	4.42
		Hospital - FCU	17.24	19.67	16.02	18.82	25.31
		Hotel/Motel	22.90	22.27	20.08	13.74	16.77
		Hotel/Motel - Common	20.81	21.15	20.13	16.38	17.21
		Hotel/Motel - Guest	22.87	22.13	19.78	13.24	16.28
		Manufacturing Facility	13.63	13.18	12.21	7.38	8.24
		MF - High Rise	19.85	19.59	17.86	15.20	15.24
		MF - High Rise - Common	23.60	22.92	20.55	14.16	18.28
		MF - High Rise - Residential	19.18	19.03	17.30	14.98	14.61
		MF - Mid Rise	21.67	21.92	18.86	13.87	15.81
		Movie Theater	23.64	23.29	21.78	16.55	19.71
		Office - High Rise - CAV no econ	26.27	26.66	24.30	16.28	17.73
		Office - High Rise - CAV econ	27.16	27.72	25.49	17.57	19.33
		Office - High Rise - VAV econ	19.87	20.26	16.70	9.87	11.00
		Office - High Rise - FCU	14.54	14.33	12.38	6.57	6.89
		Office - Low Rise	18.58	18.53	14.72	9.00	10.31
		Office - Mid Rise	20.61	20.64	17.46	11.12	12.36
		Religious Building	20.85	19.56	18.72	13.71	15.67
		Restaurant	17.55	17.61	15.81	11.96	14.18
		Retail - Department Store	18.10	16.63	15.61	10.16	11.58
		Retail - Strip Mall	17.32	16.04	14.17	9.77	10.53
		Warehouse	18.93	17.65	18.21	11.37	14.02
		Unknown	20.20	20.01	17.80	12.77	14.81
	HP Steam	All buildings, Recirculation heating season only (Hours below 55F)	65.53	64.54	58.45	52.29	53.97
	HP Steam	All buildings, Recirculation year round (All hours)	113.92	113.92	113.92	113.92	113.92

For insulation covering elbows and tees that connect straight pipe, a calculated surface area will be assumed based on the dimensions for fittings given by ANSI/ASME B36.19. The surface area is then converted to an equivalent length of pipe that must be added to the total length of straight pipe in order to calculate total savings. Equivalent pipe lengths are given in 1” increments in pipe diameter for simplicity. In the case of pipe diameters in between full inch diameters, the closest equivalent length should be used. The larger pipe sizes mostly apply to steam header piping, which has the most heat loss per foot.

Calculated Surface Areas of Elbows and Tees

Nominal Pipe Diameter	Calculated Surface Area (ft)	
	90 Degree Elbow[397]	Straight Tee[398]
1”	0.10	0.13
2”	0.41	0.39
3”	0.93	0.77
4”	1.64	1.21
5”	2.57	1.77
6”	3.70	2.44
8”	6.58	3.95
10”	10.28	5.98
12”	14.80	8.34

Equivalent Length of Other Components – Elbows and Tees (L_{oc})

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90 Degree Elbow	Straight Tee
1”	0.30	0.38
2”	0.66	0.63
3”	1.01	0.84
4”	1.40	1.03
5”	1.76	1.22
6”	2.13	1.41
8”	2.91	1.75
10”	3.65	2.13
12”	4.44	2.50

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2” pipes. For 1” pipes, which weren’t included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1” or 2” straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

Calculated Surface Areas of Flanges and Valves

Valves				
Class (psi)	150	300	600	900
NPS (in)	ft^2	ft^2	ft^2	ft^2
1	0.69	1.8	1.8	2.4
2	2.21	2.94	2.94	5.2
2.5	2.97	3.51	3.91	6.6
3	3.37	4.39	4.69	6.5
4	4.68	6.06	7.64	9.37
6	7.03	9.71	13.03	15.8
8	10.3	13.5	18.4	23.8

Flanges				
Class (psi)	150	300	600	900
NPS (in)	ft^2	ft^2	ft^2	ft^2
1	0.36	0.36	0.4	1.23
2	0.71	0.84	0.88	1.54
3	1.06	1.32	1.36	1.85
4	1.44	1.83	2.23	2.64
6	2.04	2.72	3.6	4.37
8	2.92	3.74	4.89	6.4

[397] Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19
[398] Based on the center to face and diameter dimensions given by ANSI/ASME B36.19

Valves				
Class (psi)	150	300	600	900
NPS (in)	ft^2	ft^2	ft^2	ft^2
10	13.8	18	26.5	32.1
12	16.1	24.1	31.9	41.9

Flanges				
Class (psi)	150	300	600	900
NPS (in)	ft^2	ft^2	ft^2	ft^2
10	3.68	4.8	6.93	8.47
12	5.01	6.34	7.97	10.43

Equivalent Length of Other Components - Flanges and Valves (L_{oc})

ANSI Class (psi)	Equivalent Length of Other Components (ft)			
	1" Valve	1" Flange	2" Valve	2" Flange
150	2.00	1.04	3.56	1.14
300	5.22	1.04	4.73	1.35
600	5.22	1.16	4.73	1.42
900	6.96	3.57	8.37	2.48
ANSI Class (psi)	3" Valve	3" Flange	4" Valve	4" Flange
150	3.67	1.16	3.98	1.22
300	4.79	1.44	5.15	1.56
600	5.11	1.48	6.49	1.90
900	7.09	2.02	7.96	2.24

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PINS-V05-190101

REVIEW DEADLINE: 1/1/2023

4.4.15 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 efficiency requirements can significantly reduce energy consumption. 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, EREP. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively-cooled air conditioner that exceeds the energy efficiency requirements as prescribed by the program.

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 Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

For Early Replacement programs, use the actual efficiency of the existing unit or assume IECC code base in place at the original time of existing unit installation. To qualify under the early replacement characterization, baseline equipment must meet these additional qualifications:

- The existing unit is operational when replaced or the existing unit would be operational with minor repairs[399].

Note: IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.
Note: new Federal Standards become effective January 1, 2023

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[400]

For early replacement, the remaining life of existing equipment is assumed to be 5 years[401].

DEEMED MEASURE COST

The incremental capital cost for this measure is based upon capacity and efficiency level (defined be CEE specifications[402]), as outlined in the following table:[403]

[399] Based on ComEd Small Business Trade Ally feedback. For units rated at less than 20 ton units, the cost of common repairs is under $2,000, significantly less than the cost of purchasing new equipment. Therefore, if the cost of repair is less than $2,000, it can be considered early replacement because customers would repair instead of replace a failed unit. Repair cost data was not available for units larger than 20 tons.
[400] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[401] Assumed to be one third of effective useful life
[402] CEE Commercial Unitary Air-conditioning and Heat Pumps Specification, which provides high efficiency performance specifications for single-package and split system unitary air conditioners.
[403] NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

Capacity	Incremental cost ($/ton)	
	Up to and including CEE Tier 1 units	CEE Tier 2 and above
< 135,000 Btu/hr	$63	$127
135,000 Btu/hr to > 250,000 Btu/hr	$63	$127
250,000 Btu/hr and greater	$19	$38

For early replacement the full cost of the installed unit should be used. If unknown use defaults below. The assumed deferred cost (after 5 years) of replacing existing equipment with a new baseline unit is also provided. This future cost should be discounted to present value using the real discount rate:

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 C03 - Commercial Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [404]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [405]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of Sale:

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

ΔkWH = (kBtu/hr) * [(1/SEERbase) – (1/SEERee)] * EFLH

For units with cooling capacities equal to or greater than 65 kBtu/hr:

ΔkWH = (kBtu/hr) * [(1/IEERbase) – (1/IEERee)] * EFLH

---

404 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

405 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

Early replacement[406]:

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

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

ΔkWH = (kBtu/hr) * [(1/SEERexist) – (1/SEERee)] * EFLH

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) * [(1/SEERbase) – (1/SEERee)] * EFLH

For units with cooling capacities equal to or greater than 65 kBtu/hr:

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

ΔkWH = (kBtu/hr) * [(1/IEERexist) – (1/IEERee)] * EFLH

NOTE: If the existing equipment age is such that IEER ratings are not available, EER may be substitued when necessary. In such instances both existing and efficient unit efficiencies should be specified in EER.

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) * [(1/IEERbase) – (1/IEERee)] * EFLH

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr)

SEERbase = Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER values from tables below, based on applicable Code on date of equipment purchase (if unknown assume current Code).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed)

SEERexist = Seasonal Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

IEERbase = Integrated Energy Efficiency Ratio of the baseline equipment. See table below based on applicable Code on date of equipment purchase (if unknown assume current Code).

IEERee = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed)

IEERexist = Integrated Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

[406] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

Code of Federal Redulations (baseline effective 1/1/2019):

Equipment type	Cooling capacity	Heating type	Efficiency level	Compliance date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.9	1/1/2018
		All Other Types of Heating	IEER = 12.7	1/1/2018
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.4	1/1/2018
		All Other Types of Heating	IEER = 12.2	1/1/2018
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6	1/1/2018
		All Other Types of Heating	IEER = 11.4	1/1/2018
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER = 13.0	6/16/2008
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER = 14.0	1/1/2017

2012 IECC Minimum Efficiency Requirements (baseline effective 1/1/2013)

TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, air cooled	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	13.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h[b]	All	Split System	10.0 SEER	10.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 10.1 IEER	
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 9.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 9.8 IEER	
		All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 9.6 IEER	
Air conditioners, water cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.5 EER 12.7 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	12.3 EER 12.5 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.4 EER 12.6 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 12.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.0 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.0 EER 12.2 IEER	

(continued)

TABLE C403.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, evaporatively cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.1 IEER	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER	10.5 EER 14.0 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

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

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

2015 IECC Minimum Efficiency Requirements (baseline effective 1/1/2016)

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 1/1/2016	As of 1/1/2016	
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	14.0 SEER[c]	
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	11.0 SEER	11.0 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 12.8 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.6 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 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 12.2 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 11.6 IEER	
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 11.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 11.2 IEER	
		All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 11.0 IEER	
Air conditioners, water cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	11.9 EER 13.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 12.5 IEER	12.5 EER 13.9 IEER	
		All other	Split System and Single Package	12.3 EER 12.5 IEER	12.3 EER 13.7 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 12.6 IEER	12.4 EER 13.6 IEER	
		All other	Split System and Single Package	12.2 EER 12.4 IEER	12.2 EER 13.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.2 EER 12.4 IEER	12.2 EER 13.5 IEER	
		All other	Split System and Single Package	12.0 EER 12.2 IEER	12.0 EER 13.3 IEER	

(continued)

2018 IECC Minimum Efficiency Requirements (baseline effective 3/1/2019 for New Construction measures)

TABLE C403.3.2(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]
Air conditioners, air cooled	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system	12.0 SEER	
			Single Package	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h[b]	All	Split System	11.0 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 12.8 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 12.6 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 12.2 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER	
		All other	Split System and Single Package	9.8 EER 11.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER	
		All other	Split System and Single Package	9.5 EER 11.0 IEER	
Air conditioners, water cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	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	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 13.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 13.9 IEER	
		All other	Split System and Single Package	12.3 EER 13.7 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 13.6 IEER	
		All other	Split System and Single Package	12.2 EER 13.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.2 EER 13.5 IEER	
		All other	Split System and Single Package	12.0 EER 13.3 IEER	

Air conditioners, evaporatively cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	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	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	11.7 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h	—	—	10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h	—	—	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h	—	—	13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

For example a 5 ton air cooled split system with a SEER of 15 at a retail strip mall in Rockford would save:

ΔkWH = (60) * [(1/13) – (1/15)] * 950

= 585 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

ΔkW = (kBtu/hr * (1/EERbase - 1/EERee)) * CF

Early Replacement:

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

ΔkW = (kBtu/hr) * [(1/EERexist) – (1/EERee)] * CF

For remaining measure life (next 10 years):

ΔkW = (kBtu/hr) * [(1/EERbase) – (1/EERee)] * CF

Where:

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER values from tables above, based on applicable Code on date of equipment purchase (if unknown assume current Code). (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[407] $EER = (-0.02 * SEER^2) + (1.12 * SEER)$)

EERee = Energy Efficiency Ratio of the energy efficient equipment. If the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above).

= Actual installed

EERexist = Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [408]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [409]

For example, a 5 ton air cooled split system with a SEER of 15 in Rockford would save:

ΔkW_{SSP} = (60) * [(1/11.2) – (1/12.3)] * .913

= 0.437 kW

[407] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[408] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[409] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: CI-HVC-SPUA-V06-190101

REVIEW DEADLINE: 1/1/2022

4.4.16 Steam Trap Replacement or Repair

DESCRIPTION

The measure is for the repair or replacement of faulty steam traps that are allowing excess steam to escape and thereby increasing steam generation. The measure is applicable to commercial applications, commercial HVAC (low pressure steam) including multifamily buildings, low pressure industrial applications, medium pressure industrial applications, applications and high pressure industrial applications.

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

Customers must have leaking traps to qualify for rebates. However, if a commercial customer opts to replace all traps without inspection, rebates and the savings are discounted to take into consideration the fact that some traps are being replaced that have not yet failed.

DEFINITION OF BASELINE EQUIPMENT

The baseline criterion is a faulty steam trap in need of replacing. No minimum leak rate is required. Any leaking or blow through trap can be repaired or replaced. If a commercial customer chooses to repair or replace all the steam traps at the facility without verification, the savings are adjusted. Savings for commercial full replacement projects are reduced by the percentage of traps found to be leaking on average from the studies listed. If an audit is performed on a commercial site, then the leaking and blowdown can be adjusted.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 6 years[410]

DEEMED MEASURE COST

Steam System	Cost per trap[411] ($)
Commercial Dry Cleaners	77
Commercial Heating (including Multifamily), low pressure steam	77
Industrial Medium Pressure >15 psig psig < 30 psig	180
Steam Trap, Industrial Medium Pressure ≥30 <75 psig	223
Steam Trap, Industrial High Pressure ≥75 <125 psig	276
Steam Trap, Industrial High Pressure ≥125 <175 psig	322
Steam Trap, Industrial High Pressure ≥175 <250 psig	370
Steam Trap, Industrial High Pressure ≥250 psig	418

LOADSHAPE

N/A

[410]Source paper is the CLEAResult "Steam Traps Revision #1" dated August 2011. Primary studies used to prepare the source paper include Enbridge Steam Trap Survey, KW Engineering Steam Trap Survey, Enbridge Steam Saver Program 2005, Armstrong Steam Trap Survey, DOE Federal Energy Management Program Steam Trap Performance Assessment, Oak Ridge National Laboratory Steam System Survey Guide, KEMA Evaluation of PG&E's Steam Trap Program, Sept. 2007. Communication with vendors suggested a inverted bucket steam trap life typically in the range of 5 - 7 years, float and thermostatic traps 4- 6 years, float and thermodynamic disc traps of 1 - 3 years. Cost does not include installation.

[411] Ibid.

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherm = Sa * (Hv/B) * Hours * L / 100,000

Where:

Sa = Average actual steam loss per leaking trap

= 24.24 x Pia x D^2 x A x FF

Where:

24.24 = Constant lb/(hr-psia-in^2)

Pia = Pig + Patm

= Average steam trap inlet pressure, absolute, psia

Pig = Average steam trap inlet pressure, gauge, psig

Patm = Atmospheric pressure, 14.7 psia

D = Diameter of Orifice, in.

A = Adjustment factor

= 50%,[412] all steam systems. This factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor).

FF = Flow Factor. In addition to the Adjustment factor (A), an additional 50 percent flow factor adjustment is recommended for medium and high pressure steam systems to address industrial float and thermostatic style traps where additional blockage is possible.

Steam System	Average Steam Trap Inlet Pressure psig[413]	Diameter of Orifice in	Adjustment Factor	Flow Factor	Average Actual Steam Loss per Leaking Trap (lb/hr/trap)
Commercial Dry Cleaners	-	-	50%	100%	19.1

[412] Enbridge adjustment factor used as referenced in CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012 and DOE Federal Energy Management Program Steam Trap Performance Assessment.

[413] Medium and high pressure steam trap inlet pressure based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

Steam System	Average Steam Trap Inlet Pressure psig[413]	Diameter of Orifice in	Adjustment Factor	Flow Factor	Average Actual Steam Loss per Leaking Trap (lb/hr/trap)
Commercial Heating (including Multifamily) LPS	-	-	50%	100%	6.9
Industrial or Process Low Pressure, <15 psig	-	-	50%	100%	6.9
Medium Pressure >15 psig < 30 psig	16	0.1875	50%	50%	6.5
Medium Pressure ≥30 <75 psig	47	0.2500	50%	50%	23.4
High Pressure ≥75 <125 psig	101	0.2500	50%	50%	43.8
High Pressure ≥125 <175 psig	146	0.2500	50%	50%	60.9
High Pressure ≥175 <250 psig	202	0.2500	50%	50%	82.1
High Pressure ≥250 ≤300 psig	263	0.2500	50%	50%	105.2
High Pressure > 300 psig	Custom	Custom	50%	50%	Calculated

Hv = Heat of vaporization of steam

Steam System	Average Inlet Pressure psig	Heat of Vaporization[414] (Btu/lb)
Commercial Dry Cleaners	--	890
Commercial Heating (including Multifamily) LPS	--	951
Industrial and Process Low Pressure ≤15 psig	--	951
Medium Pressure >15 psig < 30 psig	16	944
Medium Pressure ≥30 <75 psig	47	915
High Pressure ≥75 <125 psig	101	880
High Pressure ≥125 <175 psig	146	859
High Pressure ≥175 <250 psig	202	837
High Pressure ≥250 ≤300 psig	263	816
High Pressure > 300 psig	--	Custom

B = Boiler efficiency

= custom, if unknown:

= 80.7% for steam boilers, except multifamily low-pressure [415]

= 64.8% for multifamily low-pressure steam boilers [416]

Hours = Annual operating hours of steam plant

= custom, if unknown:

[414] Heat of vaporization of steam at the inlet pressure to the steam trap. Implicit assumption that the average boiler nominal pressure where the vaporization occurs, is essentially that same pressure. Referenced in CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012.

[415] Ibid.

[416] Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.

Steam System	Zone (where applicable)	Hours/Yr[417]
Commercial Dry Cleaners	All Climate Zones	2,425
Industrial and Process Low Pressure ≤15 psig		8,282
Medium Pressure >15 psig < 30 psig		8,282
Medium Pressure ≥30 <75 psig		8,282
High Pressure ≥75 <125 psig		8,282
High Pressure ≥125 <175 psig		8,282
High Pressure ≥175 <250 psig		8,282
High Pressure ≥250 psig		8,282
Commercial Heating (including Multifamily)LPS[418]	1 (Rockford)	4,272
	2 (Chicago O'Hare)	4,029
	3 (Springfield)	3,406
	4 (Belleville)	2,515
	5 (Marion)	2,546

L = Leaking & blow-thru

L is 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, the leaking and blow-thru is applied to reflect the assumed percentage of steam traps that were actually leaking and need to be replaced. A custom value can be utilized if a supported by an evaluation.

Steam System	L (%)[419]
Custom	Custom
Commercial Dry Cleaners	27%
Commercial Heating (including Multifamily) LPS	27%
Industrial and Process Low Pressure ≤15 psig	16%
Medium Pressure >15 psig < 30 psig	16%
Medium Pressure ≥30 <75 psig	16%
High Pressure ≥75 <125 psig	16%
High Pressure ≥125 <175 psig	16%
High Pressure ≥175 <250 psig	16%
High Pressure > 300 psig	16%

EXAMPLE

For example, a commercial dry cleaning facility with the default hours of operation and boiler efficiency;

ΔTherms = Sa * (Hv/B) * Hours * L

= 19.1 lbs/hr/trap * (890 Btu/lb / 80%)/100,000 * 2,425 * 27%

= 138.8 therms per trap

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

---

[417] Medium and high pressure steam trap annual operating hours based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

[418] Since commercial LPS reflect heating systems, Hours/yr are equivalent to HDD55 zone table

[419] Dry cleaners survey data as referenced in CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-STRE-V05-180101

REVIEW DEADLINE: 1/1/2020

4.4.17 Variable Speed Drives for HVAC Pumps and Cooling Tower Fans

Description

This measure is applied to variable speed drives (VSD) which are installed on the following HVAC system applications: chilled water pump, hot water pumps and cooling tower fans. There is a separate measure for HVAC supply and return fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VSD installation in existing cooling towers with 2-speed motors. (IECC 2007 requires 2-speed motors for cooling towers with motors greater than 7.5 HP)
- VSD installation in new cooling towers with motors greater than 7.5 HP

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

Definition of Efficient Equipment

The VSD is applied to a motor which does not have a VSD. This measure is not applicable for replacing failed VSDs. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

Definition of Baseline Equipment

The time of sale baseline is a new motor installed without a VSD 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 VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

Deemed Lifetime of Efficient Equipment

The expected measure life for HVAC application is 15 years;[420] measure life for process is 15 years.[421]

Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs[422] are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

HP	Cost
1 -5 HP	$ 1,330
7.5 HP	$ 1,622
10 HP	$ 1,898
15 HP	$ 2,518

[420] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
[421] DEER 2008
[422] Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied.

HP	Cost
20 HP	$ 3,059

LOADSHAPE

Loadshape C42 - VFD - Boiler feedwater pumps <10 HP

Loadshape C43 - VFD - Chilled water pumps <10 HP

Loadshape C44 - VFD Boiler circulation pumps <10 HP

Loadshape C48 - VFD Boiler draft fans <10 HP

Loadshape C49 - VFD Cooling Tower Fans <10 HP

COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = 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[423]. Custom load factor may be applied if known.

EFFi = Motor efficiency, installed. Actual motor efficiency shall be used to calculate kW. If not known a default value of 93% shall be used.[424]

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type[425]. When available, actual hours should be used.

Building Type	Heating Run Hours	Cooling Run Hours	Model Source
Assembly	4888	2150	eQuest
Assisted Living	4711	4373	eQuest
College	3990	1605	eQuest
Convenience Store	4136	2084	eQuest
Elementary School	5105	3276	eQuest
Garage	4849	2102	eQuest
Grocery	4200	2096	eQuest

[423] 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.

[424] Ohio TRM 8/6/2010 pp207-209, Com Ed TRM June 1, 2010.

[425] Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each building type. "Heating and Cooling Run Hours" are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each building type. This may overclaim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

Building Type	Heating Run Hours	Cooling Run Hours	Model Source
Healthcare Clinic	5481	1987	eQuest
High School	5480	3141	eQuest
Hospital - VAV econ	3718	2788	eQuest
Hospital - CAV econ	7170	2881	eQuest
Hospital - CAV no econ	7139	8760	eQuest
Hospital - FCU	5844	8729	eQuest
Manufacturing Facility	3821	2805	eQuest
MF - High Rise	4522	4237	eQuest
MF - Mid Rise	5749	2899	eQuest
Hotel/Motel - Guest	4480	4479	eQuest
Hotel/Motel - Common	3292	8712	eQuest
Movie Theater	5063	2120	eQuest
Office - High Rise - VAV econ	4094	2038	eQuest
Office - High Rise - CAV econ	5361	4849	eQuest
Office - High Rise - CAV no econ	5331	5682	eQuest
Office - High Rise - FCU	3758	3069	eQuest
Office - Low Rise	3834	2481	eQuest
Office - Mid Rise	6155	3036	OpenStudio
Religious Building	5199	2830	eQuest
Restaurant	4579	3350	eQuest
Retail - Department Store	4249	2528	eQuest
Retail - Strip Mall	4475	2266	eQuest
Warehouse	4606	770	eQuest
Unknown	4649	2718	n/a

The type of hours to apply depends on the VFD application, according to the table below.

Application	Hours Type
Hot Water Pump	Heating
Chilled Water Pump	Cooling
Cooling Tower Fan	Cooling

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

Application	ESF
Hot Water Pump	0.424[426]
Chilled Water Pump	0.411[427]
Cooling Tower Fan	0.126[428]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW =BHP/EFFi * DSF

Where:

[426] Based on the methodology described in the Connecticut TRM, 8th Edition (2013); derived using a temperature BIN analysis of typical heating, cooling and fan load profiles.
[427] Ibid
[428] Based on eQuest model for VSD v one-speed fan, see "CT Savings Factors.xlsx".

DSF = Demand Savings Factor varies by VFD application.[429] Units are kW/HP. Values listed below are based on typical peak load for the listed application.

Application	DSF
Hot Water Pump	0
Chilled Water Pump	0.299
Cooling Tower Fan	0.378

Fossil Fuel Impact Descriptions and Calculation

There are no expected fossil fuel impacts for this measure.

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-HVC-VSDHP-V05-190101

Review Deadline: 1/1/2021

[429] DSF assumptions are based upon the same source as the ESFs.

4.4.18 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses, as 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, it is limited to select building types, including small office, retail – strip mall, restaurants (characterized as 1, 2 or 3 meal), small manufacturing, religious facilities, and convenience stores. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years[430]

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown the capital and labor cost for this measure is assumed to be $181 per thermostat[431]. For the purposes of screening and planning it should be assumed that one thermostat will serve 5 tons of Cooling Capacity at a cost of $36.20 / ton or 115kBtuh of Heating Capacity at a cost of $1.57 / kBtu.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[430] 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.

[431] 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[432]

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use.The savings is the difference between the proposed and baseline calculated usage. 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.

Electric Energy Use Equations (kWh / ton)

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
Assembly	Continuous	***CZ***+***Fu****(0.83****Tc***+0.83****Th***+1.67****Ws***-293.018)-0.0922****Tc****Th***+1.291****Ws***
	Intermittent	***CZ***+***Fu****(1.911-0.12****Tc***)+***Tc****(0.00311****Ws***-0.229)+0.11****Ws***
Convenience Store	Continuous	***CZ***+***Fu****(-28.629****Tc***-11.69****Th***+19.118****Ws***-2935.12)+0.909****Ws***
	Intermittent	***CZ***+***Tc****(0.0863****Ws***-12.688)+***Th****(0.043****Ws***-6.38)+1.669****Ws***
Office – Low Rise	Continuous	***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)
	Intermittent	***CZ***+***Tc****(0.0806****Ws***-8.984)+***Th****(0.0864****Ws***-9.558)+1.178****Ws***
Religious	Continuous	***CZ***+***Fu****(-1.579****Tc***-18.14****Th***+15.01****Ws***-2417.74)+***Tc****(0.177****Ws***-26.412)
	Intermittent	***CZ***+***Fu****(0.266****Tc***-2.067)+***Tc****(0.0295****Ws***-4.502)+***Th****(0.0517****Ws***-8.251)+0.735****Ws***
Restaurant – Fast Food	Continuous	***CZ***+***Fu****(0.678****Tc***+0.257****Th***+2.88****Ws***-494.006)+***Tc****(0.0231****Ws***-4.074)+***Th****(0.00936****Ws***-1.655)+0.918****Ws***
	Intermittent	***CZ***+***Fu****(0.377****Tc***+0.124****Th***+0.13****Ws***-24.893)+***Tc****(-0.0143****Th***+0.0166****Ws***-2.691)+0.898****Ws***
Restaurant – Full Service	Continuous	***CZ***+***Fu****(-8.41****Th***+11.766****Ws***-1910.81)+***Tc****(0.282****Ws***-43.851)
	Intermittent	***CZ***+0.123****Fu****Tc***+***Tc****(0.0561****Ws***-8.237)+***Th****(0.0219****Ws***-3.284)+1.038****Ws***
Retail – Department Store	Continuous	***CZ***+***Fu****(-1.475****Th***+0.755****Ws***-114.373)+***Th****(0.151****Ws***-24.016)+1.612****Ws***
	Intermittent	***CZ***+***Tc****(0.0173****Ws***-1.912)+***Th****(0.0249****Ws***-3.29)+0.511****Ws***
Retail – Strip Mall	Continuous	***CZ***+***Fu****(1.077****Tc***-10.697****Th***+6.91****Ws***-1117.18)+***Tc****(0.0583****Ws***-7.54)+1.231****Ws***
	Intermittent	***CZ***+0.0894****Fu****Tc***+***Th****(-0.0142****Tc***+0.04****Ws***-5.278)+0.884****Ws***

Where:

CZ = Climate Zone Coefficient

=Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

---

[432] Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper_PECI_FinalDraft_140730_Redline.docx for details.

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode During Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)

(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)[433]					Minimum *Ws*
		1	2	3	4	5	
Assembly	Continuous	911.366	928.924	1152.83	1208.999	1210.173	98
	Intermittent	735.752	762.831	966.562	998.927	1028.906	
Convenience Store	Continuous	4817.094	4832.784	5139.133	5182.161	5208.608	108
	Intermittent	1478.133	1514.568	1784.384	1843.463	1930.47	
Office - Low Rise	Continuous	5047.662	5039.592	5187.924	5217.672	5177.449	55
	Intermittent	825.072	808.965	946.571	979.421	945.418	
Religious Facility	Continuous	4197.117	4172.858	4380.025	4370.008	4356.054	133
	Intermittent	632.404	603.395	678.294	664.717	616.853	
Restaurant – Fast Food	Continuous	1342.988	1378.661	1664.018	1714.201	1727.841	108
	Intermittent	993.764	1039.643	1307.8	1340.544	1389.791	
Restaurant – Full Service	Continuous	4070.35	4094.742	4428.966	4501.829	4522.522	117
	Intermittent	1472.014	1516.05	1856.108	1938.441	2056.45	
Retail – Department Store	Continuous	1510.201	1496.47	1706.105	1716.128	1688.464	93
	Intermittent	701.27	702.129	847.735	875.12	881.677	
Retail – Strip Mall	Continuous	1926.294	1930.137	2156.856	2174.435	2165.03	93
	Intermittent	656.479	673.257	835.906	850.322	869.921	

[433] Climate Zones Refrenced in Section 3.7, Table 3.6

EXAMPLE

A low rise office in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and has a 10 ton DX RTU controlled by a manual thermostat. The fan runs continuously during the occupied hours and building staff do not manually change the fan mode, cooling or heating setpoints during unoccupied periods.

A programmable thermostat is installed by a contractor who sets the occupied schedule to Mon-Fri 7AM-6PM with a 10°F cooling and heating unoccupied temperature setback. The contractor also programs the fan to operate continuously during the occupied periods and to intermittent "auto" during the unoccupied periods.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use(kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

$= \boldsymbol{CZ}+\boldsymbol{Fu}*(7.082*\boldsymbol{Tc}-41.199*\boldsymbol{Th}+18.734*\boldsymbol{Ws}-3288.55)+\boldsymbol{Tc}*(0.205*\boldsymbol{Ws}-34.929)$

$= 5047.662+0*(7.082*0-41.199*0+18.734*168-3288.55)+0*(0.205*168-34.929)$

= 5,047.662 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

$= \boldsymbol{CZ}+\boldsymbol{Fu}*(7.082*\boldsymbol{Tc}-41.199*\boldsymbol{Th}+18.734*\boldsymbol{Ws}-3288.55)+\boldsymbol{Tc}*(0.205*\boldsymbol{Ws}-34.929)$

$= 5047.662+1*(7.082*10-41.199*10+18.734*55-3288.55)+10*(0.205*55-34.929)$

= 2,211.722 kWh/Ton

ΔkWh = [5,047.622 (kWh/Ton) – 2,211.722 (kWh/Ton)] * 10 Tons

= 2,835.89 kWh/Ton * 10 Tons

= 28,358.9 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. 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.

Natural Gas Energy Use Equations (therms / kbtu output)

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
Assembly	Continuous	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.232*\boldsymbol{Th}+0.0984*\boldsymbol{Ws}-18.79)+\boldsymbol{Th}*(0.00271*\boldsymbol{Ws}-0.535)+0.0142*\boldsymbol{Ws}$
	Intermittent	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00405*\boldsymbol{Th}+0.000519*\boldsymbol{Ws}-0.11)+\boldsymbol{Th}*(0.0000689*\boldsymbol{Ws}-0.0118)+0.0022*\boldsymbol{Ws}$
Convenience Store	Continuous	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00545*\boldsymbol{Th}-0.00251*\boldsymbol{Ws}+0.416)+\boldsymbol{Th}*(0.000123*\boldsymbol{Ws}-0.0204)+0.00183*\boldsymbol{Ws}$
	Intermittent	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00231*\boldsymbol{Th}-0.0349)+\boldsymbol{Th}*(0.000309*\boldsymbol{Ws}-0.0494)+0.00266*\boldsymbol{Ws}$
Office – Low Rise	Continuous	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.0205*\boldsymbol{Th}+0.364)+\boldsymbol{Th}*(0.00046*\boldsymbol{Ws}-0.0554)+0.00169*\boldsymbol{Ws}$
	Intermittent	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00745*\boldsymbol{Th}-0.142)+\boldsymbol{Th}*(0.00077*\boldsymbol{Ws}-0.111)+0.00199*\boldsymbol{Ws}$
Religious	Continuous	$\boldsymbol{CZ}+0.00791*\boldsymbol{Fu}*\boldsymbol{Th}+\boldsymbol{Th}*(0.00096*\boldsymbol{Ws}-0.167)+0.00184*\boldsymbol{Ws}$
	Intermittent	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00143*\boldsymbol{Th}-0.0309)+\boldsymbol{Th}*(0.0008*\boldsymbol{Ws}-0.134)+0.00219*\boldsymbol{Ws}$
Restaurant – Fast Food	Continuous	$\boldsymbol{CZ}+\boldsymbol{Fu}*(0.0431*\boldsymbol{Th}+0.0424*\boldsymbol{Ws}-7.517)+\boldsymbol{Th}*(0.00113*\boldsymbol{Ws}-0.213)+0.0119*\boldsymbol{Ws}$

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
	Intermittent	***CZ***+***Fu****(0.0125****Th***+0.0036****Ws***-0.71)+***Th****(0.000329****Ws***-0.0615)+0.00738****Ws***
Restaurant –Full Service	Continuous	***CZ***+***Fu****(0.00445****Ws***-0.535)+***Th****(0.000679****Ws***-0.1)+0.00218****Ws***
	Intermittent	***CZ***+***Fu****(0.00144****Th***+0.000262****Ws***-0.0553)+***Th****(0.00018****Ws***-0.0299)+0.00166****Ws***
Retail – Department Store	Continuous	***CZ***+0.00203****Fu****Th***+***Th****(0.000591****Ws***-0.0812)+0.00194****Ws***
	Intermittent	***CZ***+***Th****(0.000406****Ws***-0.0611)+0.00228****Ws***
Retail – Strip Mall	Continuous	***CZ***+***Fu****(0.00998****Th***+0.00207****Ws***-0.206)+***Th****(0.000665****Ws***-0.101)+0.00292****Ws***
	Intermittent	***CZ***+***Fu****(0.00383****Th***-0.0656)+***Th****(0.000575****Ws***-0.0912)+0.00249****Ws***

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Th = Degrees of Heating Setback °F

= Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode During Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)

(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
Assembly	Continuous	19.872	17.83	15.828	15.282	13.482	98
	Intermittent	0.237	0.0989	0.0267	-0.0131	-0.0871	
Convenience Store	Continuous	1.493	1.081	0.782	0.544	0.114	108
	Intermittent	1.128	0.854	0.619	0.437	0.0854	
Office - Low Rise	Continuous	1.718	1.317	0.971	0.739	0.319	55
	Intermittent	3.447	3.022	2.503	2.251	1.646	
Religious Facility	Continuous	6.294	5.55	4.678	4.202	3.122	133
	Intermittent	5.914	5.368	4.557	4.137	3.246	
Restaurant – Fast Food	Continuous	8.383	7.211	6.034	5.767	4.71	108
	Intermittent	1.227	0.636	0.302	0.102	-0.262	
Restaurant – Full Service	Continuous	5.247	4.484	3.753	3.465	2.627	117
	Intermittent	0.951	0.704	0.51	0.381	0.0746	
Retail – Department Store	Continuous	4.385	3.854	3.192	2.784	1.858	93
	Intermittent	3.061	2.672	2.182	1.829	1.008	
Retail – Strip Mall	Continuous	3.917	3.394	2.728	2.394	1.617	93
	Intermittent	2.659	2.292	1.811	1.543	0.909	

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PROG-V02-190101

REVIEW DEADLINE: 1/1/2022

4.4.19 Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO2) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

Demand controlled ventilation controls can also be added to the exhaust fans to enclosed parking garages. The fans modulate the ventilation airflow based on pollutant concentrations (primarily carbon monoxide) in the space.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new CO_2 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years and based on CO2 sensor estimated life. [434]

DEEMED MEASURE COST

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost ($500) and installation ($1000 labor) for a total of $1500[435].

Adding demand controlled ventilation to parking garages is assumed to cost $500 per sensor including the cost of the controller. The installation cost is estimated at $1,000 for labor[436].

LOADSHAPE

Commercial ventilation C23

---

[434] During the course of conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors have to 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.
[435] Discussion with vendors
[436] California Utilities Statewide Codes and Standards Team. 2011. "2013 California Building Energy Efficiency Standards", Garage Exhaust, Section 4.2 Page 14

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas,

$$\Delta kWh = Condition\ Space/1000 * SF_{cooling}$$

For facilities heated by heat pumps,

$$\Delta kWh = Condition\ Space/1000 * SF_{cooling} + Condition\ Space/1000 * SF_{Heat\ HP}$$

For facilities heated by electric resistance,

$$\Delta kWh = Condition\ Space/1000 * SF_{cooling} + Condition\ Space/1000 * SF_{Heat\ ER}$$

Where:

Conditioned Space = actual square footage of conditioned space controlled by sensor

$SF_{cooling}$ = Cooling Savings Factor

= value in table below based on building type and weather zone

$SF_{Heat\ HP}$ = Heating Savings factor for facilities heated by Heat Pump (HP)

= value in table below based on building type and weather zone

$SF_{Heat\ ER}$ = Heating Savings factor for facilities heated by Electric Resistance (ER)

= value in table below based on building type and weather zone

Saving Factor Tables[437]

Building Type	$SF_{cooling}$ (kWh/1000 SqFt)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Office - Low-rise	285	289	299	298	305
Office - Mid-rise	225	228	234	233	237
Office - High-rise	267	271	279	279	284
Religious Building	763	780	886	889	910
Restaurant	498	510	573	593	615
Retail - Department Store	388	393	410	415	423
Retail - Strip Mall	269	272	285	285	290
Convenience Store	355	357	368	370	374
Elementary School	358	367	410	405	415
High School	350	359	401	396	406
College/University	400	426	472	488	519

[437] The electric energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by current ASHRAE 62.1and 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.

Building Type	$SF_{cooling}$ (kWh/1000 SqFt)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Healthcare Clinic	349	354	389	392	398
Lodging	407	409	423	424	428
Manufacturing	175	177	183	248	185
Special Assembly Auditorium	563	581	668	677	711
Default (non-garage)	377	385	419	426	433
Enclosed Parking Garage[438]	925	925	925	925	925

Building Type	$SF_{Heat\ HP}$ (kWh/1000 SqFt)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Office - Low-rise	234	205	181	171	147
Office - Mid-rise	157	138	121	115	99
Office - High-rise	211	185	163	154	133
Religious Building	1,508	1,333	1,180	1,125	1,008
Restaurant	1,067	962	837	816	720
Retail - Department Store	368	329	291	285	249
Retail - Strip Mall	246	215	195	186	165
Convenience Store	180	163	141	138	121
Elementary School	657	572	508	473	418
High School	641	558	495	461	406
College/University	1,267	1,114	980	945	798
Healthcare Clinic	447	396	348	334	299
Lodging	205	184	159	154	135
Manufacturing	130	114	101	172	83
Special Assembly Auditorium	1,773	1,564	1,414	1,378	1,212
Default (non-garage)	606	535	474	460	400

Building Type	$SF_{Heat\ ER}$ (kWh/1000 SqFt)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Office - Low-rise	703	615	542	512	441
Office - Mid-rise	471	413	364	345	298
Office - High-rise	633	554	489	462	398
Religious Building	4,523	3,999	3,541	3,376	3,024
Restaurant	3,201	2,886	2,511	2,449	2,159
Retail - Department Store	1,103	987	874	855	748
Retail - Strip Mall	738	646	584	559	495
Convenience Store	541	488	423	413	364
Elementary School	1,972	1,715	1,523	1,420	1,254
High School	1,924	1,673	1,484	1,383	1,219
College/University	3,801	3,341	2,940	2,834	2,394

438 Savings are estimated based on a study done by California Utilities Statewide Codes and Standards Team, "2013 California Building Energy Efficiency Standards", 2013, Section 2.4, Table 1. The savings are primarily fan savings, and are not dependent on climate zone.

Building Type	SF Heat ER (kWh/1000 SqFt)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Healthcare Clinic	1,341	1,188	1,044	1,001	896
Lodging	616	551	477	462	406
Manufacturing	390	343	303	516	250
Special Assembly Auditorium	5,320	4,691	4,243	4,133	3,636
Default (non-garage)	1,819	1,606	1,423	1,381	1,199

For example: 7,500 SqFt of low-rise office space in Chicago with gas heat.

ΔkWh = 7,500 /1000 *289

= 2,168 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

NATURAL GAS SAVINGS

$$\Delta therms = \text{Condition Space}/1000 * SF_{\text{Heat Gas}}$$

Where:

$SF_{\text{Heat Gas}}$ = value in table below based on building type and weather zone[439]

Building Type	SFHeat Gas (Therm/1000 sq ft)				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Office - Low-rise	30	26	23	22	19
Office - Mid-rise	20	18	16	15	13
Office- High-rise	27	24	21	20	17
Religious Building	193	171	151	144	129
Restaurant	137	123	107	104	92
Retail - Department Store	47	42	37	36	32
Retail - Strip Mall	31	28	25	24	21
Convenience Store	23	21	18	18	16
Elementary School	84	73	65	61	53
High School	82	71	63	59	52
College/ University	162	143	125	121	102
Healthcare Clinic	57	51	45	43	38
Lodging	26	23	20	20	17
Manufacturing	17	15	13	22	11
Special Assembly Auditorium	227	200	181	176	155
De-fault	78	68	61	59	51

[439] The natural gas energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.

For example: 7500 SqFt of low-rise office space in Chicago.

ΔTherms = 7,500/1,000 * 26

= 195 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-DCV-V05-190101

REVIEW DEADLINE: 1/1/2024

4.4.20 High Turndown Burner for Space Heating Boilers

Description

This measure is for a non-residential boilers equipped with linkageless controls providing space heating with burners having a turndown less than 6:1.[440] Turndown is the ratio of the high firing rate to the low firing rate. When boilers are subjected to loads below the low firing rate, the boiler must cycle on/off to meet the load requirements. A higher turndown ratio reduces burner startups, provides better load control, saves wear-and-tear on the burner, and reduces purge-air requirements, all of these benefits result in better overall efficiency.

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

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

Definition of Efficient Equipment

To qualify the boiler linkageless burner must operate with a turndown greater than or equal to 10:1 and be subjected to loads less than or equal to 30%[441] of the full fire input MBH for greater than 60%[442] of the operating hours.

Definition of Baseline Equipment

The baseline boiler utilizes a linkageless burner with a turndown ration of 6:1 or less and is used primarily for space heating. Redundant boilers do not qualify.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 21 years.[443]

Deemed Measure Cost

The deemed installed measure cost including labor is approximately $2.53/MBtu/hr.[444]

Deemed O&M Cost Adjustments

N/A

Loadshape

N/A

Coincidence Factor

N/A

[440] The standard turndown ratio for boilers is 6:1. Understanding Fuel Savings in the Boiler Room, ASHRAE Journal, David Eoff, December, 2008 p 38

[441] Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

[442] FES Analysis of bin hours based upon a 30% oversizing factor.

[443] "Burner," Obtained from a nation-wide survey conducted by ASHRAE TC 1.8 (Akalin 1978). Data changed by TC 1.8 in 1986.

[444] FES review of PY2/PY3 costs for custom People's and North Shore high turndown burner projects. See High Turndown Costs.xlsx for details.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Δtherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings Factor = Percentage of energy loss per hour

= (∑ ((EL_base – EL_eff) * H_cycling)) / H)*100

Where:

EL_base = Base Boiler Percentage of energy loss due to cycling at % of Base Boiler Load where BL_base ≤ TDR_base

= 0.003 * $(Cycles\_base)^2$ – 0.001 * Cycles_base [445]

Where:

Cycles_base = Number of Cycles/hour of base boiler

= TDR_base / BL

Where:

BL = % of full boiler load at bin hours being evaluated. This is assumed to be a straight line based on 0% load at the building balance point (assumed to be 55F), and full load corrected for the oversizing (OSF) at the lowest temperature bin of -10 to -5F.

OSF = Oversizing Factor = 1.3[446] or custom

TDR_base = Turndown ratio = 0.33[447] or custom

EL_eff = Efficient Boiler Percentage of energy loss due to cycling at % of Efficient Boiler Load

= 0.003 * $(Cycles\_eff)^2$ – 0.001 * Cycles_eff

Where:

Cycles_eff = Number of Cycles/hour

= TDR_eff / BL

[445] Release 3.0 Operations & Maintenance Best Practices A Guide to Achieving Operational Efficiency, August 2010, Federal Energy Management Program, US Department of Energy. The equation was determined by plotting the values in Table 9.2.1 – Boiler Cycling Energy Loss.

[446] PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010, Page 4-12.

[447] Ibid.

Where:

TDR_eff = Turndown ratio = 0.10[448] or custom

H_cycling = Hours base boiler is cycling at % of base boiler load

= see table below or custom

H = Total Number of Hours in Heating Season

= 4,946 or custom

100 = convert to a percentage

SF = 69.1 / 4946 *100 = 1.4% or custom (see table below for summary of values)

Temperature	H_cycling	BL	EL_base	EL_eff	(EL_base-EL_eff)* Hours
50 to 55	601	6.0%	8.5%	0.7%	47.2
45 to 50	603	12.0%	2.0%	0.0%	12.0
40 to 45	455	18.0%	0.8%	0.0%	3.8
35 to 40	925	24.0%	0.4%	0.0%	4.0
30 to 35	814	30.0%	0.3%	0.0%	2.1
				Total	69.1

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use.

100 = convert kBtu to therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-HVAC-HTBC-V04-140601

Review Deadline: 1/1/2020

[448] 10:1 ratio used to qualify for efficient equipment.

4.4.21 Linkageless Boiler Controls for Space Heating

Description

This measure is for a non-residential boiler providing space heating and currently having single point positioning combustion control. In single-point positioning control, the fuel valve is linked to the combustion air damper via a jackshaft mechanism to maintain correspondence between fuel and combustion air input. Most boilers with single point positioning control do not maintain low excess air levels over their entire firing range. Generally these boilers are calibrated at high fire, but due to the non-linearity required for efficient combustion, excess air levels tend to dramatically increase as the firing rate decreases. Boiler efficiency drops as the excess air levels are increased.

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

To qualify the boiler burner must have a linkageless control system allowing the combustion air damper position to be adjusted and set for optimal efficiency at several firing rates throughout the burner's firing range. This requires the fuel valve and combustion air damper to each be powered by a separate actuator. An alternative to the combustion air damper is a Variable Speed Drive on the combustion air fan.

Definition of Baseline Equipment

The baseline boiler utilizes single point positioning for the burner combustion control.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[449]

Deemed Measure Cost

The deemed measure cost is estimated at $2.50/MBtu/hr burner input.[450]

Deemed O&M Cost Adjustments

N/A

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

When a Variable Speed Drive is incorporated, electrical savings are calculated according to the "4.4.17 Variable Speed Drive for HVAC Pumps and Cooling Tower Fans" measure.

[449] Total number of hours for heating with a base temperature of 55°F for Chicago, IL as noted by National Climate Data Center

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings factor

Note: Savings factor is the percentage increase in efficiency as a result of the addition of linkageless burner controls. At an average boiler load of 35%, single point controls are assumed to have excess air of 91%, while linkageless controls are assumed to have 34% excess air.[451] The difference between controls types is 57% at this average operating condition. A 15% reduction in excess air is approximately a 1% increase in efficiency.[452] Therefore the nominal combustion efficiency increase is 57 / 15 * 1% = 3.8%.

= 3.8%

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

100 = convert kBtu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-LBC-V05-160601

REVIEW DEADLINE: 1/1/2022

---

[451] Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, Prepared by the Sector Policies and Programs Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711, October 2010, Table 1. ICI Boilers – Summary of Greenhouse Gas Emission Reduction Measures, pg. 8

[452] Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improve 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.

4.4.22 Oxygen Trim Controls for Space Heating Boilers

DESCRIPTION

This measure is for a non-residential boiler providing space heating without oxygen trim combustion controls. Oxygen 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, linkageless 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 was developed to be applicable to the following program types: NC, TOS, RF.

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 linkageless fuel valve and combustion air controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes single point positioning for the burner combustion control.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the O2 Trim controls is 18 years.[453]

DEEMED MEASURE COST

The deemed measure cost is approximately $23,250.[454]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

---

[453] 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.

[454] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

NATURAL GAS ENERGY SAVINGS

ΔTherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

Note: Savings factor is the percentage reduction in gas consumption as a result of the addition of O2 trim controls. Linkageless controls have an excess air rate of 28% over the entire firing range.[455] O2 trim controls have an excess air rate of 15%.[456] The average difference is 13%. A 15% reduction in excess air is approximately a 1% increase in efficiency.[457] Therefore the nominal combustion efficiency increase is 13 / 15 * 1% = 0.87%.

= 0.87%

EFLH = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed annual Operations and Maintenance cost is $800.[458]

MEASURE CODE: CI-HVC-O2TC-V01-140601

REVIEW DEADLINE: 1/1/2022

[455] 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.

[456] Ibid

[458] 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.

4.4.23 Shut Off Damper for Space Heating Boilers or Furnaces

Description

This measure is for non-residential 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.[459]

Deemed Measure Cost

The deemed measure cost for this approximately $1,500.[460]

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

[459] 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.
[460] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

Natural Gas Energy Savings

ΔTherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%[461]

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 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

The deemed annual Operations and Maintenance cost is $112.[462]

Measure Code: CI-HVC-SODP-V01-140601

Review Deadline: 1/1/2020

[461] 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", March 2012,
"1 - 2%": Page 2, Sustainable Energy Authority of Ireland "Steam Systems Technical Guide".

[462] 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

4.4.24 Small Pipe Insulation

DESCRIPTION

This measure provides rebates for adding insulation to bare pipes with inner diameters of ½” and ¾”. Insulation must be at least one inch thick. Since new construction projects are required by code to have pipe insulation, this measure is only for retrofits of existing facilities. This covers bare straight pipe as well as all fittings.

Default savings are provided on a per linear foot basis. It is assumed that the majority of pipes less than one inch in commercial facilities are used for domestic hot water. However, this measure can cover hydronic heating systems as well as low and high pressure steam 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 case is a ½“or ¾“ diameter pipe with at least one inch of insulation. Insulation must be protected from damage which includes moisture, sunlight, equipment maintenance and wind. Outdoor pipes should have a weather protective jacket. Insulation must be continuous over straight pipe, elbows and tees.

DEFINITION OF BASELINE EQUIPMENT

The base case for savings estimates is a bare hot water or steam pipe with a fluid temperature of 105 degrees Fahrenheit or greater. Current new construction code requires insulation amounts similar to this measure though this base case is commonly found in older existing buildings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[463]

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.[464]

Insulation Thickness	¾” pipe	½” pipe
1”	$4.45	$4.15

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[463] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[464] A market survey was performed to determine these costs.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms per foot[465] = [((Q_base – Q_eff) * EFLH) / (100,000 * ηBoiler)] * TRF

= [Modeled or provided by tables below] * TRF

ΔTherms = (L_{sp} + $L_{oc,i}$) * Δtherms per foot

Where:

EFLH = Equivalent Full Load Hours for Heating

= Actual or defaults by building type provided in Section 4.4, HVAC end use

For year round recirculation or domestic hot water:

= 8,766

For heating season recirculation, hours with the outside air temperature below 55°F:

Zone	Hours
Zone 1 (Rockford)	5,039
Zone 2 (Chicago)	4,963
Zone 3 (Springfield)	4,495
Zone 4 (Belleville/	4,021
Zone 5 (Marion)	4,150

Q_{base} = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

Q_{eff} = Heat Loss from Insulated Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000 = conversion factor (1 therm = 100,000 Btu)

ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe

= 81.9% for water boilers [466]

= 80.7% for steam boilers, except multifamily low-pressure [467]

[465] This value comes from the reference table "Savings Summary by Building Type and System Type." The formula and the input tables in this section document assumptions used in calculation spreadsheet "Pipe Insulation Savings 2013-11-12.xlsx"
[466] Average efficiencies of units from the California Energy Commission (CEC).
[467] Ibid.

= 64.8% for multifamily low-pressure steam boilers [468]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [469]

= 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.470

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

L_{sp} = Length of straight pipe to be insulated (linear foot)

$L_{oc,i}$ = Total equivalent length of (elbows and tees) of pipe to be insulated. Use table below to determine equivalent lengths.

Nominal Pipe Diameter	Equivalent Length (ft)	
	90 Degree Elbow	Straight Tee
1/2"	0.04	0.03
3/4"	0.06	0.05

The table below shows the deemed therm savings by building type and region on a per linear foot basis for both ½” and ¾” copper pipe.

The following table provides deemed values for 1/2" copper pipe, temperatures are assumed by category below, and insulation is assumed to be one inch fiberglass.

Piping Use	Building Type	Annual Therms Saved / Linear Foot				
		Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Space Heating	Assembly	0.117	0.120	0.107	0.071	0.109
	Assisted Living	0.110	0.107	0.094	0.069	0.083
	College	0.100	0.093	0.083	0.046	0.055

468 Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993.

469 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.

470 Thermal Regain Factor_4-30-14.docx

Piping Use	Building Type	Annual Therms Saved / Linear Foot				
		Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Non-recirculating	Convenience Store	0.097	0.089	0.079	0.057	0.064
	Elementary School	0.116	0.113	0.100	0.069	0.084
	Garage	0.064	0.063	0.056	0.044	0.049
	Grocery	0.105	0.105	0.092	0.057	0.068
	Healthcare Clinic	0.103	0.106	0.092	0.063	0.066
	High School	0.120	0.121	0.109	0.077	0.091
	Hospital - CAV no econ	0.115	0.119	0.101	0.087	0.099
	Hospital - CAV econ	0.117	0.121	0.103	0.089	0.101
	Hospital - VAV econ	0.048	0.045	0.034	0.020	0.022
	Hospital - FCU	0.087	0.099	0.080	0.094	0.127
	Hotel/Motel	0.115	0.112	0.101	0.069	0.084
	Hotel/Motel - Common	0.104	0.106	0.101	0.082	0.086
	Hotel/Motel - Guest	0.115	0.111	0.099	0.066	0.082
	Manufacturing Facility	0.068	0.066	0.061	0.037	0.041
	MF - High Rise	0.100	0.098	0.090	0.076	0.076
	MF - High Rise - Common	0.118	0.115	0.103	0.071	0.092
	MF - High Rise - Residential	0.096	0.096	0.087	0.075	0.073
	MF - Mid Rise	0.109	0.110	0.095	0.070	0.079
	Movie Theater	0.119	0.117	0.109	0.083	0.099
	Office - High Rise - CAV no econ	0.132	0.134	0.122	0.082	0.089
	Office - High Rise - CAV econ	0.136	0.139	0.128	0.088	0.097
	Office - High Rise - VAV econ	0.100	0.102	0.084	0.050	0.055
	Office - High Rise - FCU	0.073	0.072	0.062	0.033	0.035
	Office - Low Rise	0.093	0.093	0.074	0.045	0.052
	Office - Mid Rise	0.103	0.104	0.088	0.056	0.062
	Religious Building	0.105	0.098	0.094	0.069	0.079
	Restaurant	0.088	0.088	0.079	0.060	0.071
	Retail - Department Store	0.091	0.083	0.078	0.051	0.058
	Retail - Strip Mall	0.087	0.081	0.071	0.049	0.053
	Warehouse	0.095	0.089	0.091	0.057	0.070
	Unknown	0.101	0.100	0.089	0.064	0.074
Space Heating - recirculation heating season only	All buildings (Hours below 55°F)	0.329	0.324	0.293	0.262	0.271
Space Heating - recirculation year round	All buildings (All hours)	0.572	0.572	0.572	0.572	0.572
DHW	Recirculation loop	0.572	0.572	0.572	0.572	0.572
Process	Custom	Custom				

The following table provides deemed savings values for 3/4" copper pipe with temperatures assumed by category below, insulation is assumed to be one inch fiberglass.

Piping Use	Building Type	Annual Therms Saved / Linear Foot				
		Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Space Heating Non-recirculating	Assembly	0.142	0.145	0.129	0.086	0.132
	Assisted Living	0.133	0.130	0.115	0.084	0.101
	College	0.121	0.113	0.101	0.056	0.067
	Convenience Store	0.117	0.108	0.096	0.069	0.077
	Elementary School	0.141	0.137	0.121	0.084	0.102
	Garage	0.078	0.077	0.067	0.054	0.060
	Grocery	0.127	0.127	0.111	0.069	0.083
	Healthcare Clinic	0.125	0.128	0.112	0.076	0.081
	High School	0.146	0.147	0.132	0.094	0.110
	Hospital - CAV no econ	0.140	0.144	0.123	0.105	0.120
	Hospital - CAV econ	0.142	0.147	0.125	0.108	0.123
	Hospital - VAV econ	0.058	0.055	0.041	0.025	0.027
	Hospital - FCU	0.105	0.120	0.098	0.115	0.154
	Hotel/Motel	0.140	0.136	0.122	0.084	0.102
	Hotel/Motel - Common	0.127	0.129	0.123	0.100	0.105
	Hotel/Motel - Guest	0.139	0.135	0.120	0.081	0.099
	Manufacturing Facility	0.083	0.080	0.074	0.045	0.050
	MF - High Rise	0.121	0.119	0.109	0.093	0.093
	MF - High Rise - Common	0.144	0.140	0.125	0.086	0.111
	MF - High Rise - Residential	0.117	0.116	0.105	0.091	0.089
	MF - Mid Rise	0.132	0.134	0.115	0.085	0.096
	Movie Theater	0.144	0.142	0.133	0.101	0.120
	Office - High Rise - CAV no econ	0.160	0.162	0.148	0.099	0.108
	Office - High Rise - CAV econ	0.165	0.169	0.155	0.107	0.118
	Office - High Rise - VAV econ	0.121	0.123	0.102	0.060	0.067
	Office - High Rise - FCU	0.089	0.087	0.075	0.040	0.042
	Office - Low Rise	0.113	0.113	0.090	0.055	0.063
	Office - Mid Rise	0.126	0.126	0.106	0.068	0.075
	Religious Building	0.127	0.119	0.114	0.084	0.095
	Restaurant	0.107	0.107	0.096	0.073	0.086
	Retail - Department Store	0.110	0.101	0.095	0.062	0.071
	Retail - Strip Mall	0.106	0.098	0.086	0.059	0.064
	Warehouse	0.115	0.108	0.111	0.069	0.085
	Unknown	0.123	0.122	0.108	0.078	0.090
Space Heating - recirculation heating season only	All buildings (Hours below 55°F)	0.399	0.393	0.356	0.319	0.329
Space Heating - recirculation year round	All buildings (All hours)	0.694	0.694	0.694	0.694	0.694
DHW	Recirculation loop	0.694	0.694	0.694	0.694	0.694
Process	Custom	Custom				

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-HVC-SPIN-V02-160601

Review Deadline: 1/1/2023

4.4.25 Small Commercial Programmable Thermostat Adjustments

Description

This measure involves reprogramming existing commercial programmable thermostats or building automation systems for reduced energy consumption through adjustments of unoccupied heating/cooling setpoints and/or fan control. This measure is limited to packaged HVAC units that are controlled by a commercial thermostat or building automation system. The measure is limited to select building types presented below.

Eligible Small Commercial Building Types

Building Type
Assembly
Convenience Store
Office - Low Rise
Restaurant - Fast Food
Religious Facility
Restaurant - Full Service
Retail - Strip Mall
Retail - Department Store

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

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

Definition of Efficient Equipment

The criteria for this measure is established by optimizing heating/cooling temperature setbacks and fan operation with a commercial programmable thermostat or building automation system, which reprogrammed to match actual facility occupancy.

Definition of Baseline Equipment

The baseline for this measure is a commercial programmable thermostat or building automation system that is currently operating packaged HVAC units with heating/cooling temperature setbacks and fan operation that do not align with a facilities actual occupancy.

Deemed Lifetime of Efficient Equipment

The expected measure life of a programmable thermostat is assumed to be 8 years[471]. For the purposes of claiming savings for a adjustment of an existing programmable thermostat, this is reduced to a 25% persistence factor to give a final measure life of 2 years. It is recommended that this assumption be evaluated by future energy measurement and verification activities.

Deemed Measure Cost

Actual labor costs should be used if the implementation method allows. If unknown the labor cost for this measure is assumed to be $70.34[472] per thermostat, as summarized in the table below.

---

[471] 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.

[472] RSMeans, "Instrumentation and Control for HVAC", Mechanical Cost Data , Kingston, MA: Reed Construction Data, 2010, pg. 255 & 632

Measure	Units	Materials	Labor	Total Cost (including O&P)	City Cost Index (Install Only)*	Total	Source
Adjust Temperature Set Points	4	$0.00	$5.95	$6.55	134.5%	$35.24	RS Means 2010 (pg 255, Section 23-09-8100)
Adjust Fan Schedule	2	$0.00	$11.86	$13.05	134.5%	$35.10	RS Means 2010 (pg 255, Section 23-09-8120)
Totals						**$70.34**	

* Chicago, IL - Division 23

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[473]

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. 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.

Electric Energy Use Equations (kWh / ton)

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
Assembly	Continuous	***CZ***+***Fu****(0.83****Tc***+0.83****Th***+1.67****Ws***-293.018)-0.0922****Tc********Th***+1.291****Ws***
	Intermittent	***CZ***+***Fu****(1.911-0.12****Tc***)+***Tc****(0.00311****Ws***-0.229)+0.11****Ws***
Convenience Store	Continuous	***CZ***+***Fu****(-28.629****Tc***-11.69****Th***+19.118****Ws***-2935.12)+0.909****Ws***
	Intermittent	***CZ***+***Tc****(0.0863****Ws***-12.688)+***Th****(0.043****Ws***-6.38)+1.669****Ws***
Office – Low Rise	Continuous	***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)
	Intermittent	***CZ***+***Tc****(0.0806****Ws***-8.984)+***Th****(0.0864****Ws***-9.558)+1.178****Ws***
Religious	Continuous	***CZ***+***Fu****(-1.579****Tc***-18.14****Th***+15.01****Ws***-2417.74)+***Tc****(0.177****Ws***-26.412)
	Intermittent	***CZ***+***Fu****(0.266****Tc***-2.067)+***Tc****(0.0295****Ws***-4.502)+***Th****(0.0517****Ws***-8.251)+0.735****Ws***
Restaurant – Fast Food	Continuous	***CZ***+***Fu****(0.678****Tc***+0.257****Th***+2.88****Ws***-494.006)+***Tc****(0.0231****Ws***-4.074)+***Th****(0.00936****Ws***-1.655)+0.918****Ws***
	Intermittent	***CZ***+***Fu****(0.377****Tc***+0.124****Th***+0.13****Ws***-24.893)+***Tc****(-0.0143****Th***+0.0166****Ws***-2.691)+0.898****Ws***
Restaurant – Sit Down	Continuous	***CZ***+***Fu****(-8.41****Th***+11.766****Ws***-1910.81)+***Tc****(0.282****Ws***-43.851)
	Intermittent	***CZ***+0.123****Fu********Tc***+***Tc****(0.0561****Ws***-8.237)+***Th****(0.0219****Ws***-3.284)+1.038****Ws***
Retail – Large	Continuous	***CZ***+***Fu****(-1.475****Th***+0.755****Ws***-114.373)+***Th****(0.151****Ws***-24.016)+1.612****Ws***
	Intermittent	***CZ***+***Tc****(0.0173****Ws***-1.912)+***Th****(0.0249****Ws***-3.29)+0.511****Ws***

[473] Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper_PECI_FinalDraft_140730_Redline.docx for details.

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
Retail – Strip Mall	Continuous	***CZ***+***Fu****(1.077****Tc***-10.697****Th***+6.91****Ws***-1117.18)+***Tc****(0.0583****Ws***-7.54)+1.231****Ws***
	Intermittent	***CZ***+0.0894****Fu****Tc***+***Th****(-0.0142****Tc***+0.04****Ws***-5.278)+0.884****Ws***

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode during Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode,

= Minimum values depend on Building Type (see table below), maximum value of 168 (24/7) ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59

Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
Assembly	Continuous	911.366	928.924	1152.83	1208.999	1210.173	98
	Intermittent	735.752	762.831	966.562	998.927	1028.906	
Convenience Store	Continuous	4817.094	4832.784	5139.133	5182.161	5208.608	108
	Intermittent	1478.133	1514.568	1784.384	1843.463	1930.47	
Office - Low Rise	Continuous	5047.662	5039.592	5187.924	5217.672	5177.449	55
	Intermittent	825.072	808.965	946.571	979.421	945.418	
Religious Facility	Continuous	4197.117	4172.858	4380.025	4370.008	4356.054	133
	Intermittent	632.404	603.395	678.294	664.717	616.853	
Restaurant – Fast Food	Continuous	1342.988	1378.661	1664.018	1714.201	1727.841	108
	Intermittent	993.764	1039.643	1307.8	1340.544	1389.791	
Restaurant – Full Service	Continuous	4070.35	4094.742	4428.966	4501.829	4522.522	117
	Intermittent	1472.014	1516.05	1856.108	1938.441	2056.45	
Retail – Department Store	Continuous	1510.201	1496.47	1706.105	1716.128	1688.464	93
	Intermittent	701.27	702.129	847.735	875.12	881.677	

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
Retail – Strip Mall	Continuous	1926.294	1930.137	2156.856	2174.435	2165.03	93
	Intermittent	656.479	673.257	835.906	850.322	869.921	

EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBtu output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent "auto" mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)

= *5047.662*+1*(7.082**0*-41.199**0*+18.734**55*-3288.55)+*0**(0.205**55*-34.929)

= 2,789.482 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)

= *5047.662+1**(7.082**10*-41.199*10+18.734*55-3288.55)+*10*(*0.205**55*-34.929)

= 2,211.722 kWh/Ton

ΔkWh = [2,789.482 (kWh/Ton) – 2,211.722 (kWh/Ton)] * 10 Tons

= 577.71 kWh/Ton * 10 Tons

= 5777.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. 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.

Natural Gas Energy Use Equations (therms / kbtu)

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
Assembly	Continuous	**CZ+Fu***(0.232*Th+0.0984*Ws-18.79)+Th*(0.00271*Ws-0.535)+0.0142*Ws
	Intermittent	***CZ***+***Fu****(0.00405****Th***+0.000519****Ws***-0.11)+***Th****(0.0000689****Ws***-0.0118)+0.0022****Ws***
Convenience Store	Continuous	***CZ***+***Fu****(0.00545****Th***-0.00251****Ws***+0.416)+***Th****(0.000123****Ws***-0.0204)+0.00183****Ws***
	Intermittent	***CZ***+***Fu****(0.00231****Th***-0.0349)+***Th****(0.000309****Ws***-0.0494)+0.00266****Ws***
Office – Low Rise	Continuous	***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws***
	Intermittent	***CZ***+***Fu****(0.00745****Th***-0.142)+***Th****(0.00077****Ws***-0.111)+0.00199****Ws***
Religious	Continuous	***CZ***+0.00791****Fu****Th***+***Th****(0.00096****Ws***-0.167)+0.00184****Ws***
	Intermittent	***CZ***+***Fu****(0.00143****Th***-0.0309)+***Th****(0.0008****Ws***-0.134)+0.00219****Ws***
Restaurant – Fast Food	Continuous	***CZ***+***Fu****(0.0431****Th***+0.0424****Ws***-7.517)+***Th****(0.00113****Ws***-0.213)+0.0119****Ws***
	Intermittent	***CZ***+***Fu****(0.0125****Th***+0.0036****Ws***-0.71)+***Th****(0.000329****Ws***-0.0615)+0.00738****Ws***
Restaurant –Sit Down	Continuous	***CZ***+***Fu****(0.00445****Ws***-0.535)+***Th****(0.000679****Ws***-0.1)+0.00218****Ws***
	Intermittent	***CZ***+***Fu****(0.00144****Th***+0.000262****Ws***-0.0553)+***Th****(0.00018****Ws***-0.0299)+0.00166****Ws***
Retail – Large	Continuous	***CZ***+0.00203****Fu****Th***+***Th****(0.000591****Ws***-0.0812)+0.00194****Ws***
	Intermittent	***CZ***+***Th****(0.000406****Ws***-0.0611)+0.00228****Ws***
Retail – Strip Mall	Continuous	***CZ***+***Fu****(0.00998****Th***+0.00207****Ws***-0.206)+***Th****(0.000665****Ws***-0.101)+0.00292****Ws***
	Intermittent	***CZ***+***Fu****(0.00383****Th***-0.0656)+***Th****(0.000575****Ws***-0.0912)+0.00249****Ws***

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Th = Degrees of Heating Setback °F

= Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode during Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode,

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7) ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59.

Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
Assembly	Continuous	19.872	17.83	15.828	15.282	13.482	98
	Intermittent	0.237	0.0989	0.0267	-0.0131	-0.0871	
Convenience Store	Continuous	1.493	1.081	0.782	0.544	0.114	108
	Intermittent	1.128	0.854	0.619	0.437	0.0854	
Office - Low Rise	Continuous	1.718	1.317	0.971	0.739	0.319	55
	Intermittent	3.447	3.022	2.503	2.251	1.646	
Religious Facility	Continuous	6.294	5.55	4.678	4.202	3.122	133
	Intermittent	5.914	5.368	4.557	4.137	3.246	
Restaurant – Fast Food	Continuous	8.383	7.211	6.034	5.767	4.71	108
	Intermittent	1.227	0.636	0.302	0.102	-0.262	
Restaurant – Full Service	Continuous	5.247	4.484	3.753	3.465	2.627	117
	Intermittent	0.951	0.704	0.51	0.381	0.0746	
Retail – Department Store	Continuous	4.385	3.854	3.192	2.784	1.858	93
	Intermittent	3.061	2.672	2.182	1.829	1.008	
Retail – Strip Mall	Continuous	3.917	3.394	2.728	2.394	1.617	93
	Intermittent	2.659	2.292	1.811	1.543	0.909	

EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBtu output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent "auto" mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws***

= *1.718*+*1**(0.0205**0*+0.364)+*0**(0.00046**55*-0.0554)+0.00169**55*

= 2.17495 Therms/kBtuh output

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws***

= *1.718*+*1**(0.0205**10*+0.364)+*10**(0.00046**55*-0.0554)+0.00169**55*

= 2.07895 Therms/kBtuh output

ΔTherms = [2.17495 (Therms/kBtuh output) – 2.07895 (Therms/kBtuh output)] * 150kBtuh output

= 0.096 (Therms/kBtuh output) * 150kBtuh output

= 14.4 Thermsrr

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PRGA-V03-190101

REVIEW DEADLINE: 1/1/2022

4.4.26 Variable Speed Drives for HVAC Supply and Return Fans

DESCRIPTION

This measure is applied to variable speed drives (VSD) which are installed on HVAC supply fans and return fans. There is a separate measure for HVAC pumps and cooling tower fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VSD is applied to a motor which does not have a VSD. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VSD 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 VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years;[474] measure life for process is 10 years.[475]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs[476] are noted below for up to 75 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

HP	Cost
5 HP	$ 2,250
15 HP	$ 3,318
25 HP	$ 4,386
50 HP	$ 6,573
75 HP	$ 8,532

LOADSHAPE

Loadshape C39 - VFD - Supply fans <10 HP

Loadshape C40 - VFD - Return fans <10 HP

Loadshape C41 - VFD - Exhaust fans <10 HP

[474] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
[475] DEER 2008
[476] NEEP Incremental Cost Study Phase Two Final Report

COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[477]

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

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

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

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

Where:

kWh_{Base} = Baseline annual energy consumption (kWh/yr)

$kWh_{Retrofit}$ = Retrofit annual energy consumption (kWh/yr)

ΔkWh_{fan} = Fan-only annual energy savings

ΔkWh_{total} = Total project annual energy savings

0.746 = Conversion factor for HP to kWh

HP = Nominal horsepower of controlled motor

LF = Load Factor; Motor Load at Fan Design CFM (Default = 65%)[478]

η_{motor} = Installed nominal/nameplate motor efficiency

Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

NEMA Premium Efficiency Motors Default Efficiencies[479]

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855

477 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.

478 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.

479 Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA, October 2005.

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.954	0.958	0.950	0.958	0.962	0.958
300	0.954	0.958	0.954	0.958	0.962	0.958
350	0.954	0.958	0.954	0.958	0.962	0.958
400	0.958	0.958	0.958	0.958	0.962	0.958
450	0.962	0.962	0.958	0.958	0.962	0.958
500	0.962	0.962	0.958	0.958	0.962	0.958

$RHRS_{Base}$ = Annual operating hours for fan motor based on building type

Default hours are provided for HVAC applications which vary by HVAC application and building type[480]. When available, actual hours should be used.

Building Type	Total Fan Run Hours	Model Source
Assembly	7235	eQuest
Assisted Living	8760	eQuest
College	6103	eQuest
Convenience Store	7004	eQuest
Elementary School	7522	eQuest
Garage	7357	eQuest
Grocery	7403	eQuest
Healthcare Clinic	6345	eQuest
High School	7879	eQuest
Hospital - VAV econ	8760	eQuest
Hospital - CAV econ	8760	eQuest
Hospital - CAV no econ	8760	eQuest

480 Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

Building Type	Total Fan Run Hours	Model Source
Hospital - FCU	8760	eQuest
Manufacturing Facility	8706	eQuest
MF - High Rise	8760	eQuest
MF - Mid Rise	8760	eQuest
Hotel/Motel - Guest	8760	eQuest
Hotel/Motel - Common	8760	eQuest
Movie Theater	7505	eQuest
Office - High Rise - VAV econ	6064	eQuest
Office - High Rise - CAV econ	5697	eQuest
Office - High Rise - CAV no econ	5682	eQuest
Office - High Rise - FCU	6163	eQuest
Office - Low Rise	6288	eQuest
Office - Mid Rise	6856	OpenStudio
Religious Building	7380	eQuest
Restaurant	7809	eQuest
Retail - Department Store	7155	OpenStudio
Retail - Strip Mall	6846	eQuest
Warehouse	6832	OpenStudio
Unknown	7100	n/a

$\%FF$ = Percentage of run-time spent within a given flow fraction range

Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

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 40%	15.5%
40% to 50%	22.0%
50% to 60%	25.0%
60% to 70%	19.0%
70% to 80%	8.5%
80% to 90%	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

$PLR_{Retrofit}$ = Part load ratio for a given flow fraction range based on the retrofit flow control type

Control Type	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

Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
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 is 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%)

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

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

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

Where:

kW_{Base} = Baseline summer coincident peak demand (kW)

$kW_{Retrofit}$ = Retrofit summer coincident peak demand (kW)

ΔkW_{fan} = Fan-only summer coincident peak demand impact

ΔkW_{total} = Total project summer coincident peak demand impact

$PLR_{Base,FFpeak}$ = The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the baseline flow control type (default average flow fraction during peak period = 90%)

$PLR_{Retrofit,FFpeak}$ = 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%)

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

There are no expected fossil fuel impacts for this measure.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-VSDF-V03-190101

REVIEW DEADLINE: 1/1/2022

4.4.27 Energy Recovery Ventilator

Description

This measure includes the addition of energy recovery equipment on existing or new unitary equipment, where energy recovery is not required by the IECC 2012/2015/2018. This measure analyzes the heating and cooling savings potential from recovering energy from exhaust or relief building air. This measure assumes that during unoccupied hours of the building no exhaust or relief air is available for energy recovery.

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

Efficient equipment is unitary equipment that incorporates energy recovery not required by the IECC 2012/2015/2018.

Definition of Baseline Equipment

The baseline is unitary equipment not required by IECC 2012/2015/2018 to incorporate energy recovery.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

Deemed Lifetime of Efficient Equipment

The measure life for the domestic energy recovery equipment is 15 years.[481]

Deemed Measure Cost

The incremental cost for this measure assumes cost of cabinet and controls incorporated into packaged and built up air handler units. Additionally it assumes a 1 to 1 ratio of fresh and exhausted air.

Energy Recovery Equipment Type	Incremental Cost $/CFM[482]
Plate Heat Exchanger	$6
Rotary Wheel	$6
Heat Pipe	$6

Deemed O&M Cost Adjustments

There are no expected O&M savings associated with this measure.

Loadshape

N/A

Coincidence Factor

N/A

[481] Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

[482]"Map to HVAC Solutions", by Michigan Air, Issue 3, 2006

Algorithm

Calculation of Energy Savings Electric Energy Savings

The electric energy savings calculation here represents the net electric energy savings from reduced cooling requirements after accounting for increased fan power caused by additional pressure drop from the ERV device. These savings do not account for heating energy savings in HVAC systems using heat pumps or electric resistance heat. This calculation does not apply to wheel-type devices with purge sections, or to sensible-only devices such as heat pipes.

ΔkWh = (cfm) * Normalized Electric Energy Savings

cfm = design supply air flow of energy recovery ventilator in cubic feet per minute

= rated energy recovery ventilator supply air flow * (1 – Exhaust Air Transfer Ratio)

Exhaust Air Transfer Ratio = percentage of supply air made up of cross-leakage from exhaust air; value provided by vendor

= 0.05 (default)

Normalized Electric Energy Savings

= kWh/cfm savings value for the expected energy savings (net of fan energy penalty) as detailed in Table 1 – Electric Energy Savings Summary (kWh/cfm)

Table 1 – Electric Energy Savings Summary (kWh/cfm)[483]

Building Type	Normalized Electricity Savings (kWh/OA cfm)				
	Zone 1 - Rockford	Zone 2 - Chicago	Zone 3 - Springfield	Zone 4 - Mt. Vernon/Belleville	Zone 5 - Marion
Enthalpy Wheel - 75% sensible and latent effectiveness					
Assembly	NA	NA	NA	0.107	0.229
Education	NA	NA	0.371	0.245	0.369
Grocery	NA	NA	0.239	0.523	0.630
Healthcare	1.551	1.594	2.508	2.999	3.077
Multifamily	2.178	2.566	3.781	4.746	5.029
Office	0.974	1.169	2.379	2.998	3.194
Retail	0.048	0.124	0.389	1.027	1.063
Enthalpy Plate - 50% sensible and latent effectiveness					
Assembly	NA	NA	NA	NA	NA
Education	NA	NA	NA	NA	0.035
Grocery	NA	NA	NA	0.002	0.102
Healthcare	0.923	0.963	1.548	1.841	1.908
Multifamily	0.627	0.908	1.450	2.341	2.509
Office	0.309	0.487	1.321	1.705	1.918
Retail	NA	NA	NA	0.398	0.435

Summer Coincident Peak Demand Savings

ΔkW = (cfm) * Normalized Electric Peak Demand Savings * CF

= design supply air flow of energy recovery ventilator in cubic feet per minute

483 Energy savings modeled using IL TRM energy models with added energy recovery wheels or enthalpy plates. Energy recovery device specifications based on product data from the AHRI Certification Directory (https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f). See reference "ERV Effectiveness AHRI Directory Survey."

= rated energy recovery ventilator supply air flow * (1 – Exhaust Air Transfer Ratio)

Exhaust Air Transfer Ratio = percentage of supply air made up of cross-leakage from exhaust air; value provided by vendor

= 0.05 (default)

CF = 1.0

Normalized Electric Peak Demand Savings

= kW/cfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 2 – Electric Peak Demand Savings Summary (kW/cfm)

Table 2 – Electric Peak Demand Savings Summary (kW/cfm)[484]

Building Type	Normalized Electric Demand Savings (kW/OA cfm)				
	Zone 1 - Rockford	Zone 2 - Chicago	Zone 3 - Springfield	Zone 4 - Mt. Vernon/Belleville	Zone 5 - Marion
Enthalpy Wheel - 75% sensible and latent efficiency					
Assembly	0.00127	0.00092	0.00111	0.00213	0.00209
Education	0.00159	0.00164	0.00282	0.00202	0.00308
Grocery	0.00115	0.00159	0.00152	0.00153	0.00187
Healthcare	0.00465	0.00433	0.00480	0.00443	0.00443
Multifamily	0.00210	0.00325	0.00298	0.00370	0.00381
Office	0.00538	0.00518	0.00527	0.00529	0.00589
Retail	0.00156	0.00195	0.00020	0.00217	0.00223
Enthalpy Plate - 50% sensible and latent efficiency					
Assembly	NA	NA	0.00024	0.00115	0.00113
Education	0.00114	0.00118	0.00201	0.00142	0.00218
Grocery	0.00059	0.00089	0.00083	0.00079	0.00102
Healthcare	0.00287	0.00284	0.00306	0.00292	0.00275
Multifamily	NA	0.00128	0.00111	0.00172	0.00167
Office	0.00351	0.00344	0.00344	0.00345	0.00384
Retail	0.00087	0.00123	0.00001	0.00119	0.00124

NATURAL GAS SAVINGS

Gas savings algorithm is derived from the following:

ΔTherms = (Design Heating Load * TE_ERV * EFLH * OccHours/24) / (100,000 * µHeat)

Where:

Design Heating Load = (1.08 * CFM * ΔT)

1.08 = A constant for sensible heat equations (BTU/h/CFM.°F)

CFM = Cubic Feet per Minute of Energy Recovery Ventilator

ΔT = T_RA – T_DD

T_RA = Temperature of the Return Air = 70°F or custom

[484] Demand savings modeled using IL TRM energy models with added energy recovery wheels or enthalpy plates. Energy recovery device specifications based on product data from the AHRI Certification Directory (https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f). Coincident demand measured according to TRM guidelines, though in 1-hour increments as established by the eQUEST simulation.

T_DD = Temperature on design day of outside air[485]

= (see Table below) or custom

Zone	Weather Station	T_DD, Temperature, °F
1	Greater Rockford	-5.8
2	Chicago/O'Hare ARPT.	-1.5
3	Springfield/Capital	0.4
4	Scott AFB MidAmerica	9.0
5	Cape Girardeau Regional	9.7
Average	-	2.4

TE_ERV = Thermal Effectiveness of Energy Recovery Equipment[486]

= (see Table below) or custom

Heat Recovery Equipment Type	TE_ERV (%)
Fixed Plate	0.65
Rotary Equipment	0.68
Heat Pipe	0.55

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

OccHours = Average Hours per day facility is occupied

= custom or use Modeling Inputs in eQuest models:

	Weekday	Saturday	Sunday	Holiday	Annual Operating Hours	OccHours
Assembly/Convention Center	10am-9pm	10am-9pm	10am-9pm	closed	3905	10.7
Assisted Living	24/7	24/7	24/7	24/7	8760	24.0
College	8am-9pm	closed	closed	closed	3263	8.9
Convenience Store	7am-10pm	9am-9pm	10am-5pm	10am-5pm	4823	13.2
Elementary School	8am-4pm (20% in summer)	closed	closed	closed	1606	4.4
Garage	7am-5pm	8am-12pm	closed	closed	3342	9.1
Grocery	7am-9pm	7am-9pm	9am-8pm	closed	4814	13.2
Healthcare Clinic	7am-7pm	9am-5pm	closed	closed	3428	9.4
High School	8am-4pm (20% in summer)	closed	closed	closed	1606	4.4
Hospital	24/7	24/7	24/7	24/7	8760	24.0
Motel	24/7	24/7	24/7	24/7	8760	24.0
Manufacturing Facility (Light Industry)	Mfg: 6am-10pm, Office: 8am-5pm	Mfg: 6am-10pm, Office: closed	closed	closed	4848	13.3
Multi-Family Mid-Rise	24/7; Reduced occupancy 7am - 5pm	24/7; Reduced occupancy 9am - 3pm	24/7; Reduced occupancy 9am - 3pm	24/7; Reduced occupancy 9am - 3pm	7038	19.3

485 Weather Station Data, 99.6% Heating DB - 2013 Fundamentals, ASHRAE Handbook

486 Energy Recovery Fact Sheet - Center Point Energy, MN

	Weekday	Saturday	Sunday	Holiday	Annual Operating Hours	OccHours
Multi-Family High-Rise	24/7; Reduced occupancy 7am - 5pm	24/7; Reduced occupancy 9am - 3pm	24/7; Reduced occupancy 9am - 3pm	24/7; Reduced occupancy 9am - 3pm	7038	19.3
Movie Theater	10am-Midnight	10am-Midnight	10am-Midnight	10am-Midnight	5110	14.0
Office - Low-rise	8am-5pm	closed	closed	closed	2259	6.2
Office - Mid-rise	8am-5pm	20% 8am-noon	closed	closed	2301	6.3
Office - High-rise	8am-5pm	20% 8am-noon	closed	closed	2301	6.3
Religious Building	Office: 8am-5pm, other: closed	closed	8am-1pm	closed	260	0.7
Restaurant	7am-8pm	7am-8pm	7am-8pm	closed	4615	12.6
Retail - Department Store	9am-9pm	9am-9pm	10am-5pm	10am-5pm	4070	11.1
Retail - Strip Mall	9am-9pm	9am-9pm	10am-5pm	10am-5pm	4070	11.1
Warehouse (Conditioned Storage)	7am-7pm	7am-7pm (reduced occupancy)	closed	closed	3324	9.1

µHeat = Efficiency of heating system

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ERVE-V03-190101

REVIEW DEADLINE: 1/1/2020

4.4.28 Stack Economizer for Boilers Serving HVAC Loads

Measure Description

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of HVAC boilers with stack economizers. HVAC boilers are defined as those used for space heating applications. There is another, similar measure for boilers that serve process loads.

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

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

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 for the boiler stack economizer is 15 years.[487]

Deemed Measure Cost

The incremental and full measure cost for this measure is custom.

Deemed O&M Cost Adjustments

The O&M cost for this measure is custom.

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

$$\Delta therms = SF * MBH\_In * EFLH / 100$$

Where:

[487] PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

SF = (T_existing – T_eff) / 40°F * TRE

= see default Savings Factor table below

Where:

T_existing = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 425F[488] (water, 81.9% eff) or custom

= 480F[3] (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)[489] or custom

= 365°F (conventional economizer – Steam Boiler)[490] or custom

= 280°F (condensing economizer – Water Boiler)[491] or custom

= 308°F (condensing economizer – Steam Boiler)[492] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[493] or custom

Based on defaults provided above:

Boiler Type	SF[494]	
	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

= Actual

EFLH = Equivalent Full Load Hours for heating are provided in Section 4.4 HVAC End Use

488 Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

489 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°F + 250°F) / 2 = 338°F.

490 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°F + 250°F) / 2 = 365°F.

491 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°F + 135°F) / 2 = 280°F.

492 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°F + 135°F) / 2 = 308°F.

493 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.

494 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-BECO-V01-150601

REVIEW DEADLINE: 1/1/2021

4.4.29 Stack Economizer for Boilers Serving Process Loads

MEASURE DESCRIPTION

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of process boilers with stack economizers. Process boilers are defined as those used for industrial, manufacturing, or other non-HVAC applications. There is another, similar measure for boilers that serve HVAC loads.

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

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

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 for the boiler stack economizer is 15 years.[495]

DEEMED MEASURE COST

The incremental and full measure cost for this measure is custom.

DEEMED O&M COST ADJUSTMENTS

The O&M cost for this measure is custom.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Δtherms = SF * MBH_In * 8766 * UF / 100

[495] PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

Where:

SF = (T_existing – T_eff)/40°F * TRE

= see default Savings Factor table below

T_existing = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 425F[496] (water, 81.9% eff per IL TRM) or custom

= 480F[3] (steam, 80.7% eff per IL TRM) or custom

T_eff = Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 338°F (conventional economizer – Water Boiler)[497] or custom

= 365°F (conventional economizer – Steam Boiler)[498] or custom

= 280°F (condensing economizer – Water Boiler)[499] or custom

= 308°F (condensing economizer – Water Boiler)[500] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[501] or custom

Based on defaults provided above:

Boiler Type	SF[502]	
	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

= Actual

8766 = Hours a year

UF = Utilization Factor

[496] Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

[497] 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°F + 250°F) / 2 = 338°F.

[498] 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°F + 250°F) / 2 = 365°F.

[499] 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°F + 135°F) / 2 = 280°F.

[500] 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°F + 135°F) / 2 = 308°F.

[501] 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.

[502] 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.

= 41.9%[503] or custom

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PECO-V01-150601

REVIEW DEADLINE: 1/1/2022

[503] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

4.4.30 Notched V Belts for HVAC Systems

Measure Description

This measure is for replacement of smooth v-belts in non-residential package and split HVAC systems with notched v-belts or for installing new equipment with synchronous belts instead of smooth v-belts. Typically there is a v-belt between the motor and the supply air fan and/or return air fan in larger package and split HVAC systems (RTU).

In general there are two styles of grooved v-belts, notched and synchronous. The DOE defines each as follows;

Notched V-Belts - A notched belt has grooves or notches that run perpendicular to the belt's length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts.

Synchronous Belts - Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Smooth v-belts are usually referred to in five basic groups:

- "L" belts are low end belts that are for small, fractional horsepower motors and these are not used in RTUs.
- "A" and "B" belts are the two types typically used in RTUs. The "A" belt is a ½ inch width by 5/16 inch thickness and the "B" belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
- "C" and "D" belts are primarily for industrial applications with high power transmission requirements.
- V-belts are provided by various vendors. The notched version of these belts typically have an "X" added to the designation. For this HVAC fans notched v-belt Replacement measure, only the "A" and "B" v-belts are considered. A typical "A" v-belt is replaced by a notched "AX" v-belt and a "B" is replaced by a "BX." In general, smooth v-belts have an efficiency of 90% to 98% while notched v-belts have an efficiency of 95% to 98%. Because notched v-belts are more flexible they work with smaller diameter pulleys and they have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

Three research papers[504] [505] [506] show that the notched v-belt efficiency is 2% to 5% better than a typical smooth v-belt. A fourth paper by USDOE's Energy Efficiency and Renewable Energy[507] group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

For this measure it is assumed that upgrading a standard smooth v-belt with a new notched v-belt will result in a fan energy reduction of 2%.

Definition of Efficient Equipment

For the Notched V-Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have notched v-belts installed on the supply and/or return air fans. This can be done as a retrofit, TOS, or NC project.

For the Synchronous Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have synchronous belts installed on the supply and/or return air fans. This can be done as a TOS or NC project. Retrofit projects can also claim savings, but costs should be verified independently (typically the cost of installing synchronous belts as a retrofit is not economically viable).

---

[504] "Gates Corporation Announces New EPDM Molded Notch V-Belts," The Gates Rubber Co., June 2010 (Assumed 3% efficiency improvement).

[505] "Synchronous Belt Drives Offer Low Cost Energy Savings," Baldor. February 2009. (attached in Reference Documents)

[506] "Energy Savings from Synchronous Belts," The Gates Rubber Co., February 2014. (Assumed 5% efficiency improvement)

[507] "Motor System Tip Sheet #5, Replace V-Belts with Cogged or Synchronous Belt Drives," USDOE-EERE, September 2005. (Assumed 2% efficiency improvement)

DEFINITION OF BASELINE EQUIPMENT

The Baseline Equipment is HVAC RTUs that have smooth v-belts installed on the supply and/or return air fans (i.e. RTU does not already have a notched v-belt installed).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

A v-belt has a life based on fan run hours which varies by building type based primarily on occupancy schedule because the fans are required by code to operate continuously during occupied hours. The supply and return fans will also run a few hours during unoccupied hours for heating and cooling as needed. For the notched v-belt EUL calculation, the default hours[508] in the following table are used for a variety of building types and HVAC applications.

EUL = Belt Life / Occupancy Hours per year

Where:

Belt Life = 24,000 hours[509]

Occupancy Hours per year = values from Table below

The notched v-belt measure EUL is summarized by building type in the following table.

Notched v-belt Effective Useful Life (EUL)

Building Type	Total Fan Run Hours	EUL (Years)	Model Source
Assembly	7235	3.3	eQuest
Assisted Living	8760	2.7	eQuest
College	6103	3.9	eQuest
Convenience Store	7004	3.4	eQuest
Elementary School	7522	3.2	eQuest
Garage	7357	3.3	eQuest
Grocery	7403	3.2	eQuest
Healthcare Clinic	6345	3.8	eQuest
High School	7879	3.0	eQuest
Hospital - VAV econ	8760	2.7	eQuest
Hospital - CAV econ	8760	2.7	eQuest
Hospital - CAV no econ	8760	2.7	eQuest
Hospital - FCU	8760	2.7	eQuest
Manufacturing Facility	8706	2.8	eQuest
MF - High Rise	8760	2.7	eQuest
MF - Mid Rise	8760	2.7	eQuest
Hotel/Motel - Guest	8760	2.7	eQuest
Hotel/Motel - Common	8760	2.7	eQuest
Movie Theater	7505	3.2	eQuest
Office - High Rise - VAV econ	6064	4.0	eQuest
Office - High Rise - CAV econ	5697	4.2	eQuest
Office - High Rise - CAV no econ	5682	4.2	eQuest
Office - High Rise - FCU	6163	3.9	eQuest
Office - Low Rise	6288	3.8	eQuest
Office - Mid Rise	6856	3.5	OpenStudio

[508] ComEd Trm June 1, 2010 page 139. The Office hours is based upon occupancy from the eQuest model developed for EFLH, since it was agreed the ComEd value was too low.
[509] "DEER2014-EUL-table-update_2014-02-05.xlsx," Database for Energy Efficiency Resources (DEER), DEER2014 EUL Table. (attached in Reference Documents)

Building Type	Total Fan Run Hours	EUL (Years)	Model Source
Religious Building	7380	3.3	eQuest
Restaurant	7809	3.1	eQuest
Retail - Department Store	7155	3.4	OpenStudio
Retail - Strip Mall	6846	3.5	eQuest
Warehouse	6832	3.5	OpenStudio
Unknown	7100	3.4	n/a

The lifetime of a synchronous belt system is the same as the lifetime of the equipment it is installed on because it is a permanent upgrade, involving the installation of toothed pulleys. Typical HVAC RTU lifetime is 15 years, which applies to synchronous belts as well. This is not to suggest that the actual belt component has an equivalent lifetime because they do require replacement. However, their O&M cost savings (derived from not having to tension, etc.) are assumed to offset the replacement cost of the belt, resulting in a net cost of zero. As a result, neither a separate lifetime nor O&M savings are quantified for synchronous belts and lifetime can therefore be considered as the lifetime of the equipment they're installed on because it would not be possible to install a traditional or notched belt on the synchronous pulleys.

DEEMED MEASURE COST

A review of the Grainger online[510] pricing for "A," "B," "AX," and "BX" v-belts showed the incremental cost to upgrade to notched v-belts would result in a 28% price increase. The notched v-belt incremental cost is summarized in the table below:

Notched V-belt Incremental Cost Summary

Smooth V-Belt Industry Number	Outside Length (Inches)	Dayton Smooth V-Belt*	Notched V-belt Industry Number	Dayton Notched v-belt*	Price Increase	% Increase
A30 (Item # 1A095)	32	$12.70	AX29 (Item # 3GWU4)	$17.65	$4.95	28%
B29 (Item # 6L208)	32	$16.75	BX29 (Item # 5TXL4)	$23.23	$6.48	28%
* Pricing based on Dayton Belts as found on Grainger Website 10/30/14						

Note that the incremental cost for notched V-Belts assumes that the notched belt is purchased and installed instead of a smooth v-belt. There is no difference in the cost of installation, only the material.

Synchronous Belt Incremental Cost Summary

Smooth V-Belt Industry Number	Smooth belt system Price*	Synchronous Belt Industry Number	Synchronous System Price*	Price Difference
Belt A30 (Item # 1A095)	$12.70	Belt 1DHL5 (Item # 322L050)	$20.51	$7.81
Gearbelt pulley BK47 (Item #5UHD5)	$45.90	Gearbelt sprocket GTR-36G-8M-12 (Item # 2UWH6)	$113.00	$67.10
* Costs based on Grainger pricing.				

Incremental cost for a NC or TOS project is $142. This is the price of synchronous equipment (belt, two sprockets) subtract v-belt equipment (belt, two pulleys). Labor cost is assumed to be equal in the baseline and efficient cases.

510 Grainger catalog on-line web-site for Dayton v-belt pricing

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor[511] to install it (not including a trip charge) subtract the cost of the v-belt (but not the pulleys).

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape C05 - Commercial Electric Heating and Cooling

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = kW_{connected} * Hours * ESF$

Where:

$kW_{Connected}$ =kW of equipment is calculated using motor efficiency[512].

= (HP * 0.746 kW/HP* Load Factor)/Motor Efficiency

Load Factor =Motors are assumed to have a load factor of 80% for calculating KW if actual values cannot be determined[513]. Custom load factor may be applied if known.

Motor Efficiency = Actual motor efficiency shall be used to calculate KW. If not known a value from the motor efficiency refrence tables below should be used[514]. Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

[511] Assumed to be $150 based on mechanical contractor estimate.
[512] Note that kWConnected may be determined using various methodologies. The examples provided use rated HP and assumed load factor. Other methodologies include rated voltage and full load current with assumed load factor, or actual measured voltage and current.
[513] Com Ed TRM June 1, 2010
[514] Efficiency values for motors less than one HP taken from Baldor Electric Catalog 501, standard motor product catalog.

Baseline Motor Efficiencies (EPACT)						
Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles					
	6	*4*	*2*	*6*	*4*	*2*
	Speed (RPM)					
	1200	*1800*	*3600*	*1200*	*1800*	*3600*
1/8	-	44.00%	-	-	-	-
1/6	57.50%	62.00%	-	-	-	-
1/4	68.00%	68.00%	-	68.00%	64.00%	-
1/3	70.00%	70.00%	72.00%	70.00%	68.00%	72.00%
1/2	78.50%	80.00%	68.00%	72.00%	74.00%	68.00%
3/4	77.00%	78.50%	74.00%	77.00%	75.50%	74.00%
1	80.00%	82.50%	75.50%	80.00%	82.50%	75.50%
1.5	84.00%	84.00%	82.50%	85.50%	84.00%	82.50%
2	85.50%	84.00%	84.00%	86.50%	84.00%	84.00%
3	86.50%	86.50%	84.00%	87.50%	87.50%	85.50%
5	87.50%	87.50%	85.50%	87.50%	87.50%	87.50%
7.5	88.50%	88.50%	87.50%	89.50%	89.50%	88.50%
10	90.20%	89.50%	88.50%	89.50%	89.50%	89.50%
15	90.20%	91.00%	89.50%	90.20%	91.00%	90.20%
20	91.00%	91.00%	90.20%	90.20%	91.00%	90.20%
25	91.70%	91.70%	91.00%	91.70%	92.40%	91.00%

Efficient Motor Efficiencies (NEMA Premium)						
Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	2	4	6	2	4	6
	Speed (RPM)			Speed (RPM)		
	1200	1800 (Default)	3600	1200	1800	3600
0.125 *	-	44.00%	-	-	-	-
1/6	57.50%	62.00%	-	-	-	-
1/4	68.00%	68.00%	-	68.00%	64.00%	-
1/3	70.00%	70.00%	72.00%	70.00%	68.00%	72.00%
1/2	78.50%	80.00%	68.00%	72.00%	74.00%	68.00%
3/4	77.00%	78.50%	74.00%	77.00%	75.50%	74.00%
1	82.50%	85.50%	77.00%	82.50%	85.50%	77.00%
1.5	86.50%	86.50%	84.00%	87.50%	86.50%	84.00%
2	87.50%	86.50%	85.50%	88.50%	86.50%	85.50%
3	88.50%	89.50%	85.50%	89.50%	89.50%	86.50%
5	89.50%	89.50%	86.50%	89.50%	89.50%	88.50%
7.5	90.20%	91.00%	88.50%	91.00%	91.70%	89.50%
10	91.70%	91.70%	89.50%	91.00%	91.70%	90.20%
15	91.70%	93.00%	90.20%	91.70%	92.40%	91.00%
20	92.40%	93.00%	91.00%	91.70%	93.00%	91.00%
25	93.00%	93.60%	91.70%	93.00%	93.60%	91.70%

Hours = When available, actual hours should be used. If actual hours are not available default hours[515] are provided in table below for HVAC fan operation which varies by building type:

Building Type	Total Fan Run Hours	Model Source
Assembly	7235	eQuest
Assisted Living	8760	eQuest
College	6103	eQuest
Convenience Store	7004	eQuest
Elementary School	7522	eQuest
Garage	7357	eQuest
Grocery	7403	eQuest
Healthcare Clinic	6345	eQuest
High School	7879	eQuest
Hospital - VAV econ	8760	eQuest
Hospital - CAV econ	8760	eQuest
Hospital - CAV no econ	8760	eQuest
Hospital - FCU	8760	eQuest
Manufacturing Facility	8706	eQuest
MF - High Rise	8760	eQuest
MF - Mid Rise	8760	eQuest
Hotel/Motel - Guest	8760	eQuest
Hotel/Motel - Common	8760	eQuest
Movie Theater	7505	eQuest
Office - High Rise - VAV econ	6064	eQuest
Office - High Rise - CAV econ	5697	eQuest
Office - High Rise - CAV no econ	5682	eQuest
Office - High Rise - FCU	6163	eQuest
Office - Low Rise	6288	eQuest
Office - Mid Rise	6856	OpenStudio
Religious Building	7380	eQuest
Restaurant	7809	eQuest
Retail - Department Store	7155	OpenStudio
Retail - Strip Mall	6846	eQuest
Warehouse	6832	OpenStudio
Unknown	7100	n/a

ESF = Energy Savings Factor, the ESF for notched v-belt Installation is assumed to be 2%

= the ESF for notched Synchronous Belt Installation is assumed to be 3.1%[516]

[515] Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

[516] Based on information found in Advanced Manufacturing Office, US DOE, "Replace V-Belts with Notched or Synchronous Drives", (US Department of Energy Motor Systems Tip Sheet #5, DOE/GO-102012-3740, November 2012). V-belt drives can have a peak efficiency of 95% and synchronous belts operate at 98%, therefore ESF is (1-95%/98%) = 3.1%.

EXAMPLE

For example, a notched v-belt installation in an low rise office building RTU with a 5 HP NEMA premium efficiency motor using the default hours of operation, motor load and 89.5% motor efficiency;

$\Delta kWh = kW_{connected} * Hours * ESF$

$= ((HP * 0.746\ kW/HP * Load\ Factor)/Motor\ Efficiency) * Hours * ESF$

$= ((5\ HP * 0.746\ kW/HP * 80\%) / 89.5\%) * 6288 * 2\%$

= 419 kWh Savings

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = kW_{connected} * ESF$

Where:

$kW_{Connected}$ = kW of equipment is calculated using motor efficiency.

$= (HP * 0.746\ kW/HP * Load\ Factor)/Motor\ Efficiency$

Variables as provided above

EXAMPLE

For example, an office building RTU with a 5 HP NEMA premium efficiency motor using the default motor load and 89.5% motor efficiency;

$\Delta kW = kW_{connected} * ESF$

$= ((HP * 0.746\ kW/HP * Load\ Factor)/Motor\ Efficiency) * ESF$

$= ((5\ HP * 0.746\ kW/HP * 80\%) / 89.5\%) * 2\%$

= 0.0667 kW Savings

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-NVBE-V04-190101

REVIEW DEADLINE: 1/1/2022

4.4.31 Small Business Furnace Tune-Up

DESCRIPTION

This measure is for a natural gas Small Business furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an approved technician must complete the tune-up requirements[517] listed below:

- 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
- 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 thermostat operation is per manufacturer's recommendations (if adjustments made, refer to 'Small Commercial Programmable Thermostat Adjustment' measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

DEFINITION OF BASELINE EQUIPMENT

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune up is 2 years.[518]

DEEMED MEASURE COST

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

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

LOADSHAPE

Loadshape C04 - Commercial Electric Heating

[517] American Standard Heating & Air Conditioning, Maintenance for Indoor Units
[518] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

COINCIDENCE FACTOR

N/A

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = ΔTherms * F_e * 29.3

Where:

ΔTherms = as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[519]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = (Capacity * EFLH * (((Effbefore + Ei)/ Effbefore) – 1)) / 100,000

Where:

Capacity = Furnace gas input size (Btu/hr)

= Actual

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Effbefore = Efficiency of the furnace before the tune-up

= Actual

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

100,000 = Converts Btu to therms

[519] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

EXAMPLE

A 200 kBtu furnace in a Rockford low rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

Δtherms = (200,000 * 1428 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 62.3 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-FTUN-V02-160601

REVIEW DEADLINE: 1/1/2022

4.4.32 Combined Heat and Power

DESCRIPTION

The Combined Heat and Power (CHP) measure can provide energy savings within the State of Illinois through the development and operation of CHP projects. This measure is applicable for Conventional or Topping Cycle CHP systems, as well as Waste Heat-to-Power (WHP) or Bottoming Cycle CHP systems. The measure will reduce the total Btu's of energy required to meet the end use needs of the facility.

It is recognized that CHP system design and configuration may be complex, and as such the calculation of energy savings may not be reducible to the equations within this measure. In such cases a more comprehensive engineering and financial analysis may be developed that more accurately incorporates the attributes of complex CHP configurations such as variable-capacity systems, and partial combined-cycle CHP systems. Where noted, the use of values that are determined through an external engineering analysis may be substituted by agreement between the participant, the program administrator and independent evaluator. This substitution of values does not eliminate ex post evaluation risk (retroactive adjustments to savings claims) that exists when using custom inputs.

This measure was developed to be applicable to the following program types: Retrofit (RF), New Construction (NC). If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Conventional or Topping Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that utilizes a prime mover (reciprocating engine, gas turbine, micro-turbine, fuel cell, boiler/steam turbine combination) for the purpose of generating electricity and useful thermal energy (such as steam, hot water, or chilled water) where the primary function of the facility where the CHP is located is not to generate electricity for use on the grid. An eligible system must demonstrate a minimum total system efficiency of 60% (HHV)[520] with at least 20% of the system's total useful energy output in the form of useful thermal energy on an annual basis.

Measuring and Calculating Conventional CHP Total System Efficiency:

CHP efficiency is calculated using the following equation:

$$CHP_{Efficiency}(HHV) = \frac{\left[CHP_{thermal}\ \left(\frac{kBtu}{yr}\right) + E_{CHP}\ \left(\frac{kWh}{yr}\right) * 3.412\ \left(\frac{kBtu}{kWh}\right)\right]}{F_{totalCHP}\left(\frac{kBtu}{yr}\right)}$$

Where:

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

$F_{totalCHP}$ = Total annual fuel consumed by the CHP system

For further definition of the terms, please see "Calculation of Energy Savings" Section below.

---

[520] Higher Heating Value (HHV): refers to the heating value of the fuel and is defined as the total thermal energy available, including the heat of condensation of water vapors,resulting from complete combustion of the fuel versus the Lower Heating Value (LHV) which assumes the heat of condensation is not available

Waste Heat-to-Power or Bottoming Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that does one of the following:

- Utilizes exhaust heat from an industrial/commercial process to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid); or
- Utilizes the pressure drop in an industrial/commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility; or
- Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

Since these types of systems utilize waste heat as their fuel, they do not have to meet any specific total system efficiency level (assuming they use no additional fossil fuel in their operation) If additional fuel is used onsite, it should be accounted for using the following methodology:

- Treat the portion of Waste-Heat-to-Power that does not require any additional fuel using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of Waste-Heat-to-Power that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

These systems may export power to the grid.

DEFINITION OF BASELINE EQUIPMENT

Electric Baseline: The baseline facility would be a facility that purchases its electric power from the grid.

Heating Baseline (for CHP applications that displace onsite heat): The baseline equipment would be the boiler/furnace operating onsite, or a boiler/furnace meeting the baseline equipment defined in the High Efficiency Boiler (Section 4.4.10)/Furnace (Section 4.4.11) measures of this TRM.

Cooling Baseline (for CHP applications that displace onsite cooling demands): The baseline equipment would be the chiller (or chillers) operating onsite, or a chiller (or chillers) meeting the definition of baseline equipment defined in the Electric Chiller (Section 4.4.6) measure of this TRM.

Facilities that use biogas or waste gas: Facilities that use (but are not purchasing) biogas or waste gas that is not otherwise used, whether they are using biogas or waste gas only or a combination of biogas or waste gas and natural gas to meet their energy demands are also eligible for this measure. If additional fuel is purchased to power the CHP system, then the additional natural gas should be taken into account using the following methodology:

- Treat the portion of CHP system that does not require any additional fuel, or that requires additional fuel that would otherwise be wasted (e.g. flared), using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of CHP that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

Consumption of any biogas or waste gas that would not otherwise being wasted (*e.g.,* flared) will be accounted for in the overall net BTU savings calculations the same as for purchased natural gas.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Measure life is a custom assumption, dependent on the technology selected and the system installation.

DEEMED MEASURE COST

Custom installation and equipment cost will be used. These costs should include the cost of the equipment and the cost of installing the equipment. Equipment costs include, but are not limited to: prime mover, heat recovery system(s), exhaust gas treatment system(s), controls, and any interconnection/electrical connection costs.

The installations costs include labor and material costs such as, but not limited to: labor costs, materials such as ductwork, piping, and wiring, project and construction management, engineering costs, commissioning costs, and other fees.

Measure costs will also include the present value of expected maintenance costs over the life of the CHP system.

LOADSHAPE

Use Custom Loadshape. The loadshape should be obtained from the actual CHP operation strategy, based on the On-Peak and Off-Peak Energy definitions specified in Table 3.3 of “Section 3.5 Electrical Loadshapes” of the TRM.

COINCIDENCE FACTOR

Custom coincidence factor will be used. Actual value based on the CHP operation strategy will be used.

Algorithm

CALCULATION OF ENERGY SAVINGS

i) Conventional or Topping Cycle CHP Systems:

Step 1: (Calculating Total Annual Source Fuel Savings in Btus)

The first step is to calculate the total annual source fuel savings associated with the CHP installation, in order to ensure the CHP project produces positive total annual source fuel savings (i.e. reduction in source Btus):

$S_{FuelCHP}$ = Annual fuel savings (Btu) associated with the use of a Conventional CHP system to generate the useful electricity output (kWh, converted to Btu) and useful thermal energy output (Btu) versus the use of the equivalent electricity generated and delivered by the local grid and the equivalent thermal energy provided by the onsite boiler/furnace.

$= (F_{grid} + F_{thermalCHP}) – F_{total\ CHP}$

Where:

F_{grid} = Annual fuel in Btu that would have been used to generate the useful electricity output of the CHP system if that useful electricity output was provided by the local utility grid.

$= E_{CHP} * H_{grid}$

Where:

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process. [521]

$= (CHP_{capacity} * Hours\ ) - E_{Parasitic}$

$CHP_{capacity}$ = CHP nameplate capacity

= Custom input

[521] For complex systems this value may be obtained from a CHP System design/financial analysis study.

$Hours$ = Annual operating hours of the system

= Custom input

$E_{parasitic}$ = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

= Custom input

H_{grid} = Heat rate of the grid in Btu/kWh, based on the average fossil heat rate for the EPA eGRID subregion, adjusted to take into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[522]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest). Also include any line losses.

$F_{thermalCHP}$ = Annual fuel in Btu that would have been used on-site by a boiler/furnace to provide the useful thermal energy output of the CHP system. [523]

= $CHP_{thermal}$ / $Boiler_{eff}$ (or $CHP_{thermal}$ / $Furnace_{eff}$)

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

= Custom input

$Boiler_{eff}$ /$Furnace_{eff}$= Efficiency of the on-site Boiler/Furnace that is displaced by the CHP system or if unknown, the baseline equipment value stated in the High Efficiency Boiler (Section 4.4.10) measure or High Efficiency Furnace (Section 4.4.11) measure in this TRM. .

= Custom input

$F_{total\ CHP}$ = Total fuel in Btus consumed by the CHP system

= Custom input

<u>Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))</u>

Savings claims are a function of the electric output of the CHP system (E_{CHP}), the used thermal output of the CHP system ($F_{thermalCHP}$), and the CHP system efficiency (CHP_{Eff}(HHV)). The percentages of electric output and used

[522] These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

[523] For complex systems this value may be obtained from a CHP System design/financial analysis study.

thermal output that can be claimed also differ slightly depending on whether the project was included in both electric[524] and gas[525] Energy Efficiency Portfolio Standard (EEPS)[526] efficiency programs, only an electric EEPS program or only a gas EEPS program. The tables below provide the specific percentages of electric and/or thermal output that can be claimed under each of those three scenarios. These percentages apply only to cases in which natural gas is the fuel used by the CHP system. Saving estimates for systems using other fuels should be calculated on a custom basis. If the waste heat recovered from the CHP system is offsetting electric equipment, such as an absorption chiller offsetting an electric chiller, then the net change in electricity consumption associated with the electric equipment should be added to the allocated electric savings.

1) For systems participating in both electric EEPS and gas EEPS programs:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP} (kWh)	No gas savings
>60% to 65%	65% of E_{CHP} (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of E_{CHP} in kWh)	No gas Savings
>65%	70% of E_{chp} (kWh)	2.5% of $F_{thermal}$ (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 65%.

Example: System with measured annual system efficiency (HHV) of 70%: Electric savings (kWh) = 70% of E_{CHP} measured over 12 months, and Gas savings (therms) = 12.5% of $F_{thermal}$ measured over 12 months (70% - 65% = 5 X 2.5% = 12.5%)

2) For systems participating in only an electric EEPS program:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP} (useful electric output of CHP system in kWh)	No gas Savings
Greater than 60%	65% + one percentage point increase for every one percentage point increase in CHP system efficiency (no max)	No gas Savings

Example: System with measured annual fuel use efficiency of 75%: Electric savings (kWh) = 65% + 15% = 80% of E_{CHP} measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

3) For systems participating in only a gas EEPS program:

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60% or greater	No electric savings	2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%.

[524] 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B
[525] 220 ILCS 5/8-104
[526] As used in this measure characterization, EEPS programs are defined as those energy efficiency programs implemented pursuant to Sections 8-103, 8-104, and 16-111.5B of the Illinois Public Utilities Act. Technically, EEPS programs pertain to energy efficiency programs implemented pursuant to 220 ILCS 5/8-103 and 220 ILCS 5/8-104. However, for simplicity in presentation, this measure defines EEPS programs as also including those programs implemented pursuant to 220 ILCS 5/16-111.5B (these programs are funded through the same energy efficiency riders established pursuant to Section 8-103).

Example: System with measured annual system efficiency (HHV) of 70%: No Electric savings (kWh). Gas savings (therms) = 25% of $F_{thermal}$ measured over 12 months (70% - 60% = 10 X 2.5% = 25%)

Conventional or topping cycle CHP systems virtually always require an increase in the use of fuel on-site in order to produce electricity. Different jurisdictions and experts across the country have employed and/or put forward a variety of approaches[527] to address how increased on-site fuel consumption should be reflected in the attribution of electric savings to CHP systems. The approach reflected in the tables above is generally consistent – for CHP systems consuming natural gas – with approaches recently put forward by the Southwest Energy Efficiency Project (SWEEP) and Institute for Industrial Productivity (IIP) that determine reduced electric savings based on the equivalent amount of carbon dioxide generated from the increased fuel used[528].

There are a variety of ways one could treat the potential for gas utilities to claim savings from CHP projects in their EEPS portfolios. For projects in which a natural gas EEPS program is involved, the tables above treat savings from CHP installations in two steps: (1) a fuel-switch from electricity to natural gas (i.e. using more natural gas to eliminate the need to generate as much electricity on the grid); and (2) possible increases in CHP efficiency above a “benchmark” level. When both electric EEPS and natural gas EEPS programs are involved in a project, the program administrator claims all the electricity savings associated with a fuel-switch up to a “benchmark” 65% efficient CHP system. All the savings associated with increasing CHP efficiencies above that benchmark level are allocated to natural gas (e.g. if the CHP efficiency is 75%, the natural gas savings associated with an increase in CHP efficiency from 65% to 75% are allocated to natural gas). That is consistent with the notion that CHP efficiency typically increases primarily by increasing the use of the thermal output of the system (increasing the displacement of baseline gas use). For projects that involve only a natural gas EEPS program, the “benchmark” above which the gas utility can claim savings is lowered to 60%.

ii) **Waste-Heat-to-Power CHP Systems :**

ELECTRIC ENERGY SAVINGS:

$$\Delta kWh = E_{CHP}$$

Where:

E_{CHP} = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

= Custom input

527 Approaches range from ignoring the increased gas use entirely (i.e., no “penalty”) to applying approximately 40-60% “penalties”, depending on the CHP efficiency and based on the equivalent grid kWh that the increased gas use represents.

528 Consider, for example, a hypothetical CHP system that produces 5 million kWh annually, consumes 50 million kBtu of gas annual to generate that electricity (i.e. electric efficiency of approximately 34.8% HHV), reduces on-site gas use for space heating by 26 million kBtu of gas (i.e. equivalent to approximately 81.5% CHP thermal output utilization displacing gas used in a 70% efficient space heating boiler) and has a total annual CHP efficiency of 70.6% HHV. In this example, the net increase in on-site gas use is 24 million kBtu. At a carbon dioxide emission rate of 53.06 kg/MMBtu for burning natural gas, that translates to an increase in on-site carbon dioxide emissions of 1404 tons per year. At an estimated marginal emission rate of 1.098 tons of carbon dioxide per MWh in Illinois, that is equivalent to electric grid production of approximately 1.28 million kWh, or penalty of about 25.6% of the CHP system’s electrical output if a precise calculation of carbon equivalency was utilized to assign savings. In comparison, the simplified table above would entitle an electric utility to claim savings equal to 75.6% of the electric output (i.e. a penalty of 24.4% of electrical output) if it was the only utility promoting the system. In a gas and electric example, the electric savings claimed would be 70% of the production (a penalty of 30% of the CHP system’s electrical output) and 12.5% of the recovered thermal output, equivalent to 2.23 million kBtu. The difference between the electric only scenario and the electric and gas, on the electric side, is 5% of the electric output or 250,000 kWh, which would require 2.45 million kBtu input at an efficiency of 34.8% HHV.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = CF * CHP_{capacity}$

Where:

CF = Summer Coincidence factor. This factor should also consider any displaced chiller capacity[529]

= Custom input

$CHP_{Capacity}$ = CHP nameplate capacity

= Custom input

NATURAL GAS ENERGY SAVINGS:

$\Delta Therms = F_{thermalCHP} \div 100{,}000$

Where:

$F_{thermalCHP}$ = Net savings in annual purchased fuel in Btu, if any, that would have been used on-site by a boiler/furnace to provide some or all of the useful thermal energy output of the CHP system[530].

100,000 = Conversion factor for Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Custom estimates of maintenance costs that will be incurred for the life of the measure will be used**.** Maintenance costs vary with type and size of the prime mover. These costs include, but are not limited to:

- Maintenance labor
- Engine parts and materials such as oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc. and consumables such as oil
- Minor and major overhauls

For screening purposes, the US EPA has published resource guides that provide average maintenance costs based on CHP technology and system size[531].

COST-EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING

For the purposes of forecasting load reductions due to CHP projects, changes in site energy use at the customer's meter – reduced consumption of utility provided electricity – adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

For the purposes of screening a CHP measure application for cost-effectiveness, changes in site energy use – reduced consumption of utility provided electricity and the net change in consumption of fuel – should be used. In general, the benefit and cost components used in evaluating the cost-effectiveness of a CHP project would include at least the following terms:

[529] If some or all of the existing electric chiller peak demand is no longer needed due to new waste heat powered chillers (e.g., absorption), the coincidence factor should be adjusted appropriately.
[530] In most cases, it is expected that waste-heat-to-power systems will not provide any new net useful thermal energy output, since the CHP system will be driven by thermal energy that was otherwise being wasted. If additional natural gas or other purchased energy is used onsite, it should be properly accounted for.
[531] "EPA Combined Heat and Power Partnership Resources" Oct 07, 2014, in the document "Catalog of CHP Technologies", US EPA, September 2017, pages 2-16,, 3-14, 4-14, 5-14, and 6-16.

Benefits: $E_{CHP} + \Delta kW + F_{thermal\_CHP}$

Costs: $F_{total\_CHP} + CHP_{COSTS} + O\&M_{COSTS}$

Where:

CHP_{Costs} = CHP equipment and installation costs as defined in the "Deemed Measure Costs" section

$O\&M_{Costs}$ = CHP operations and maintenance costs as defined in the "Deemed O&M Cost Adjustment Calculation" section

MEASURE CODE: CI-HVC-CHAP-V03-190101

REVIEW DEADLINE: 1/1/2022

4.4.33 Industrial Air Curtain

DESCRIPTION

This measure applies to buildings with exterior entryways that utilize overhead doors. All other air curtain applications, such as through sliding door entryways or conventional foot-traffic entryways, require custom analysis as air curtain designs must often accommodate other factors that may change their effectiveness.

The use of overhead doors within exterior entryways during the heating season leads to the exfiltration of warm air from the upper portion of the door opening and the infiltration of colder air from the lower portion of the door opening. This results in increase heating energy use to compensate for heat losses every time a door is opened. By reducing heat losses, air curtains can also enhance the physical comfort of employees or customers near the entryway as there will be reduced temperature fluctuations when the door is opened and closed. In addition, in some cases excess heating capacity may be installed in buildings to meet this larger heating load. The addition of air curtains to exterior entryways that currently utilize overhead doors will result in energy savings and enhanced personal comfort, and also possibly in reduced equipment sizing and corresponding costs.

The primary markets for this measure are commercial and industrial facilities with overhead doors in exterior entryways, including but not limited to the following building types: retail, manufacturing, and warehouse (non-refrigerated).

Limitations

- For use in conditioned spaces with an overhead door in an exterior entryway. This measure does include other door types such doorways to commercial spaces such as retail.
- This measure should only be applied to spaces in which the overhead door separates a conditioned space and an unconditioned space.
- Installation must follow manufacturer recommendations to attain proper air velocity, discharge angle down to the floor level, and unit position.
- Certain heating systems may not be a good fit for air curtains, such as locations with undersized heating capacity. In these cases, the installation of an air curtain may not effectively reduce heating system cycling given the inappropriately sized heating capacity.
- Buildings with slightly positive to slightly negative (~5 Pa to -10 Pa). For all other scenarios, custom analysis is recommended.
- Measure assumes that wind speeds at near ground level are less than or equal to 12 mph for 90% of the heating or cooling season. For areas with more extreme weather, custom analysis is necessary.
- Note: for cost effectiveness, it is recommended that minimum door open times should be approximately 15 hours per week.[532]

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.

The following methodology is highly complex and requires significant data collection. It is hoped that simplifying steps can be made in future iterations based on continued metering and evaluation of installations. Also the data collected through implementing the measure in the way currently drafted will aid in simplifying efforts at a future date.

DEFINITION OF EFFICIENT EQUIPMENT

Overhead air curtains designed for commercial and industrial applications that have been tested and certified in accordance with ANSI/AMCA 220 and installed following manufacturer guidelines. Measure is for standard models without added heating.

[532] Spentzas, Steve, et. al, "1009: Commercial and Industrial Air Curtains – Public Project Report," Nicor Gas Emerging Technology Program (Oct 2014): 9

DEFINITION OF BASELINE EQUIPMENT

No air curtain or other currently installed means to effectively reduce heat loss and air mixing during door openings, such as a vestibule or strip curtain.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[533]

DEEMED MEASURE COST

The incremental capital cost for overhead air curtains for exterior entryways are as follows, with an added average installation cost approximately equal to the capital cost.[534]

Door Size	Capital Cost
8'w x 8'h	$3,600
10'w x 10'h	$4,500
10'w x 12'h	$5,400
12'w x 14'h	$8,000
16'w x 16'h	$13,300

LOADSHAPE

Heating Season: If electric heating, use Commercial Electric Heating Loadshape: C04. Otherwise, N/A

Cooling Season: Commercial Cooling Loadshape C03. Or, if applicable, use Commercial Electric Heating and Cooling Loadshape C05.

COINCIDENCE FACTOR

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[535]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [536]

Algorithm

CALCULATION OF ENERGY SAVINGS

The following formulas provide a methodology for estimating cooling load (kWh) and heating load (therm) savings associated with the installation of air curtains on exterior entryways such as a single door or loading bay. This algorithm is based on the assumption that therm savings are directly related to the difference in cooling or heating losses due to infiltration or exfiltration through an entryway before and after the installation of an AMCA certified air curtain. Energy savings are assumed to be the result of a reduction of natural infiltration effects due to wind and thermal forces and follow the calculation methodology outlined by the ASHRAE Handbook.[537] The calculation assumes that the air curtain is appropriately sized and commissioned to be effective in mitigating infiltration of winds

---

[533] Navigant Consulting Inc, Measures and Assumptions for Demand Side Management (DSM) Planning: Appendix C: Substantiation Sheets, "Air Curtains – Single Door," Ontario Energy Board, (April 2009): C-137.
2014 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, February 4, 2014.

[534] Based on manufacturer interviews and air curtain specification sheets.

[535] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[536]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[537] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): Ch 16.1 - 16.37

of up to 12 mph for at a least 90% of the year (based on manufacturer literature and TMY3 wind speed ranges at near ground level for Illinois).[538] Additionally, this measure assumes the HVAC systems are appropriately balanced such that the maximum pressure differential between indoor air and outdoor air is within the range of 5 Pa < ΔP < -10 Pa.[539] Custom analysis is necessary if building pressurization exceeds this range. However, while effectiveness decreases, some studies suggest that air curtains outperform vestibules and single door construction for negatively pressurized buildings with a ΔP of above -30 Pa.[540]

This algorithm allows either actual inputs or provides estimates if actual data is not available. All weather dependent values are derived from TMY3 data for the closest weather station to those locations defined elsewhere in the Illinois TRM (which are based on 30 year climate normals). If TMY3 weather station data was not available for the data used in the Illinois TRM, the next closest weather station was used. It is assumed that weather variations are negligible between the weather stations located within the same region. This approach was followed as the air curtain algorithm has a number of weather dependent variables which are all calculated in relation to the heating season or cooling season as defined by the balance point temperature deemed appropriate for the facility. All weather dependent data is based on TMY3 data and is listed in tables by both climate zone and balance point temperature, which is then normalized to the Illinois TRM climate zoned HDD/CDD definitions unless otherwise noted.

ELECTRIC ENERGY SAVINGS

$\Delta kWhcooling = [(Q_{tbc} – Q_{tac}) / EER – (HP * 0.7457)] * t_{open} * CD$

$\Delta kWhHPheating = [(Q_{tbc} – Q_{tac}) / HSPF – (HP * 0.7457)] * t_{open} * HD$

$\Delta kWhGasheating = - (HP * 0.7457) * t_{open} * HD$

Where:

Q_{tbc} = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)

Q_{tac} = rate of total heat transfer through the open entryway, after air curtain (kBtu/hr)

(see calculation in 'Heat Transfer Through Open Entryway with/without Air Curtain' sections below)

EER = energy efficiency ratio of the cooling equipment (kBtu/kWh)

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

HP = Input power for air curtain (hp)

= Actual value. If actual value not available, use the following estimates based on manufacturer specs

Door Size	Fan HP
8'w x 8'h	1
10'w x 10'h	1.5
10'w x 12'h	4
12'w x 14'h	6

538 National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological Year 3, NREL.

539 Spentzas, Steve, et. al, "1009: Commercial and Industrial Air Curtains – Public Project Report," Nicor Gas Emerging Technology Program (Oct 2014): 10
Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

540 Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

Door Size	Fan HP
16'w x 16'h	12

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

t_{open} = average hours per day the door is open (hr/day)

= Actual or user defined estimated value.

CD = cooling days per year, total days in year above balance point temperature (day)

= use table below to select the best value for location[541]

.	CD (Balance Point Temperature)				
Climate Zone -Weather Station/City	45 ºF	50 ºF	55 ºF	60 ºF	65 ºF
1 - Rockford AP / Rockford	194	168	148	124	97
2 - Chicago O'Hare AP / Chicago	194	173	153	127	95
3 - Springfield #2 / Springfield	214	194	174	148	114
4 - Belleville SIU RSCH / Belleville	258	229	208	174	138
5 - Carbondale Southern IL AP / Marion	222	201	181	158	130

HSPF = Heating System Performance Factor of heat pump equipment

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[542]:

	HD				
Climate Zone Weather Station/City	45 ºF	50 ºF	55 ºF	60 ºF	65 ºF
1 -Rockford AP / Rockford	142	160	183	204	228
2 - Chicago O'Hare AP / Chicago	150	166	192	219	253
3 - Springfield #2 / Springfield	125	142	167	194	230
4 - Belleville SIU RSCH / Belleville	101	115	134	156	180
5 - Carbondale Southern IL AP / Marion	103	123	148	174	205

Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

Q_{tbc} = 4.5 * CFM_{tot} *(h_{oc} – h_{ic}) / (1,000 Btu/kBtu)

Where:

[541] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological Year 3, NREL.
Note that cooling days (CD) are calculated by first determining its value from the TMY3 data associated with the appropriate weather station as defined by and used elsewhere in the Illinois TRM. Using the TMY3 outdoor air dry bulb hourly data, the annual hours are totaled for every hour that the outdoor air dry bulb temperature is above a designated zero heat loss balance point temperature or base temperature for cooling. For commercial and industrial (C&I) buildings, a base temperature for heating of 55 ºF is designated in the Illinois TRM, but building specific base temperatures are recommended for large C&I projects. Additionally, the TRM uses a 30-year normal data for degree-days while the CD calculation was based on TMY3 data; in order to account for this, calculations of CD were also normalized by the ratio of CDD to align the calculated values more closely with the TRM.

[542] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

4.5 = unit conversion factor with density of air: 60 min/hr * 0.075 lbm/ft3 (lb*min/(ft*hr))

CFM_{tot} = Total air flow through entryway (cfm), see calculation below

h_{oc} = average enthalpy of outside air during the cooling season (Btu/lb)

= use the below table to determine the approximate outdoor air enthalpy associated with an indoor temperature setpoint and climate zone.[543]

	h_{oc}		
Climate Zone -Weather Station/City	**67 °F**	**72 °F**	**77 °F**
1 -Rockford AP / Rockford	31.6	33.0	35.3
2 - Chicago O'Hare AP / Chicago	32.0	33.6	35.4
3 - Springfield #2 / Springfield	32.9	34.6	36.6
4 - Belleville SIU RSCH / Belleville	33.5	35.0	36.4
5 - Carbondale Southern IL AP / Marion	34.6	36.2	37.7

h_{ic} = average enthalpy of indoor air, cooling season (Btu/lb)

= use the below table to determine the approximate indoor air enthalpy associated with an indoor temperature setpoint in indoor relative humidity.

	h_{ic}		
Relative Humidity (%)	**67 °F**	**72 °F**	**77 °F**
60	25.5	28.5	31.8
50	23.9	26.6	29.5
40	22.3	24.7	27.3

= an estimate 26.6 Btu/lb associated with the 72 °F and 50% indoor relative humidity case can be used as an approximation if no other data is available. For other indoor temperature setpoints and RH, enthalpies may be interpolated.

The total airflow through the entryway, CFM_{tot}, includes both infiltration due to wind as well as thermal forces, as follows:

CFM_{tot} = sqrt[$(CFM_w)^2 + (CFM_t^2)$]

Where:

CFM_w = Infiltration due to the wind (cfm)

CFM_t = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFM_w = $(v_{wc} * C_{wc}) * C_v * A_d$ * (88 fpm/mph)

Where:

v_{wc} = average wind speed during the cooling season based on entryway orientation (mph)

[543] Average enthalpies were estimated following ASHRAE guidelines for perfect gas relationships for dry air associated with hourly TMY3 data. Enthalpies were then averaged for all values associated with a dry-bulb outdoor air temperature that exceeded the indoor air temperature setpoint. Other enthalpy values may be interpolated for indoor air temperature setpoints not represented in the table. Note that while outdoor air enthalpies increase with higher temperature setpoints, the change in enthalpy from indoor to outdoor will decrease.

= use the below table to for the wind speed effects based on climate zone and entryway orientation[544]:

	Entryway Orientation			
Climate Zone -Weather Station /City	N	E	S	W
1 -Rockford AP / Rockford	4.2	4.1	4.7	4.8
2 - Chicago O'Hare AP / Chicago	4.7	4.5	5.4	4.6
3 - Springfield #2 / Springfield	4.1	3.7	6.0	5.0
4 - Belleville SIU RSCH / Belleville	3.3	2.7	3.8	4.2
5 - Carbondale Southern IL AP / Marion	3.1	2.9	4.4	3.8

C_{wc} = wind speed correction factor due to wind direction in cooling season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the cooling season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for cooling applications.

	Entryway Orientation			
Climate Zone -Weather Station/City	N	E	S	W
1 -Rockford AP / Rockford	0.18	0.13	0.30	0.31
2 - Chicago O'Hare AP / Chicago	0.18	0.17	0.36	0.26
3 - Springfield #2 / Springfield	0.17	0.12	0.46	0.21
4 - Belleville SIU RSCH / Belleville	0.21	0.15	0.35	0.16
5 - Carbondale Southern IL AP / Marion	0.18	0.15	0.37	0.11

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

C_v = effectiveness of openings,

= 0.3, assumes diagonal wind[20]

A_d = area of the doorway (ft^2)

= user defined

The infiltration due to thermal forces is calculated as follows:

$CFM_t = A_d * C_{dc} * (60 \text{ sec/min}) * \text{sqrt}[2 * g * H/2 * (T_{oc} - T_{ic}) / (459.7 + T_{oc})]$

Where:

C_{dc} = the discharge coefficient during the cooling season[545]

$= 0.4 + 0.0025 * |T_{ic} – T_{oc}|$

= 0.42, Illinois average at indoor air temp of 72°F

Note, values for C_{dc} show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec^2

[544] Average wind speeds are calculated based on the TMY3 wind speed data. Because this data is collected at an altitude of 33 ft, wind speed is approximated for a 5 ft level based on ASHRAE Handbook guidelines using the urban/suburban parameters for adjusting wind speed based on altitude (? = 1200, ? = 0.22).
ASHRAE, "Airflow Around Buildings," in 2013 ASHRAE Handbook – Fundamentals (2013): p 24.3
[545] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): p 16.13

H = the height of the entryway (ft)

= user input

T_{ic} = Average indoor air temperature during cooling season

= User input, can assume indoor cooling temperature set-point

T_{oc} = Average outdoor temp during cooling season (°F)

= the average outdoor temperature is dependent on the CD period and zone. As such, the following table may be used for average outdoor temperature during the cooling period[546]:

	T_{oc}				
Climate Zone Weather Station/City	**62 °F**	**67 °F**	**72 °F**	**77 °F**	**82 °F**
1 -Rockford AP / Rockford	72.9	76.0	79.2	82.5	85.5
2 - Chicago O'Hare AP / Chicago	72.9	76.0	79.4	82.8	85.5
3 - Springfield #2 / Springfield	73.7	76.7	79.9	83.4	86.4
4 - Belleville SIU RSCH / Belleville	74.9	77.7	81.0	84.3	86.9
5 - Carbondale Southern IL AP / Marion	75.1	77.7	80.9	84.7	87.4

459.7 = conversion factor from °F to °R

= calculation requires absolute temperature for values not calculated as a difference of temperatures.

Heat Transfer Through Open Entryway with Air Curtain (Cooling Season)

$Q_{tac} = Q_{tbc} * (1 – E)$

Where:

E = the effectiveness of the air curtain (%)

= 0.60[547]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (\Delta kWh_{cooling} / (CD *24)) * CF$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[548]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[549]

---

[546] Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed.

[547] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008).
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[548] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[549]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

NATURAL GAS SAVINGS

Natural gas savings, ∆therms, associated with reduced infiltration through an entryway during the heating season are calculated by determining the difference between heat loss through the entryway before and after the installation of the air curtain.

$$\Delta therms = (Q_{bc} - Q_{ac}) * t_{open} * HD / \eta$$

Where:

Q_{bc} = rate of sensible heat transfer through the open entryway, before air curtain (therm/hr)

Q_{ac} = rate of sensible heat transfer through the open entryway, after air curtain (therm/hr)

t_{open} = average hours per day the door is open (hr/day)

= Actual or estimated user input value

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[550]:

	HD				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	142	160	183	204	228
2 - Chicago O'Hare AP / Chicago	150	166	192	219	253
3 - Springfield #2 / Springfield	125	142	167	194	230
4 - Belleville SIU RSCH / Belleville	101	115	134	156	180
5 - Carbondale Southern IL AP / Marion	103	123	148	174	205

η = efficiency of heating equipment

= Actual. If unknown, assume 0.8

Heat Transfer Through Open Entryway without Air Curtain (Heating Season)

$$Q_{bc} = (1.08\ Btu/(hr*°F*cfm)) * CFM_{tot} * (T_{ih} - T_{oh}) / (100{,}000\ Btu/therm)$$

Where:

1.08 = sensible heat transfer coefficient (specific heat of air and unit conversions)

CFM_{tot} = Total air flow through entryway (cfm)

T_{ih} = Average indoor air temperature during heating season

= User input, can assume indoor heating temperature set-point

T_{oh} = Average outdoor temp during heating season (°F)

= use table below, based on binned data from TMY3 & balance point temperature

	Avg Outdoor Air Temp - Heating Season				
Climate Zone -Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	26.3	28.8	31.6	34.2	37.3
2 - Chicago O'Hare AP / Chicago	29.4	31.2	34.0	36.8	40.3
3 - Springfield #2 / Springfield	29.4	31.5	34.6	37.7	41.6
4 - Belleville SIU RSCH / Belleville	31.7	33.6	36.2	39.2	42.3

550 Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

	Avg Outdoor Air Temp - Heating Season				
Climate Zone -Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
5 - Carbondale Southern IL AP / Marion	32.5	34.9	37.8	40.7	44.0

The total airflow through the entryway, CFM_{tot}, includes both infiltration due to wind as well as thermal forces, as follows:

CFM_{tot} = sqrt[$(CFM_w)^2$ + (CFM_t^2)]

Where:

CFM_w = Infiltration due to the wind (cfm)

CFM_t = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFM_w = $(v_{wh} * C_{wh}) * C_v * A_d$ * (88 fpm/mph)

Where:

v_{wh} = average wind speed during the heating season (mph)

= similar to cooling season wind speed assumptions, use the following table to determined average wind speed based on entryway orientation:

	Entryway Orientation			
Climate Zone -Weather Station/ City	N	E	S	W
1 -Rockford AP / Rockford	5.0	4.6	4.9	5.6
2 - Chicago O'Hare AP / Chicago	5.5	5.2	4.9	5.1
3 - Springfield #2 / Springfield	5.0	4.9	5.3	5.1
4 - Belleville SIU RSCH / Belleville	4.3	3.4	3.5	5.3
5 - Carbondale Southern IL AP / Marion	4.6	3.2	4.2	4.4

C_{wh} = wind speed correction factor due to wind direction in heating season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the heating season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for the heating applications.

	Entryway Orientation			
Climate Zone -Weather Station/ City	N	E	S	W
1 -Rockford AP / Rockford	0.18	0.13	0.30	0.31
2 - Chicago O'Hare AP / Chicago	0.21	0.10	0.26	0.39
3 - Springfield #2 / Springfield	0.21	0.14	0.27	0.34
4 - Belleville SIU RSCH / Belleville	0.31	0.15	0.22	0.29
5 - Carbondale Southern IL AP / Marion	0.31	0.11	0.27	0.18

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

C_v = effectiveness of openings,

= 0.3, assumes diagonal wind[24]

A_d = area of the doorway (ft^2)

= user input

The infiltration due to thermal forces is calculated as follows:

CFM_t = A_d * C_{dh} * (60 sec/min) * sqrt[2 * g * H/2 * (T_{ih} – T_{oh}) / (459.7 + T_{ih})]

Where:

C_{dh} = the discharge coefficient during the heating season

= 0.4 + 0.0025 * |T_{ih} – T_{oh}|

= 0.49, Illinois average at indoor air temp of 72°F

Note, values for C_{dh} show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec^2

H = the height of the entryway (ft)

= user defined

Heat Transfer Through Open Entryway without Air Curtain (Heating Season)

Q_{ac} = Q_{bc} * (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[551]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The air curtain would need to be regularly serviced and commissioned to ensure that it is appropriately operating. This is estimated at a cost of $150[552].

MEASURE CODE: CI-HVC-AIRC-V02-190101

REVIEW DEADLINE: 1/1/2022

[551] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008).
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[552] Assumes approximately 1 hour of maintenance (include cleaning out filters, greasing, and checking that the designed angle of attack on the blower nozzle is at the designed position) based on manufacturer inpur and product spec sheets.

4.4.34 Destratification Fan

DESCRIPTION

This measure applies to buildings with high bay ceiling construction without fans currently installed for the purpose of destratifying air. There is also a separate measure for destratification fans as applied to agricultural settings ("High Volume Low Speed Fans"). All other destratification fan applications require custom analysis.

Air stratification leads to higher temperatures at the ceiling and lower temperatures at the ground. During the heating season, destratification fans improve air temperature distribution in a space by circulating warmer air from the ceiling back down to the floor level, thereby enhancing comfort and saving energy. Energy savings are realized by a reduction of heat loss through the roof-deck and walls as a result of a smaller temperature differential between indoor temperature and outdoor air.

Note that further, but limited, empirical evidence suggests that improved air mixing due to destratification would also result in shorter heating system runtimes due to warmer air reaching the thermostat level sooner, and possibly even allow a facility to lower the thermostat set point while maintaining a similar level of occupant comfort. This is supported by measured data in which an increase in temperatures was observed at the thermostat (5 foot level) level when air is destratified, resulting in an approximate temperature increase at the 5 foot level in the range of 1 - 3°F[553]. This measure does not currently attempt to quantify the potential impacts of air mixing from destratification; however, it should be noted that additional therms savings may be possible.

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.

Limitations

- For use in conditioned, high bay structures. Recommended minimum ceiling height of 20 ft.
- This measure should only be applied to spaces in which the ceiling is subject to heat loss to outdoor air (i.e., single story or top floor spaces) and where there is sufficient space to allow for appropriate spacing of the fans. Other applications require custom analysis.
- Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Please see calculation of effective area, A_{eff}, in the therms savings algorithm as a check if this criteria is met. Otherwise, custom calculation is necessary.
- Measure does not currently support facilities with night setbacks on heating equipment. Custom analysis is needed in this case.
- Certain heating systems may not be a good fit for destratification fans, such as locations with: high velocity vertical throw unit heaters, radiant heaters, and centralized forced air systems. In these cases, measured evidence of stratification should be confirmed and custom analysis may be necessary.

DEFINITION OF EFFICIENT EQUIPMENT

High Volume, Low Speed (HVLS) fans with a minimum diameter of 14 ft with Variable Speed Drive (VSD) installed[554].

Note that bell-shaped fans are currently excluded from this measure due to limited validation of the technology available. Further verification of effectiveness compared to HVLS is needed. A manufacturer of bell shaped fans indicates that four bell-shaped fans provide an equivalent effective area as a typical HVLS fan. However, there is a need for further review of bell shaped fan field test data supporting manufacturer claims regarding comparable effectiveness to HVLS technologies.

---

[553] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 16
[554] Ibid.

Definition of Baseline Equipment

No destratification fans or other means to effectively mix indoor air.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[555]

Deemed Measure Cost

Measure cost = [incremental cost of HVLS fans] + [installation costs (including materials and labor)]

The incremental capital cost for HVLS fans are as follows[556]:

Fan Diameter (ft)	Incremental Cost
14	$6,600
16	$6,650
18	$6,700
20	$6,750
22	$6,800
24	$6,850

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

Loadshape

Loadshape C04: Commercial Electric Heating.

Coincidence Factor

N/A due to no savings attributable to cooling during the summer peak period.

Algorithm

Calculation of Savings

The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

Electric Energy Savings

The algorithm for this measure was developed for natural gas heating applications, however, for electric heating applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:

System Type	Age of Equipment	HSPF Estimate	η (Effective COP Estimate) (HSPF/3.413)
Heat Pump	Before 2006	6.8	2.0
	2006 - 2014	7.7	2.3
	2015 on	8.2	2.40

[555] Consistent with both 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008 and GDS Associates, Inc, "Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures," New England Stat Program Working Group (June 2007), p30.

[556] Costs were obtained from manufacturer interviews and are based off of average or typical prices for base model HVLS fans. Costs include materials and labor to install the fans and tie fans into an existing electrical supply located near the fan.

System Type	Age of Equipment	HSPF Estimate	η (Effective COP Estimate) (HSPF/3.413)
Resistance	N/A	N/A	1

Regardless of how the building is heated, the energy consumption of the fans must be accounted for. If the building is electrically heated, fan energy shall be subtracted from the savings as calculated above. If the building is heated with natural gas, this shall represent an electric penalty, i.e., an increase in consumption. This is calculated as follows:

$\Delta kWh = -(W_{fan} * N_{fan}) * t_{eff}$

W_{fan} = fan input power (kW)

N_{fan} = number of fans

t_{eff} = effective annual operation time, based on balance point temperature (hr)

= see table below in Natural Gas Savings section for further detail

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = [(\Delta Q_r + \Delta Q_w) * t_{eff}] / (100{,}000 * \eta)$

Where:

ΔQ_r = the heat loss reduction through the roof due to the destratification fan (Btu/hr)

= See calculation section below

ΔQ_w = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)

= See calculation section below

t_{eff} = effective annual operation time, based on balance point temperature (hr)

= use table below to select an appropriate value[557]:

Climate Zone -Weather Station/City	t_{eff}				
	45 °F	50 °F	55 °F	60 °F	65 °F
1 -Rockford AP / Rockford	3810	4226	4880	5571	6436
2 - Chicago O'Hare AP / Chicago	3593	3986	4603	5254	6070
3 - Springfield #2 / Springfield	3038	3370	3891	4442	5131
4 - Belleville SIU RSCH / Belleville	2243	2488	2873	3280	3789
5 - Carbondale Southern IL AP / Marion	2271	2519	2909	3320	3836

100,000 = conversion factor (1 therm = 100,000 Btu)

η = thermal efficiency of heating equipment

[557] These were calculated at various base temperatures using TMY3 data and adjusted to make consistent with the 30 year normal data used elsewhere. For more information see 'Destratification Fan Workpaper'; Robert Irmiger, Gas Technology Institute, 9/6/2015.

= Actual. If unknown assume 0.8.

EXAMPLE:

For a warehouse facility located in Rockford, IL, installing destratification fans could reduce heat loss through the roof of 95,000 Btu/hr and a reduced heat loss through the wall of 51,228 Btu/hr. Assuming a balance point of 55°F the therms savings for the facility would be estimated as:

ΔTherms = $[(\Delta Q_r + \Delta Q_w) * t_{eff}] / (100,000 * \eta)$

= [(95,000 Btu/hr + 51,282 Btu/hr) * 4880 hr] / [(100,000 Btu/therm) * 0.8)]

= 8,923 therms

Heat loss reduction through the roof

ΔQ_r = $Q_{r,s} - Q_{r,d}$

= $(1/R_r) * A_r * [(T_{r,s} - T_{oa}) - (T_{r,d} - T_{oa})]$

= $(1/R_r) * A_r * (T_{r,s} - T_{r,d})$

Where:

$Q_{r,s}$ = roof heat loss for stratified space

$Q_{r,d}$ = roof heat loss for destratified space

R_r = overall thermal resistance through the roof (hr * ft^2 * °F / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

Thermal Resistance Factor (R-Factor) for Roof	Retrofit[558]	New Construction[559]
R_r	15.0 (hr * ft^2 * °F / Btu)	30.0 (hr * ft^2 * °F / Btu)

A_r = roof area (ft^2)

= user input

= can be approximated with floor area

T_{oa} = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

$T_{r,s}$ = indoor temperature at roof deck, stratified case (°F)

= Actual. If unknown, use the following equation

= $m_s * h_r + T_{f,s}$

h_r = ceiling height/roof deck (ft)

m_s = estimated heat gain per foot elevation, stratified case (°F/ft)

= 0.8 °F/ft

558 Professional judgement was used to address older vintage structures and an estimate of 50% of current code standard was used.

559 ANSI/ASHRAE/IESNA Standard 90.1-2016, "Energy Standard for Buildings Except Low-Rise Residential Buildings," ASHRAE Standard (20016): Table 5.5-4 and Table 5.5-5

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[560,561]. Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 $^oF/ft$ heat gain.

$T_{f,s}$ = estimated floor temperature, stratified case (^oF)

$= T_{tstat} - m_s * h_{tstat}$

$= T_{tstat} - 4\ ^oF$

T_{tstat} = temperature set point at the thermostat

h_{tstat} = vertical distance between the floor and the thermostat, assumed 5ft

$T_{r,d}$ = indoor temp at roof, destratified case

= actual value, or may be estimated using the following:[562,563]

$= T_{tstat} + 1\ ^oF$

> EXAMPLE:
>
> For a 50,000 ft^2 warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 ^oF. No further measured values available.
>
> $\Delta Q_r = (1/R_r) * A_r * (T_{r,s} - T_{r,d}) = (1/R_r) * A_r * [(m_s * h_r + T_{tstat} - 4\ ^oF) - (T_{tstat} + 1\ ^oF)]$
>
> $= (1/R_r) * A_r * [(0.8^oF/ft * h_r) - 5\ ^oF]$
>
> $= 1/(10\ hr * ft^2 * {}^oF / Btu) * (50{,}000\ ft^2) * [(0.8^oF/ft * 30\ ft) - 5\ ^oF]$
>
> = 95,000 Btu/hr

Heat loss reduction through exterior walls

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%.[564]

$\Delta Q\_w = Q_{w,s} - Q_{w,d}$

$= (1/R_w) * A_w * (T_{w,s} - T_{w,d})$

Where:

R_w = overall thermal resistance through the exterior walls ($hr * ft^2 * {}^oF / Btu$)

= Actual or estimated based on construction type[565]. If unknown, assume the following

560 Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.

561 Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain.

562 12. Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.

563 13. Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48.

564 Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 51

565 Because heat loss through the walls is estimated using the average space temperature pre- and post- destratification. There are a number of factors that can impact the average space temperature causing deviations from estimates of many degrees in some cases. As such, it is recommended that a conservative value for the thermal resistance through the walls, R_w, be used. A recommended method for determining R_w would be to use the highest R-value for the wall space, neglecting lower R-values associated with windows, thermal bridges, etc.

Thermal Resistance Factor (R-Factor) for Wall	Retrofit[566]	New Construction[567] (2010 or newer)
R_w	6.5 (hr * ft^2 * ^{o}F / Btu)	13.0 (hr * ft^2 * ^{o}F / Btu)

A_w = area of exterior walls (ft^2)

= user input

$T_{w,s}$ = average indoor air temperature for wall heat loss, stratified case

= If actual $T_{r,s}$ measurement is available[568]

= $[(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r$

h_a = vertical distance between the heat source and the ceiling

h_b = vertical distance between the floor and the heat source

= Otherwise, use the linear stratification equation at average space height, see definition above.

= $m_s * (h_r / 2) + T_{f,s}$

= $m_s * (h_r / 2) + (T_{tstat} – 4)$

$T_{w,d}$ = average indoor air temperature for wall heat loss, destratified case

= T_{tstat} + 0.5

= conservative estimate using engineering judgment based on the same assumption used for $T_{r,f}$ estimate.

EXAMPLE:

For a 50,000 ft^2 warehouse built in 1997 with 1200 ft length of perimeter wall and 30 ft ceilings and a thermostat set point of 65 ^{o}F and a measured temperature at the ceiling of 85 ^{o}F and unit heaters located 10 feet from the roof:

ΔQ_w = $(1/R_w) * A_w * (T_{w,s} – T_{w,d})$

= $(1/R_w) * A_w * [(([(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r) – (T_{tstat} + 0.5\ ^oF)]$

= 1/(6.5 hr*ft^2*^{o}F/Btu) * (1200 * 30) * [(([(85^{o}F * 10ft) + (65 ^{o}F * 20ft)] / 30ft) – (65 + 0.5 ^{o}F)]

= 1/(6.5 hr*ft^2*^{o}F/Btu) * (36,000ft^2) * (71.7 ^{o}F – 65.5 ^{o}F)

= 34,338 Btu/hr

Measure eligibility check

Use the following algorithm to verify a fan system is sufficiently sized to destratify air across the entire area.

Effective area, A_{eff}, is the area over which a fan or a group of fans can be expected to effectively destratify a space. If A_{eff} is less than the roof area, A_r, a custom analysis approach should be followed to account for the change in the effectiveness of the system. In lieu of more detailed studies, effective area is defined

566 ANSI/ASHRAE/IESNA 100-1995, "Energy Conservation in Existing Buildings," ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.
567 ANSI/ASHRAE/IESNA Standard 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings," ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5
568 Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48

based on the measured results from an Enbridge Gas field study in which the area a fan was expected to effectively destratify was equal to 5 times the fan diameter[569]. Effective area, is calculated as follows:

$$A_{eff} = [\pi * (5*D_{fan})^2) / 4] * N_{fan}$$

$$= 6.25 * \pi * D_{fan}^2 * N_{fan}$$

Where:

A_{eff} = the effective area fan area on the floor (ft^2)

D_{fan} = fan diameter

N_{fan} = the number of fans

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-DSFN-V03-190101

REVIEW DEADLINE: 1/1/2021

[569] Enbridge Gas Distribution, Inc., "Big Fans Deliver Big Bonus," (Aug 2007). Additionally, multiple utilities have adopted this definition in their programs in including Enbridge Gas and Consumers Energy.

4.4.35 Economizer Repair and Optimization

DESCRIPTION

Economizers are designed to use unconditioned outside air (OSA) instead of mechanical cooling to provide cooling when exterior conditions permit. When the OSA temperature is less than the changeover temperature (determined by a static setpoint or a reference return air sensor) up to 100% OSA is supplied to help meet the facility's cooling needs, thus reducing mechanical cooling energy and saving energy. An economizer that is not working or is not properly adjusted can waste energy and cause comfort issues. This HVAC Economizer Optimization measure involves the repair and optimization of common economizer problems such as adjusting changeover setpoint, repairing damper motors & 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.

This measure is only appropriate for single zone packaged rooftop units. Custom calculations are required for savings for multi-zone systems.

In general the HVAC Economizer Optimization measure may involve both repair and/or optimization;

Economizer Repair – The Economizer repair work is preformed 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 outside air (OSA) 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 OSA, the OSA damper position will be adjusted to meet minimum ventilation requirements.
- **Economizer Sensor Replacement** – 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.
- **Economizer Control Replacement** – 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 preformed 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 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 by fully functional 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)[570].

[570] ASHRAE, Standard 90.1-2013

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	$T_{OA} > 75°F$	Outdoor air temperature exceeds 75°F
	5a, 6a	$T_{OA} > 70°F$	Outdoor air temperature exceeds 70°F
	1a, 2a, 3a, 4a,	$T_{OA} > 65°F$	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	$h_{OA} > 28$ Btu/lb[a] or $T_{OA} > 75°F$	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 $T_{OA} > 75°F$	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.

Figure 2 – ASHRAE Climate Zone Map

NORMATIVE APPENDIX B
CLIMATE ZONES FOR U.S. STATES AND COUNTIES

This normative appendix provides the climate zones for U.S. states and counties. Figure B-1 contains the county-level climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

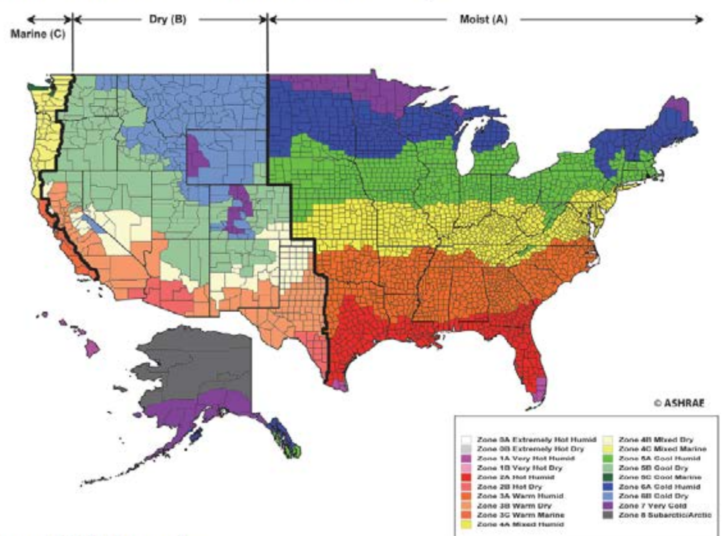


FIGURE B-1 Climate zones for United States counties.

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[571].

[571] DEER 2014 (DEER2014 EUT Table D08 v2.05)

Deemed Measure Cost

The cost for this measure can vary considerably depending upon the existing condition 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 C03 - Commercial Cooling

Coincidence Factor

N/A

Algorithm

Calculation of Energy Savings

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations[572]. 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

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use[573].

Electric Energy Use Equations (kWh / ton)

Building Type	Changeover Type	Equation
Assembly	Fixed Dry-Bulb (DB)	cz+CSP*-2.021+EL*-16.362+OAn*1.665+OAx*-3.13
	Dual Temperature Dry-Bulb (DTDB)	cz+EL*-11.5+OAn*1.635+OAx*-2.817
	Dual Temperature Enthalpy (DTEnth)	cz+EL*-17.772+OAn*1.853+OAx*-3.044
	Fixed Enthalpy (Enth)	cz+CSP*-5.228+EL*-17.475+OAn*1.765+OAx*-3.003
	Analog ABCD Economizers (ABCD)	cz+CSP*-2.234+EL*-16.394+OAn*1.744+OAx*-3.01
Convenience Store	DB	cz+CSP*-3.982+EL*-27.508+OAn*2.486+OAx*-4.684
	DTDB	cz+EL*-20.798+OAn*2.365+OAx*-3.773
	DTEnth	cz+EL*-30.655+OAn*2.938+OAx*-4.461
	Enth	cz+CSP*-8.648+EL*-25.678+OAn*2.092+OAx*-3.754
	ABCD	cz+CSP*-3.64+EL*-24.927+OAn*2.09+OAx*-3.788
Office - Low Rise	DB	cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
	DTDB	cz+OAn*2.968+OAx*-0.943
	DTEnth	cz+EL*-9.799+OAn*3.106+OAx*-1.085
	Enth	cz+CSP*-2.773+EL*-7.392+OAn*2.941+OAx*-0.974
	ABCD	cz+CSP*-1.234+EL*-7.229+OAn*2.936+OAx*-0.995
	DB	cz+CSP*-1.131+OAn*3.542+OAx*-1.01

[572] For more information on methodology, please refer to workpaper submitted by CLEAResult titled "CLEAResult_Economizer Repair_151020_Finalv2.doc". Note that the original ComEd eQuest models were used in the analysis, rather than the VEIC developed models used elsewhere. VEIC do not consider this a significant issue as adjustments from the ComEd models were focused on calibrating EFLH values, not to overall energy use metrics. We also believe using the ComEd models is likely more conservative. It may be appropriate to update the analysis with the updated models at a later time.

[573] 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
Religious Facility	DTDB	cz+EL*-10.198+OAn*4.056+OAx*-1.279
	DTEnth	cz+OAn*3.775+OAx*-1.031
	Enth	cz+CSP*-2.13+OAn*3.317+OAx*-0.629
	ABCD	cz+CSP*-0.95+OAn*3.313+OAx*-0.647
Restaurant	DB	cz+CSP*-2.243+EL*-21.523+OAx*-1.909
	DTDB	cz+EL*-14.427+OAn*0.295+OAx*-1.451
	DTEnth	cz+EL*-25.99+OAn*0.852+OAx*-1.951
	Enth	cz+CSP*-4.962+EL*-16.868+OAn*-0.12+OAx*-1.418
	ABCD	cz+CSP*-2.115+EL*-16.15+OAn*-0.125+OAx*-1.432
Retail - Department Store	DB	cz+CSP*-1.003+OAn*3.765+OAx*-0.938
	DTDB	cz+OAn*3.688+OAx*-0.676
	DTEnth	cz+OAn*4.081+OAx*-1.072
	Enth	cz+CSP*-2.545+OAn*3.725+OAx*-0.788
	ABCD	cz+CSP*-1.175+OAn*3.708+OAx*-0.809
Retail - Strip Mall	DB	cz+CSP*-1.192+EL*-5.62+OAn*3.353+OAx*-1.142
	DTDB	cz+OAn*3.355+OAx*-0.915
	DTEnth	cz+EL*-9.202+OAn*3.642+OAx*-1.215
	Enth	cz+CSP*-2.997+EL*-5.938+OAn*3.312+OAx*-0.964
	ABCD	cz+CSP*-1.36+EL*-5.884+OAn*3.3+OAx*-0.987

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

		Electric Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
Assembly	DB	874.07	886.73	1043.38	1071.48	1072.20
	DTDB	698.45	711.89	870.13	899.51	903.10
	DTEnth	702.06	715.42	873.43	902.76	906.50
	Enth	851.95	865.43	1020.65	1047.10	1053.32
	ABCD	884.19	897.63	1053.12	1080.58	1086.35
Convenience Store	DB	1739.12	1787.09	2128.78	2206.65	2245.93
	DTDB	1389.28	1436.30	1780.99	1863.45	1904.89
	DTEnth	1398.42	1446.82	1789.71	1869.89	1912.59
	Enth	1643.51	1691.34	2032.83	2112.21	2157.63
	ABCD	1692.80	1740.62	2082.35	2162.73	2207.68
Office - Low Rise	DB	674.06	687.17	899.17	993.84	989.16
	DTDB	583.62	597.02	811.39	907.61	903.58
	DTEnth	588.94	602.11	816.02	912.49	908.26
	Enth	668.83	682.23	893.61	987.52	986.59
	ABCD	690.27	703.52	915.27	1009.94	1008.59
Religious Facility	DB	613.26	630.50	853.53	923.99	931.74
	DTDB	518.40	535.45	760.76	832.57	840.72
	DTEnth	513.59	531.20	756.26	829.13	837.26
	Enth	576.94	594.17	817.64	888.37	897.18

Building Type	Changeover Type	Electric Climate Zone Coefficients				
		CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
	ABCD	593.78	611.04	834.69	905.83	914.27
Restaurant	DB	1397.27	1430.45	1763.21	1837.63	1872.18
	DTDB	1191.82	1225.12	1558.32	1633.95	1669.13
	DTEnth	1192.84	1226.77	1559.41	1635.13	1671.11
	Enth	1343.56	1377.52	1710.11	1783.66	1821.67
	ABCD	1373.72	1407.70	1740.43	1814.74	1852.55
Retail - Department Store	DB	717.89	730.07	968.85	1034.78	1035.06
	DTDB	628.83	641.70	883.37	951.09	951.33
	DTEnth	629.35	641.90	882.84	951.33	951.44
	Enth	705.06	717.99	956.42	1020.57	1024.45
	ABCD	728.60	741.47	980.19	1045.30	1048.57
Retail - Strip Mall	DB	800.69	818.68	1070.39	1129.87	1133.84
	DTDB	692.97	711.31	965.63	1026.68	1030.41
	DTEnth	698.12	716.34	970.06	1031.78	1035.72
	Enth	784.54	803.35	1054.37	1112.72	1120.74
	ABCD	810.10	828.86	1080.11	1139.39	1146.95

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
	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 (% OSA)[574]

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 30%
Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) - 30% (Assume Minimum Ventilation (Three Fingers)[575])

Oax = Maximum Outside Air (%)[i]

[574] 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)
[575] Technician rule of thumb taken from CPUC 'HVAC Impact Evaluation Final Report', WO32, 28Jan 2015, p18.

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 70%
Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) –– 30% (Assume Minimum Ventilation (Three Fingers))

EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found that the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise

= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047

= 674.06+62*-0.967+0*-6.327+30*2.87+30*-1.047

= 668.8 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise

= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047

= 674.06+70*-0.967+0*-6.327+ 30*2.87+70*-1.047

= 619.2 kWh/Ton

ΔkWh = [668.8 (kWh/Ton) – 619.2 (kWh/Ton)] * 5 Tons

= 49.6 kWh/Ton * 5 Tons

= 248.08 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - It is assumed that repair or optimization of the economizer will not typically have a significant impact summer peak demand.

NATURAL GAS SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use (Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed electric energy use.

Natural Gas Energy Use Equations (therms / kbtu output)

Building Type	Changeover Type	Equation
Assembly	Fixed Dry-Bulb (DB)	cz+OAn*0.0853
	Dual Temperature Dry-Bulb (DTDB)	cz+OAn*0.0866
	Dual Temperature Enthalpy (DTEnth)	cz+OAn*0.0866
	Fixed Enthalpy (Enth)	cz+OAn*0.0855
	Analog ABCD Economizers (ABCD)	cz+OAn*0.0855
Convenience Store	DB	cz+OAn*0.26

Building Type	Changeover Type	Equation
	DTDB	cz+OAn*0.263
	DTEnth	cz+OAn*0.263
	Enth	cz+OAn*0.261
	ABCD	cz+OAn*0.261
Office - Low Rise	DB	cz+OAn*0.3
	DTDB	cz+OAn*0.301
	DTEnth	cz+OAn*0.301
	Enth	cz+OAn*0.3
	ABCD	cz+OAn*0.3
Religious Facility	DB	cz+OAn*0.35
	DTDB	cz+OAn*0.348
	DTEnth	cz+OAn*0.348
	Enth	cz+OAn*0.349
	ABCD	cz+OAn*0.349
Restaurant	DB	cz+OAn*0.0867
	DTDB	cz+OAx*-0.038+OAn*OAx*0.00149
	DTEnth	cz+OAx*-0.038+OAn*OAx*0.00149
	Enth	cz+OAn*0.0878
	ABCD	cz+OAn*0.0878
Retail - Department Store	DB	cz+OAn*0.319
	DTDB	cz+OAn*0.318
	DTEnth	cz+OAn*0.318
	Enth	cz+OAn*0.318
	ABCD	cz+OAn*0.318
Retail - Strip Mall	DB	cz+OAn*0.215
	DTDB	cz+OAn*0.216
	DTEnth	cz+OAn*0.216
	Enth	cz+OAn*0.215
	ABCD	cz+OAn*0.215

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

		Natural Gas Climate Zone Coefficients				
Building Type	Changeover Type	CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
Assembly	DB	-0.03	-0.55	-1.06	-1.28	-1.71
	DTDB	-0.02	-0.57	-1.11	-1.34	-1.79
	DTEnth	-0.02	-0.57	-1.11	-1.34	-1.79
	Enth	-0.03	-0.55	-1.06	-1.29	-1.72
	ABCD	-0.03	-0.55	-1.06	-1.29	-1.72
Convenience Store	DB	2.95	0.50	-1.48	-2.96	-5.56
	DTDB	3.06	0.52	-1.56	-3.11	-5.81
	DTEnth	3.06	0.52	-1.56	-3.11	-5.81
	Enth	2.96	0.50	-1.49	-2.98	-5.59

Building Type	Changeover Type	Natural Gas Climate Zone Coefficients CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
	ABCD	2.96	0.50	-1.49	-2.98	-5.59
Office - Low Rise	DB	5.83	3.02	0.46	-0.92	-4.13
	DTDB	5.98	3.08	0.41	-1.03	-4.36
	DTEnth	5.98	3.08	0.41	-1.03	-4.36
	Enth	5.85	3.03	0.46	-0.93	-4.16
	ABCD	5.85	3.03	0.46	-0.93	-4.16
Religious Facility	DB	9.23	6.71	3.75	2.40	-0.80
	DTDB	9.41	6.83	3.77	2.39	-0.86
	DTEnth	9.41	6.83	3.77	2.39	-0.86
	Enth	9.25	6.73	3.75	2.40	-0.80
	ABCD	9.25	6.73	3.75	2.40	-0.80
Restaurant	DB	8.30	6.54	4.94	4.00	1.95
	DTDB	10.51	8.71	7.07	6.10	4.00
	DTEnth	10.51	8.71	7.07	6.10	4.00
	Enth	8.28	6.51	4.91	3.96	1.90
	ABCD	8.28	6.51	4.91	3.96	1.90
Retail - Department Store	DB	8.20	5.86	3.19	1.25	-2.59
	DTDB	8.35	5.94	3.18	1.18	-2.75
	DTEnth	8.35	5.94	3.18	1.18	-2.75
	Enth	8.21	5.87	3.18	1.24	-2.61
	ABCD	8.21	5.87	3.18	1.24	-2.61
Retail - Strip Mall	DB	6.40	4.35	2.07	0.49	-2.18
	DTDB	6.51	4.38	2.03	0.39	-2.34
	DTEnth	6.51	4.38	2.03	0.39	-2.34
	Enth	6.41	4.35	2.06	0.48	-2.20
	ABCD	6.41	4.35	2.06	0.48	-2.20

EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise

= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise

= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

ΔTherms = [14.8(Therms/kBtuh output) – 14.8 (Therms/kBtuh output)] * 92kBtuh output

= 0.0 (Therms/kBtuh output) * 92kBtuh output

= 0 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ECRP-V03-180101

REVIEW DEADLINE: 1/1/2023

4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls

DESCRIPTION

This measure covers multi-family space heating boiler averaging controls. Temperature sensors are placed in interior spaces to monitor the average temperature of the building. At minimum a sensor must be placed at each corner and at one central location. Additionally, a temperature sensor must monitor the outside air temperature. These sensors shall provide data to the averaging controls. The averaging controls will adjust the boiler operation based upon an average of the indoor sensors and the outside air temperature. These controls shall also incorporate a night-time setback capability. Buildings utilizing thermostatic radiator valves, or other modulating control valves or sequences to control the temperature in individual spaces are not eligible.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler(s) must incorporate an averaging control system utilizing at least 4 indoor sensors and 1 outdoor sensor. The controls shall have the capability to incorporate a nighttime setback throughout the building.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a boiler system without averaging controls or other steam supply modulating controls. Current boiler control system can utilize a single thermostat or aquastat and timer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic hot water boilers is 20 years.[576]

DEEMED MEASURE COST

As a retrofit measure, the actual installed cost should be used for screening purposes. A deemed retrofit measure cost of $5,060[577] can be used if the actual installed cost is unknown.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[576] The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

[577] NREL, "Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection", August 2013.

NATURAL GAS ENERGY SAVINGS

ΔTherms = Capacity x EFLH x SF / 100,000

Where:

Capacity = Boiler gas input size (Btu/h)

= Actual

EFLH = Effective Full Load Hours for heating are provided in section 4.4. HVAC End Use

SF = Savings Factor

= 10.2%[578] or custom if savings can be substantiated

100,000 = converts Btu/h to therm

For Example:

A 1,000,000 btu/h steam boiler in a Mid-Rise Multi-Family building in Chicago has averaging controls installed.

ΔTherms = 1,000,000 x 1,685 x 0.102 / 100,000

= 1,719 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-SBAC-V02-190101

REVIEW DEADLINE: 1/1/2023

[578] "Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection", NREL, August 2013, states that test buildings with steam balancing measures saved an average of 10.2%. The energy savings estimate assumes additional system balancing through the installation of large capacity air vents on steam main lines and the replacement of radiator vents. This work is assumed to be done in concert with any system being retrofitted with averaging controls.

4.4.37 Unitary HVAC Condensing Furnace

DESCRIPTION

Condensing furnaces recover energy in combustion exhaust flue gasses that would otherwise simply be vented to the atmosphere, making them more efficient than non-condensing furnaces. This measure applies to a constant volume (CV), dedicated outside air system (DOAS), make-up air system (MUAS), or any unitary HVAC system that is utilizing an indirect gas fired process to heat 100% OA to provide ventilation or make-up air to commercial and industrial (C&I) building spaces. The unitary package must contain an indirect gas-fired, warm air furnace section, but the unitary package can be with or without an electric air conditioning section. The unitary package can be either a single package or split system that is applied indoors (non-weatherized) or outdoors (weatherized).

This measure excludes demand control ventilation, condensing unit heaters, and high efficiency (condensing) furnaces with annual fuel utilization efficiency (AFUE) ratings (for furnaces with less than 225,000 Btu/hr input capacity), which are covered by other measures for the C&I sector in the Technical Reference Manual (TRM)[579].

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 efficient unitary equipment must contain a condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 90% or higher, or alternatively, the unitary package must have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.90 or higher. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces[580]. The furnace must be vented and condensate disposed of in accordance with the equipment manufacturer installation instructions and applicable codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is expected to be unitary equipment that contains a non-condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 80%, or alternatively, the unitary package will have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.80. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.

Note the current Department of Energy (DOE) federal minimum efficiency standard is 80% for 225,000 Btu/hr and higher input capacity furnaces per the Energy Conservation Standard for Commercial Warm Air Furnaces[581]. In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[582] that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.

Note: new Federal Standards applicable to all gas furnaces become effective January 1, 2023.

---

[579] Illinois Statewide Technical Reference Manual (TRM), Version 4.0 (effective June 1, 2015), 2015.
[580] American National Standards Institute (ANSI), ANSI Z21.47 Standard for Central Gas-Fired Central Furnaces, 2012.
[581] Department of Energy (DOE), Commercial Warm Air Furnace Standard DOE 10 CFR, Part 431, Subpart D – Commercial Warm Air Furnaces, 2004.
[582] American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, 2013.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years, which is consistent with the established TRM measure life for single-package and split system unitary air conditioners, since in colder climates these unitary packages typically contain a gas-fired, warm air furnace section, with an electric air conditioning section.

DEEMED MEASURE COST

The actual incremental equipment and installation costs should be used, if available. If not, the incremental cost of $5.42 per 1000 Btu/hr of output capacity should be used for the condensing furnace equipment (as part of a unitary package) and its installation (including the combustion condensate drainage and disposal system). This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard[583]. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

LOADSHAPE

Loadshape C23 - Commercial Ventilation

COINCIDENCE FACTOR

The coincidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

Algorithm

CALCULATION OF SAVINGS

The following methodology provides formulas for estimating gas heating savings associated with condensing furnaces in unitary HVAC packages when applied as a CV, DOAS, MUAS, or any RTU that is indirectly heating 100% outside air (OA). These types of HVAC systems typically run continuously during the HVAC operating schedule to provide building ventilation and maintain indoor air quality or to compensate for exhaust and maintain neutral or slightly positive building pressurization. The algorithm estimates the gas use reduction resulting from utilizing condensing heating of 90% or higher thermal efficiency (TE) in place of the federal minimum TE of 80% (or other user defined baseline TE) for commercial warm air furnaces.

The methodology provides a representative group of operating schedules for the market sector applications highlighted earlier based on DOE commercial reference building models[584]. Heating loads during the operating schedule are determined based on hourly differences between a range of supply air (SA) heated to temperatures and the OA temperature using Typical Meteorological Year (TMY3)[585] weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 °F for heating in C&I settings per the TRM. To accommodate the variability in heating base temperatures in C&I settings, these hourly heating loads are also generated for base temperatures of 45 °F and 65 °F for heating. The hourly heating loads are then summed for the entire year. The annual heating loads are calculated in this manner for the climate zone 2 weather station (Chicago O'Hare Airport), which is then normalized to its National Climatic Data Center (NCDC)[586] 30 year (1981-2010) weather average by multiplying by the heating degree day (HDD) ratio of the NCDC/TRM HDD55 over the TMY3 HDD55 (HDD at base temperature of 55 °F), and likewise for the annual heating loads for HDD45 (HDD at base temperature of 45 °F) and HDD65 (HDD at base temperature of 65 °F), using the values in Table 1 and Table 2. Since detailed hourly weather data is not available for all 5 of the TRM climate zone weather stations, the annual heating loads for the other climate zones are determined by multiplying the climate zone 2 annual heating loads by the ratio of the other climate zone NCDC HDD over the climate zone 2 NCDC HDD, using the values in Table 1.

[583] Department of Energy (DOE), Rulemaking for Commercial Warm Air Furnace Standard, Technical Support Document 2015.
[584] Department of Energy (DOE) National Renewable Energy Laboratory, Commercial Reference Building Models of the National Building Stock, 2011.
[585] Department of Energy (DOE) National Renewable Energy Laboratory, Users Manual for TMY3 Data Sets, 2008.
[586] National Climatic Data Center, 1981-2010 Climate Normals, 2015.

These annual heating loads on a per unit airflow basis are then used in conjunction with the actual airflow of the 100% OA system and its condensing efficiency to calculate the gas heating savings versus the baseline (non-condensing) heating efficiency. This measure results in additional electric use by the unitary HVAC package due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

Table 1. NCDC/TRM HDD Values for All Climate Zones

Climate Zone - Weather Station/City	NCDC 30 Year Average HDD45[8]	NCDC 30 Year Average HDD55[1,8]	NCDC 30 Year Average HDD65[8]
1 - Rockford AP / Rockford	2495	4272	6569
2 - Chicago O'Hare AP / Chicago	2263	4029	6340
3 - Springfield #2 / Springfield	1812	3406	5495
4 - Belleville SIU RSCH / Belleville	1197	2515	4379
5 - Carbondale Southern IL AP / Marion	1183	2546	4477

Table 2. TMY3 HDD Values for Climate Zone 2

Climate Zone - Weather Station/City	TMY3 HDD45[7]	TMY3 HDD55[7]	TMY3 HDD65[7]
2 - Chicago O'Hare AP / Chicago	2422	4188	6497

ELECTRIC ENERGY SAVINGS

As noted previously, this measure results in additional SA fan electric use by the unitary HVAC system due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

$$\Delta kWh = -(t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$$

Where:

t_{FAN} = annual fan runtime (hr), refer to Tables 1 through 4

cfm = airflow (cfm), use actual or rated system airflow

ΔP = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known

$\eta_{FAN/MOTOR}$ = combined fan and motor efficiency, assume 0.60 if actual value not known

8520 = conversion factor (fan horsepower – HP – calculation constant of 6356 for standard air conditions adjusted by 1 HP = 0.746 kW, or 6356/ 0.746 = 8520 for this kW calculation)

EXAMPLE:

For a "big box" retail store operating 24 hours a day and 7 days a week (8760 hours per year) with a 5000 cfm DOAS that has an incremental pressure drop of 0.15 inch W.G. and a combined fan and motor efficiency of 0.6 has annual kWh savings of:

$$\Delta kWh = -(t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$$

$$= -(8760 * 5000 * 0.15) / (0.6 * 8520)$$

$$= -1285 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

The additional SA fan electric use by the unitary HVAC system will typically result in a modest electric demand increase.

$\Delta kW = (\Delta kWh / t_{FAN}) * CF$

Where:

CF = 1.0

> **EXAMPLE:**
>
> Continuing the previous example:
>
> $\Delta kW = (\Delta kWh / t_{FAN}) * CF$
>
> $= (- 1285 / 8760) * 1.0$
>
> $= - 0.15$ kW

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_{C})]/ 100,000$

Where:

Q_{OA} = annual outside air (OA) heating load per cfm of OA (Btu/cfm)

First, select the most representative operating schedule for the application from among the four (4) scenarios listed below and its set of three (3) applicable tables. Second, select the table in that set with the most representative HDD base temperature – the base temperature for OA below which heating is required. If that base temperature is not readily determined, select the TRM default base temperature of 55 °F (HDD55) for heating in C&I settings. Third, select the climate zone within that table. Fourth, select an appropriate heated to supply air (SA) temperature within that table. Use the resulting Q_{OA} value, with linear interpolation allowed between SA temperatures.

The four (4) scenarios available are indicative of the following building applications and operating schedules:

1. 24 hour a day and 7 day a week (24/7) operation, with HVAC operating schedule of 8760 hours per year, typical of large retail stores with DOAS, hotel/multifamily buildings with corridor MUAS, and healthcare facilities with DOAS. Use Table 3 through Table 5.
2. 6:00 AM to 1:00 AM every day operation, with HVAC operating schedule of 7300 hours per year, typical of full service and quick service restaurants with kitchen MUAS. Use Table 6 through Table 8.
3. 7:00 AM to 9:00 PM Monday-Friday, 7:00 AM to 10:00 PM Saturday, and 9:00 AM to 7:00 PM Sunday operations, with HVAC operating schedule of 5266 hours per year, typical of non-24/7 retail stores with DOAS. Use Table 9 through Table 11.
4. 7:00 AM to 9:00 PM Monday-Friday operation, with HVAC operating schedule of 3911 hours per year, typical of school buildings with DOAS. Use Table 12 through Table 14.

TE_{NC} = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known

TE_{C} = condensing thermal efficiency (TE), use actual TE or if unknown assume 90% (0.90)

100,000 = conversion factor (1 therm = 100,000 Btu)

EXAMPLE:

Continuing the previous example, for a climate zone 2 (Chicago O'Hare AP / Chicago) application using a 90% TE condensing DOAS with a supply air temperature from the DOAS of 95 °F:

$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_{C})]/ 100,000$

$= 303,268 * 5,000 * (1/0.80 – 1/0.90)/100,000$

$= 2,106$ therms

<u>8760 Hour Annual Operation Scenario</u>

Table 3. 8760 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	189,343	230,897	272,451	314,004
2 - Chicago O'Hare AP / Chicago	171,737	209,427	247,116	284,806
3 - Springfield #2 / Springfield	137,511	167,689	197,868	228,046
4 - Belleville SIU RSCH / Belleville	90,839	110,775	130,711	150,647
5 - Carbondale Southern IL AP / Marion	89,777	109,479	129,182	148,885

Table 4. 8760 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	216,145	268,852	321,559	374,266
2 - Chicago O'Hare AP / Chicago	203,850	253,559	303,268	352,977
3 - Springfield #2 / Springfield	172,329	214,351	256,374	298,397
4 - Belleville SIU RSCH / Belleville	127,248	158,278	189,307	220,337
5 - Carbondale Southern IL AP / Marion	128,817	160,229	191,641	223,053

Table 5. 8760 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 8760 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone - Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	239,158	308,050	376,942	445,834
2 - Chicago O'Hare AP / Chicago	230,820	297,311	363,802	430,292
3 - Springfield #2 / Springfield	200,056	257,685	315,314	372,943
4 - Belleville SIU RSCH / Belleville	159,426	205,351	251,276	297,200
5 - Carbondale Southern IL AP / Marion	162,994	209,947	256,899	303,852

<u>7300 Hour Annual Operation Scenario</u>

Table 6. 7300 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	151,914	185,369	218,823	252,278
2 - Chicago O'Hare AP / Chicago	137,788	168,132	198,476	228,819
3 - Springfield #2 / Springfield	110,328	134,624	158,921	183,217
4 - Belleville SIU RSCH / Belleville	72,882	88,932	104,982	121,033
5 - Carbondale Southern IL AP / Marion	72,030	87,892	103,755	119,617

Table 7. 7300 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	173,511	215,950	258,389	300,828
2 - Chicago O'Hare AP / Chicago	163,641	203,666	243,691	283,716
3 - Springfield #2 / Springfield	138,338	172,174	206,010	239,846
4 - Belleville SIU RSCH / Belleville	102,149	127,133	152,118	177,103
5 - Carbondale Southern IL AP / Marion	103,408	128,701	153,993	179,286

Table 8. 7300 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 7300 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	191,803	247,046	302,288	357,531
2 - Chicago O'Hare AP / Chicago	185,117	238,434	291,750	345,067
3 - Springfield #2 / Springfield	160,444	206,655	252,866	299,076
4 - Belleville SIU RSCH / Belleville	127,859	164,685	201,510	238,336
5 - Carbondale Southern IL AP / Marion	130,720	168,370	206,020	243,670

<u>5266 Hour Annual Operation Scenario</u>

Table 9. 5266 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	104,175	127,350	150,524	173,699
2 - Chicago O'Hare AP / Chicago	94,488	115,508	136,527	157,547
3 - Springfield #2 / Springfield	75,657	92,488	109,319	126,149
4 - Belleville SIU RSCH / Belleville	49,979	61,097	72,215	83,334
5 - Carbondale Southern IL AP / Marion	49,394	60,383	71,371	82,359

Table 10. 5266 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	118,320	147,406	176,492	205,578
2 - Chicago O'Hare AP / Chicago	111,590	139,021	166,452	193,884
3 - Springfield #2 / Springfield	94,335	117,524	140,714	163,904
4 - Belleville SIU RSCH / Belleville	69,657	86,780	103,904	121,027

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
5 - Carbondale Southern IL AP / Marion	70,516	87,850	105,184	122,519

Table 11. 5266 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 5266 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	130,903	168,718	206,532	244,347
2 - Chicago O'Hare AP / Chicago	126,339	162,836	199,333	235,829
3 - Springfield #2 / Springfield	109,501	141,133	172,765	204,398
4 - Belleville SIU RSCH / Belleville	87,262	112,470	137,678	162,886
5 - Carbondale Southern IL AP / Marion	89,215	114,987	140,759	166,531

3911 Hour Annual Operation Scenario

Table 12. 3911 Hour Annual Operation Scenario for HDD45

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	75,029	91,729	108,428	125,128
2 - Chicago O'Hare AP / Chicago	68,053	83,199	98,346	113,492
3 - Springfield #2 / Springfield	54,490	66,618	78,746	90,874
4 - Belleville SIU RSCH / Belleville	35,996	44,008	52,019	60,031
5 - Carbondale Southern IL AP / Marion	35,575	43,493	51,411	59,329

Table 13. 3911 Hour Annual Operation Scenario for HDD55

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	85,672	106,825	127,979	149,132
2 - Chicago O'Hare AP / Chicago	80,799	100,749	120,699	140,649
3 - Springfield #2 / Springfield	68,305	85,170	102,035	118,901
4 - Belleville SIU RSCH / Belleville	50,436	62,890	75,343	87,797
5 - Carbondale Southern IL AP / Marion	51,058	63,665	76,272	88,879

Table 14. 3911 Hour Annual Operation Scenario for HDD65

Supply Air Fan Runtime = 3911 Hours	Q_{oa} (Annual Btu/cfm) At Supply Air Temperature Of			
Climate Zone -Weather Station/City	75°F	85°F	95°F	105°F
1 - Rockford AP / Rockford	95,460	123,294	151,128	178,963
2 - Chicago O'Hare AP / Chicago	92,132	118,996	145,860	172,724
3 - Springfield #2 / Springfield	79,853	103,136	126,420	149,703
4 - Belleville SIU RSCH / Belleville	63,635	82,190	100,745	119,299
5 - Carbondale Southern IL AP / Marion	65,059	84,029	102,999	121,969

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The actual incremental annual maintenance costs should be used, if available. If not, the incremental cost of $0.05 per 1000 Btu/hr of output capacity should be used for maintaining the combustion condensate disposal system yearly. This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard6. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

MEASURE CODE: CI-HVC-DSFN-V02-190101

REVIEW DEADLINE: 1/1/2022

4.4.38 Covers and Gap Sealers for Room Air Conditioners

Description

Room air conditioners (window ACs, through-the-wall or sleeve ACs, PTACs or PTHPs) constitute a permanent or semi-permanent penetration through the building's envelope. These units are often poorly installed, resulting in gaps that act like air leakage pathways through the building's envelope. The uncontrolled movement of air across the gaps in the envelope (infiltration) increases the building's winter heating requirements and reduces its overall energy performance.

The heat loss and infiltration can be reduced by installing a rigid or flexible insulated cover on the inside of a room AC. These covers should be maintained by building staff and should remain installed through the heating season. Simple uninsulated cloth covers with no sealing at edges do not qualify for this measure.

There are several types of AC covers available that may be eligible for this measure:

1. If the room AC is left in the window or sleeve, a rigid cover that covers the indoor side of the AC unit with foam gaskets to seal the edges may be installed.
2. If the room AC is absent or is removed during the heating months, a rigid cover that fits inside the sleeve with foam gaskets along the edges for proper air sealing may be installed.
3. Flexible covers that are well insulated and perfectly cover the indoor side of the AC unit may also be eligible for this measure.

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 installed equipment is a rigid cover that fits inside the empty sleeve or completely covers the indoor side of a window AC unit, with foam gaskets sealing the edges. A flexible insulated cover that perfectly covers the indoor side of the unit and seals gaps may also be installed. Covers should remain installed throughout the winter heating season.

Definition of Baseline Equipment

The baseline equipment is a room AC (window AC, through-the-wall or sleeve AC, PTAC or PTHP) that is poorly installed with gaps around the edges and does not use AC covers or gap sealers during the winter heating months.

Deemed Lifetime of Efficient Equipment

The estimated useful life of typical AC covers is 5 years[587].

Deemed Measure Cost

The measure cost is the full cost of installing AC covers. Actual installation costs (material and labor) should be used if available. In actual costs are unknown, assume material cost[588] of $24 (flexible covers) up to $119, depending on size of the AC unit. The install time per unit is 15 to 30 minutes at assumed labor rate of $20/hour.

Loadshape

Loadshape C04 – Commercial Electric Heating

Coincidence Factor

N/A

---

[587] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs V4, April 2016 (New York TRM).
[588] Cost estimates from customer invoices and vendors. Material costs can be lower for bulk orders.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

If the building is electrically heated, electric energy savings are calculated as follows:

$$\Delta kWh = (Q_{infiltration} * 1.08 * (T_{OA} - T_{SA}) * EFLH_{heat}) / (3{,}412 * COP)$$

Where:

$Q_{infiltration}$ = Air infiltration (CFM) due to poor installation of window or through-the-wall AC[589]

= $ELA * 0.000645 * (f_s^2 * (T_{OA} - T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

Where:

ELA = Effective Leakage Area (sq. in.)

= Can be collected on site; if unknown, assume 6 sq. in.[590]

0.000645= Converts square inches to square meters

f_s = Stack Coefficient

= $1/3 * (9.81 * Height * 0.3048) / (T_{OA})^{0.5}$

f_w = Wind Coefficient

= $A * B * (Height * 0.3048) / (10)^C$

Where:

9.81 = Acceleration due to gravity (m/s^2)

Height = Height of the location of the leakage area in feet

= Assume 8 ft per floor

T_{OA} = Average Outside Air Temperature during heating period[591]. Use values from table below, based on facility location[592]. This figure must be in Kelvin to determine Stack Coefficient (f_s) and infiltration ($Q_{infiltration}$), but in Fahrenheit to determine energy savings (ΔkWh, ΔTherms).

Zone	T_{OA} (°F)	T_{OA} (K)
Zone 1 (Rockford)	31.63	272.94
Zone 2 (Chicago)	33.99	274.26
Zone 3 (Springfield)	34.58	274.58
Zone 4 (Belleville)	36.24	275.51
Zone 5 (Marion)	39.07	277.08

[589] Infiltration equation and values for stack and wind coefficient equations from "The Use of Blower Door Data." Max Sherman, 1998. The equation is adjusted for wall leakage area (i.e. no ceiling or floor leakage).

[590] Average effective leakage area for multi-family building AC units from "There are Holes in Our Walls." Prepared for Urban Green Council by Steven Winter Associates, April 2011.

[591] "Heating Period" is defined as hours when the TMY3 dry bulb temperature is less than 55°F (balance point)

[592] Based on NREL's Typical Meteorological Year 3 (TMY3) data for different weather stations.

A, B and C = Constants based on the facility site's shielding and terrain parameters. Use values from the tables below[593].

Shielding Class	Shielding Type	Shielding Description	A
1	None	No obstructions or local shielding whatsoever (i.e. isolated building)	0.324
2	Light	Light local shielding with few obstructions (e.g. A few trees or a shed in the vicinity)	0.285
3	Moderate	Moderate local shielding; some obstructions within two house heights (e.g. Thick hedge fence on fence and nearby building)	0.24
4	Heavy	Heavy shielding; obstructions around most of perimeter buildings or trees within five building heights in most directions (e.g. Well developed/dense tract house)	0.185
5	Very Heavy	Very heavy shielding, large obstruction surrounding perimeter within two house heights (e.g. Typical downtown area)	0.102

Terrain Class	Terrain Type	Terrain Description	B	C
1	None	Ocean or other body of eater with at least 5 km of unrestricted space	1.3	0.1
2	Light	Flat terrain with some isolated obstacles (e.g. Buildings or trees well separated from each other)	1	0.15
3	Moderate	Rural areas with low buildings, trees etc.	0.85	0.2
4	Heavy	Urban, industrial or forest areas	0.67	0.25
5	Very Heavy	Center of large city (e.g. Manhattan)	0.47	0.35

0.3048 = Converts feet to meters

T_{SA} = Average Indoor Air Temperature during heating period. This figure will need to be in Kelvin to calculate infiltration ($Q_{infiltration}$) and Fahrenheit to calculate energy savings (ΔkWh, ΔTherms).

= Collected on site. If unknown, assume 72°F (295 K). If known, convert °F to K by using the following equation: K = (°F + 459.67) * (5/9).

U = Average Wind Velocity (m/s) during heating period. Use table below, based on facility location[594].

Zone	U (m/s)
Zone 1 (Rockford)	4.50
Zone 2 (Chicago)	4.67
Zone 3 (Springfield)	4.60
Zone 4 (Belleville)	3.92
Zone 5 (Marion)	3.07

2118.88 = Converts m^3/s to CFM

[593] Shielding and terrain class descriptions and constants from "The Use of Blower Door Data." Max Sherman, 1998" and "Wind and Infiltration Interaction for Small Buildings." MH Sherman and DT Grimsrud, Lawrence Berkley Laboratory, 1982.
[594] Based on TMY3 data, see "Covers for Room AC_11092016.xls" for more information.

1.08 = Sensible heat transfer constant (Btu/hr.CFM.°F)

$EFLH_{heat}$ = Equivalent Full Load Hours for heating from section 4.4 HVAC End Use[595]

3,412 = Converts Btus to kWh

COP = Coefficient of Performance of the heating unit

= Collected on site. If unknown assume 2.6 for PTHP[596]

Deemed per-unit savings for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

Multi-Family - Electric Savings per Unit (kWh/unit)						
Floor	Height	Rockford	Chicago	Springfield	Belleville	Marion
1	8	55.18	53.16	45.70	31.09	25.67
2	16	68.19	65.31	56.17	38.72	32.66
3	24	77.92	74.34	63.96	44.45	37.97
4	32	86.04	81.85	70.44	49.25	42.44
5	40	93.15	88.42	76.11	53.46	46.37
6	48	99.56	94.34	81.22	57.26	49.93
7	56	105.44	99.76	85.90	60.75	53.20
8	64	110.91	104.80	90.25	63.99	56.24
9	72	116.04	109.53	94.33	67.04	59.11
10	80	120.89	114.00	98.19	69.92	61.81
12	96	129.92	122.31	105.36	75.29	66.85
14	112	138.21	129.94	111.95	80.22	71.49
16	128	145.93	137.04	118.08	84.81	75.82
18	144	153.19	143.72	123.84	89.13	79.88
20	160	160.05	150.03	129.29	93.21	83.72
22	176	166.59	156.03	134.47	97.10	87.38
24	192	172.83	161.77	139.42	100.82	90.88
26	208	178.82	167.28	144.18	104.38	94.23
28	224	184.58	172.57	148.75	107.81	97.46
30	240	190.15	177.69	153.17	111.12	100.58

[595] Although in theory the hours should be all hours that infiltration is expected (i.e. all hours <55F), the IL TAC has agreed to use the Equivalent Full Load Hours to keep the savings at a more conservative level.

[596] From IECC 2012 Minimum Efficiency Requirements. For a 1 ton PTHP, COP = 2.9 – (0.026 * 12,000/1,000).

EXAMPLE

A mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10th floor (80 feet high) with PTHPs that get covered with a cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related energy savings from the AC covers and seals are calculated as follows -

For Shielding Class 3 and Terrain Class 3,

A = 0.24, B = 0.85 and C = 0.2

Therefore,

$f_s = 1/3 * (9.81\ m/s^2 * 80\ ft * 0.3048\ m/ft / 274.26\ K)^{0.5} = 0.3\ m/K^{½}.s$

$f_w = 0.24 * 0.85 * (80\ ft * 0.3048\ m/ft / 10\ m)^{0.2} = 0.24$

Total effective leakage area (ELA) = 16 units * 6 sq. in. = 96 sq. in.

$Q_{infiltration} = ELA * 0.000645 * (f_s^2 * (T_{OA} – T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

$= 96 * 0.000645 * (0.3^2 * (296.48\ K – 274.26\ K) + 0.24^2 * 4.67^2)^{1/2} * 2118.88$

= 237 CFM

ΔkWh = (237 * 1.08 Btu/hr.CFM.°F * (74°F – 33.99°F) * 1,685) / (3,412 Btu/kWh* 2.6)

= 1,945 kWh

Summer Coincident Peak Demand Savings

As the savings occur during the winter season (non-peak), there are no demand savings associated with this measure.

Natural Gas Savings

If the building is heated with gas, the natural gas savings are calculated as follows:

$$\Delta Therms = (Q_{infiltration} * 1.08\ Btu/hr.CFM.°F * (T_{OA} – T_{SA}) * EFLH_{heat}) / (100,000\ Btu/therm * \eta)$$

Where,

η = Efficiency of heating equipment.

= Collected on site. If unknown, assume 80%[597].

100,000 = Converts Btus to therms

Other factors as defined above

Deemed per-unit savings per unit for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

Multi-Family - Gas Savings per Unit (Therms/Unit)						
Floor	Height	Rockford	Chicago	Springfield	Belleville	Marion
1	8	6.12	5.90	5.07	3.45	2.85
2	16	7.56	7.24	6.23	4.29	3.62
3	24	8.64	8.24	7.09	4.93	4.21
4	32	9.54	9.08	7.81	5.46	4.71
5	40	10.33	9.81	8.44	5.93	5.14
6	48	11.04	10.46	9.01	6.35	5.54
7	56	11.69	11.06	9.53	6.74	5.90
8	64	12.30	11.62	10.01	7.10	6.24
9	72	12.87	12.15	10.46	7.43	6.55

597 Energy Independence and Security Act of 2007 – averaged for hot water and steam boilers.

Multi-Family - Gas Savings per Unit (Therms/Unit)						
Floor	Height	Rockford	Chicago	Springfield	Belleville	Marion
10	80	13.41	12.64	10.89	7.75	6.85
12	96	14.41	13.56	11.68	8.35	7.41
14	112	15.33	14.41	12.41	8.90	7.93
16	128	16.18	15.20	13.09	9.40	8.41
18	144	16.99	15.94	13.73	9.88	8.86
20	160	17.75	16.64	14.34	10.34	9.28
22	176	18.47	17.30	14.91	10.77	9.69
24	192	19.16	17.94	15.46	11.18	10.08
26	208	19.83	18.55	15.99	11.57	10.45
28	224	20.47	19.14	16.50	11.96	10.81
30	240	21.09	19.70	16.98	12.32	11.15

EXAMPLE

A gas-heated mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10th floor (80 feet high) with room air conditioners that get covered with an AC cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related therm savings from the AC covers and seals are calculated as follows:

For Shielding Class 3 and Terrain Class 3,

A = 0.24, B = 0.85 and C = 0.2

Therefore,

$f_s = 1/3 * (9.81 \text{ m/s}^2 * 80 \text{ ft} * 0.3048 \text{ m/ft} / 274.26 \text{ K})^{0.5} = 0.3 \text{ m/K}^{½}.\text{s}$

$f_w = 0.24 * 0.85 * (80 \text{ ft} * 0.3048 \text{ m/ft} / 10 \text{ m})^{0.2} = 0.24$

Total effective leakage area (ELA) = 16 units * 6 sq.in = 96 sq. in

$Q_{infiltration} = ELA * 0.000645 * (f_s^2 * (T_{OA} – T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

$= 96 * 0.000645 * (0.3^2 * (296.48 \text{ K} – 274.26 \text{ K}) + 0.24^2 * 4.67^2)^{1/2} * 2118.88$

= 237 CFM

ΔTherms = (237 * 1.08 Btu/hr.CFM.°F * (74°F – 33.99°F) * 1,685) / (100,000 Btu/therm * 80%)

= 216 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-CRAC-V01-180101

REVIEW DEADLINE: 1/1/2023

4.4.39 High Temperature Heating and Ventilation (HTHV) Direct Fired Heater

Description

This measure applies to 100% outside air, high temperature heating and ventilation (HTHV) direct fired gas heaters. These units replace unit heaters (indirect gas fired or steam coil) or rooftop units in warehouses which suffer from extreme temperature stratification, minimal controls and reduced heating efficiencies.

Warehouses have high ceilings (~30 ft high), and suffer from stratification of air. The warm air rises and remains near the roof, which keeps the thermostat from reaching its desired setpoint. This increases the run hours of the heating unit and causes discomfort among the occupants. The HTHV units have high pressure fans that direct high temperature and high velocity air towards the floor and thus help minimize temperature stratification. On average, a 30 ft high warehouse could reduce its linear stratification from 0.53°F/ft to 0.13°F/ft, thus maintaining a more uniform temperature in the room and reducing the operating hours of the heating unit.

Since the HTHV units are direct fired, they also have improved efficiencies of 92% compared to 80% for a typical indirect fired unit heater or rooftop unit. They transfer the latent heat of the flue gases into the space instead of venting it out.

This measure only applies to high ceiling warehouses that do not have any other destratification technologies installed (i.e. destratification fans, air rotation units etc.). New HTHV units must be the warehouse's primary heat source.

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 equipment must be a 100% outside air, HTHV direct fired gas heater, with a discharge temperature greater than or equal to 150°F, a temperature rise greater than or equal to 140°F, and an efficiency exceeding 92%.

Definition of Baseline Equipment

The baseline equipment must be an indirect fired gas or steam unit heater or a rooftop unit used as the primary space heating source. Warehouses with existing destratification technologies (high volume, low speed fans or air turnover units) do not qualify for this measure.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years[598].

Deemed Measure Cost

The measure cost should be based on a contractor's evaluation of the project scope and may vary significantly on a project to project basis. If unknown, for early replacement or retrofit projects, assume $14.50/MBtu/hr (material cost for an HTHV unit) or $26/MBTUh (sum of material and installation cost)[599].

The incremental measure cost, assuming a baseline of standard efficiency unit heaters, is $7.43/MBtu/hr (material cost)[600].

[598] Based on "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014.

[599] Average costs from CLEAResult's evaluation of 9 different projects in the Chicagoland area.

[600] Based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014.

LOADSHAPE

Loadshape C04: Commercial Electric Heating

COINCIDENCE FACTOR

Assumed to be 0.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

HTHV units may increase the facility's electric energy consumption due to high pressure motors that supply air at higher velocity.

ΔkWh = - kWh/HDD * HDD

Where:

kWh/HDD = increase in electric energy consumption due to HTHV fan motor

= 1.04[601]

HDD = heating degree days

Zone	City	HDD55[602]	ΔkWh
1	Rockford	4,272	(4,443)
2	Chicago	4,029	(4,190)
3	Springfield	3,406	(3,542)
4	Belleville	2,515	(2,616)
5	Marion	2,546	(2,648)

Although HTHV fan motors have a higher power draw, they also result in decreased heating equipment operating time, potentially offsetting some of the increase in electrical energy consumption. Therefore, if replacing heating equipment other than unit heaters, a custom evaluation may be necessary to determine if there is an increase in electrical energy consumption.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Since HTHV units operate during the winter (non-peak) season, there are no demand savings associated with this measure.

NATURAL GAS SAVINGS

Custom calculation below, otherwise use a deemed savings factor from the table that follows.

$\Delta Therms = (FLH_{base} * Cap_{base} / (\eta_{base} * 100)) – (FLH_{eff} * Cap_{eff} / (\eta_{eff} * 100))$

Where:

$FLH_{base} = LF_{base} * Hours$

$FLH_{eff} = LF_{eff} * Hours$

[601] Based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. This study replaced four standard unit heaters with HTHV units, and the electrical energy increased from 0.4 kWh/HDD to 1.44 kWh/HDD. Therefore savings are assumed to be 1.04 kWh /HDD.

[602] 30-year normals from the National Climactic Data Center (NCDC), assuming base temperature 55.

Hours = Annual operating hours of the unit, calculated as total number of hours when outside air temperature is less than 55°F. This can be adjusted based on the facility's occupancy schedule.

LF_{base} = load factor of baseline unit heater

= $(Q_{inf,base} + Q_{w,base} + Q_{r,base})/(Cap_{base}*100)$

LF_{eff} = load factor of HTHVheater

= $(Q_{inf,eff} + Q_{w,eff} + Q_{r,eff})/(Cap_{eff}*100)$

Cap_{base} = existing heating unit input capacity (MBtu/hr)

= can be collected on site, or assumed to be the same as HTHV unit capacity, Cap_{eff}

Cap_{eff} = HTHV unit input capacity (MBtu/hr)

= can be collected on site or from specification sheets

η_{base} = efficiency of existing heating unit

= collected from equipment nameplate or assumed as70% for steam unit heaters, 80% for gas fired unit heaters, and 84% for rooftop units[603]

η_{eff} = efficiency of HTHV unit

= collected from equipment nameplate or assumed as 92%

100 = converts MBtu to therms

See table below for savings inputs.

Parameter	Existing Unit	Proposed (Efficient) Unit
Temperatures		
Setpoint Temperature (°F)	$T_{setpoint}$ = collected on site, or assumed as 65°F	
Ceiling Temperature[604] (°F)	Either collected on site when the existing unit is in operation with an infrared gun, or assumed as: $T_{c,base} = T_{setpoint} + 0.53°F/ft * Height$	Either collected on site when the proposed unit is in operation with an infrared gun, or assumed as: $T_{c,eff} = T_{setpoint} + 2$ to 4°F
Average Room Temperature (°F)	$T_{r,base} = (T_{setpoint} + T_{c,base})/2$	$T_{r,eff} = (T_{setpoint} + T_{c,eff})/2$
Outside Air Temperature (°F)	T_{OA} , from local weather data[605]	
Heat Loads		
Infiltration Load[606]:	$Q_{inf,base} = 0.04CFM/ft^2$ * (Wall Surface Area + Roof Surface Area) * 1.08 * $(T_{r,base} - T_{OA})$	$Q_{inf,eff} = 0.04CFM/ft^2$ * (Wall Surface Area + Roof Surface Area) * 1.08 * $(T_{r,eff} - T_{OA})$
Wall Conduction Load[607]:	$Q_{w,base} = 1/R\text{-value}_{wall}$ * (Wall Surface Area * 1.08 * $(T_{r,base} - T_{OA})$ Where $R\text{-value}_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15.	$Q_{w,eff} = 1/R\text{-value}_{wall}$ * (Wall Surface Area * 1.08 * $(T_{r,eff} - T_{OA})$ Where $R\text{-value}_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15.

[603] Efficiency of existing systems assumed from ASHRAE 90.1 – 2010 and manufacturer's specification sheets for various equipment. Steam unit heaters have a lower efficiency due to steam distribution losses.

[604] Baseline stratification rate is based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. The study also verifies that the proposed ceiling temperature cen be maintained within 2-4°F of the setpoint.

[605] Use Typical Meteorological Year (TMY3) data from NREL.

[606] Typical infiltration rate assumed from Infiltration Modeling Guidelines for Commercial Building Energy Analysis, prepared for US. DOE by Pacific Northwestern National Laboratory, 2009

[607] Roof and Wall Insulation R-values are based on ASHRAE 90.1- 2010. (Jim Young 2014) (K. Gowri 2009)

Parameter	Existing Unit	Proposed (Efficient) Unit
Roof Conduction Load:	$Q_{r,base}$ = 1/R-$value_{roof}$ * (Roof Surface Area * 1.08 * ($T_{r,base}$ - T_{OA}) Where R-$value_{roof}$ = the insulation value of the roof. It can be collected on site, or assumed as R-20.	$Q_{r,eff}$ = 1/R-$value_{roof}$ * (Roof Surface Area * 1.08 * ($T_{r,eff}$ - T_{OA}) Where R-$value_{roof}$ = the insulation value of the roof. It can be collected on site, or assumed as R-20.
Surface Areas		
Roof Surface Area:	Collected on site or assumed as: = facility area in sq.ft. If facility area is unknown, assume facility area[608] = 41.4 sq. ft./MBtu/hr * Cap_{eff}	
Wall Surface Area:	Collected on site or assumed as: = (Height * Length + Height * Width) * 2 Where: Length, Height and Width (feet) of the facility can be collected on site. If unknown, assume: Length = Width = (Facility Area)$^{1/2}$ and Height = 25 ft If facility area is unknown, assume facility area = 41.4 sq. ft./MBtu/hr * Cap_{eff}	

The default values from the table above were used to calculate the deemed savings values in the table below. Savings are provided for various rated input capacity ranges and weather stations.

Cap_{eff} (MBtu/hr)	Average Cap_{eff} (MBtu/hr)	Nearest Weather Station	ΔTherms (Baseline Equipment: Steam Fired Unit Heaters)	ΔTherms (Baseline Equipment: Gas Fired Unit Heaters)	ΔTherms (Baseline Equipment: Rooftop Units)
300 > Cap_{eff} ≥ 500	400	Rockford	3,120	1,996	1,620
500 > Cap_{eff} ≥ 900	757	Rockford	5,208	3,346	2,725
900 > Cap_{eff} ≥ 1,000	950	Rockford	6,280	4,047	3,297
1,000 > Cap_{eff} ≥ 1,400	1,200	Rockford	7,656	4,932	4,020
1,400 > Cap_{eff} ≥ 1,600	1,499	Rockford	9,249	5,966	4,872
1,600 > Cap_{eff} ≥ 2,100	1,850	Rockford	11,100	7,160	5,865
2,100 > Cap_{eff} ≥ 2,400	2,200	Rockford	12,914	8,338	6,820
Cap_{eff} ≥ 2,400	2,718	Rockford	15,547	10,084	8,236
300 > Cap_{eff} ≥ 500	400	Chicago	2,820	1,824	1,488
500 > Cap_{eff} ≥ 900	757	Chicago	4,709	3,058	2,506
900 > Cap_{eff} ≥ 1,000	950	Chicago	5,681	3,696	3,031
1,000 > Cap_{eff} ≥ 1,400	1,200	Chicago	6,924	4,512	3,696
1,400 > Cap_{eff} ≥ 1,600	1,499	Chicago	8,364	5,456	4,482
1,600 > Cap_{eff} ≥ 2,100	1,850	Chicago	10,046	6,549	5,384
2,100 > Cap_{eff} ≥ 2,400	2,200	Chicago	11,682	7,634	6,292
Cap_{eff} ≥ 2,400	2,718	Chicago	14,079	9,214	7,583
300 > Cap_{eff} ≥ 500	400	Springfield	2,452	1,588	1,300
500 > Cap_{eff} ≥ 900	757	Springfield	4,095	2,665	2,188
900 > Cap_{eff} ≥ 1,000	950	Springfield	4,950	3,221	2,651
1,000 > Cap_{eff} ≥ 1,400	1,200	Springfield	6,024	3,936	3,240
1,400 > Cap_{eff} ≥ 1,600	1,499	Springfield	7,285	4,767	3,912
1,600 > Cap_{eff} ≥ 2,100	1,850	Springfield	8,732	5,717	4,718
2,100 > Cap_{eff} ≥ 2,400	2,200	Springfield	10,164	6,666	5,500
Cap_{eff} ≥ 2,400	2,718	Springfield	12,258	8,045	6,632
300 > Cap_{eff} ≥ 500	400	Belleville	2,456	1,604	1,320
500 > Cap_{eff} ≥ 900	757	Belleville	4,103	2,687	2,218

608 Based on DOE's Commercial Prototype Modeled Warehouse building (in Chicago), via the Building Energy Codes Program

Cap_{eff} (MBtu/hr)	Average Cap_{eff} (MBtu/hr)	Nearest Weather Station	ΔTherms (Baseline Equipment: Steam Fired Unit Heaters)	ΔTherms (Baseline Equipment: Gas Fired Unit Heaters)	ΔTherms (Baseline Equipment: Rooftop Units)
900 > Cap_{eff} ≥ 1,000	950	Belleville	4,950	3,249	2,689
1,000 > Cap_{eff} ≥ 1,400	1,200	Belleville	6,036	3,972	3,276
1,400 > Cap_{eff} ≥ 1,600	1,499	Belleville	7,300	4,812	3,972
1,600 > Cap_{eff} ≥ 2,100	1,850	Belleville	8,751	5,772	4,773
2,100 > Cap_{eff} ≥ 2,400	2,200	Belleville	10,186	6,732	5,566
Cap_{eff} ≥ 2,400	2,718	Belleville	12,285	8,127	6,713
300 > Cap_{eff} ≥ 500	400	Marion	2,180	1,444	1,200
500 > Cap_{eff} ≥ 900	757	Marion	3,649	2,430	2,021
900 > Cap_{eff} ≥ 1,000	950	Marion	4,408	2,936	2,442
1,000 > Cap_{eff} ≥ 1,400	1,200	Marion	5,364	3,576	2,988
1,400 > Cap_{eff} ≥ 1,600	1,499	Marion	6,491	4,332	3,613
1,600 > Cap_{eff} ≥ 2,100	1,850	Marion	7,789	5,217	4,348
2,100 > Cap_{eff} ≥ 2,400	2,200	Marion	9,064	6,072	5,082
Cap_{eff} ≥ 2,400	2,718	Marion	10,926	7,339	6,116

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-HTHV-V01-180101

REVIEW DEADLINE: 1/1/2023

4.4.40 Gas High Efficiency Single Package Vertical Air Conditioner

Description

This measure covers the installation of a single package vertical air conditional with a high efficiency gas furnace, referred to here as a through the wall (TTW) condensing gas furnace, instead of a standard efficiency gas furnace. The primary market served by TTWs are multifamily housing and hospitality in a new construction application. High efficiency 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 gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, most of the flue gases condense and must be drained. Management of the acidic condensate is currently a major limiting factor for retrofit application, making the new construction the best initial market point until the industry develops better strategies for condensate management for retrofit applications. Also, TTWs are normally installed at the exterior wall to access outside air to reject heat in the cooling cycle. Placement of TTWs near the exterior might be prohibitive in retrofit applications. Furnaces equipped with ECM fan motors and with above code EER ratings provide an opportunity for additional electric energy savings.

This measure assumes unit size less than or equal to 65,000 Btu/hr.

This measure was developed to be applicable to the following program types: NC, TOS. If applied to other program types such as RF, the measure savings should be verified via a custom measure.

Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an TTW condensing system with code minimum 9.0 EER cooling system (minimum code scheduled to increase to 11.0 EER on September 23, 2019) and a high-efficiency gas furnace with an annual fuel utilization efficiency (AFUE) of 90% or greater.[609] Fan electrical efficiency must exceed the program requirements.

Definition of Baseline Equipment

Baseline equipment for this measure are units with a cooling system that meets the current code minimum 9.0 EER efficiency rating and a heating unit with an AFUE rating of 80% or less.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16.5 years[610].

Deemed Measure Cost

The incremental capital cost for this measure depends on efficiency as listed below[611]:

AFUE	Incremental Cost Premium
80%	$400
90%	$400
95%	$500

Loadshape

Loadshape R08 – Residential Cooling

[609] Electronic Code of Federal Regulations: 10 CFR 431.97, last modified September 27, 2016. Minimum EER standards are scheduled to increase to 11.0 EER on September 23, 2019.
[610] Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010
[611] Based on discussion with TTW Manufacturers at AHR 2018 Show in Chicago, IL.

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) [4]

= 68%[612]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[613]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings come from a high efficiency cooling unit[614]. In some instances, the TTW unit provided by the manufacturer may not have higher efficiency cooling and fan blower motor systems integrated in to the TTW design; in these cases, electric energy savings will be zero for those components.

$$\Delta kWh_{EER} = FLH_{cool} * Capacity * (1/EER_{base} - 1/EER_{eff}) / 1000$$

Where:

FLH_{cool} = Full load hours for cooling [615]:

Climate Zone (City based upon)	FLH_{cool} (multi family)
1 (Rockford)	467
2 (Chicago)	506
3 (Springfield)	663
4 (Belleville)	940
5 (Marion)	820
Weighted Average	564

Capacity = Cooling capacity of the efficient unit in Btu/hr

= Actual installed

EER_{eff} = Energy efficiency ratio of the efficient equipment

= Actual installed rating

[612] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[613] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[614] If an ECM motor in the packaged system is present, savings should be claimed for this measure by referring to the Residential Furnace Blower Motor measure in the IL TRM.

[615] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

EER_{base} = Energy efficiency ratio of the baseline equipment – Presently, the federal minimum efficiency level is 9.0 EER, increasing to 11.0 EER on September 23, 2019[616]

= 9.0

Example: for a Rockford non-weatherized multifamily unit conditioned by a SPVAC with a 2-ton (24,000 Btu/hr) cooling capacity, a rated EER of 11.0, and an ECM fan blower motor installed.

ΔkWh = [467 * 24,000 * (1/9.0 – 1/11.0) / 1000] = 958 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = CF * Capacity * (1/EER_{base} - 1/EER_{eff}) / 1000$$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[617]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[618]

NATURAL GAS SAVINGS

$$\Delta Therms = EFLH_{heat} * Capacity * (AFUE_{eff} – AFUE_{base}) / AFUE_{base} / (100,000\ Btu/Therm)$$

Where

$EFLH_{heat}$ = Equivalent Full Load Hours for heating[619]

Climate Zone (City based upon)	**EFLH$_{heat}$** (general multi family)
1 (Rockford)	1,742
2 (Chicago)	1,704
3 (Springfield)	1,498
4 (Belleville)	1,208
5 (Marion)	1,429

Capacity = Nominal heating input capacity furnace size (Btu/hr) for efficient unit

= Actual

$AFUE_{eff}$ = Efficient furnace annual fuel utilization efficiency rating

= Actual installed rating

$AFUE_{base}$ = Baseline furnace annual fuel utilization efficiency rating

= 80%

[616] Electronic Code of Federal Regulations: 10 CFR 431.97, last modified September 27, 2016. Minimum EER standards are scheduled to increase to 11.0 EER on September 23, 2019.

[617] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[618] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[619] See section 4.4 for details.

For example for a Chicago non-weatherized multifamily unit heated by an SPVAC with a 40 kBtu/hr capacity and a rated AFUE of 93%.

ΔTherms = 1,704 * 40,000 * [(0.93 – 0.8)/0.8] / (100,000 Btu/Therm) = 111 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC -SPVA-V01-190101

REVIEW DEADLINE: 1/1/2023

4.4.41 Advanced Rooftop Controls (ARC)

Description

The Advanced Rooftop Controls (ARC) measure installs demand-controlled ventilation with optional supply-fan speed control via a variable-frequency drive 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 a number of 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.[620]

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 minimizing the energy required to unnecessarily heat and cool outside air. Demand-controlled ventilation can also be combined with the installation of a variable-frequency drive 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 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 cooling, heating, and fan energy reduction.

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 CO2 sensor estimated life.[621]

Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used.

---

[620] Katipamula, S., et al, "Advanced Rooftop Control (ARC) Retrofit: Field-Test Results", Pacific Northwest National Laboratory, July 2013

[621] Based on IL TRM v6.0 Vol. 2 – 4.4.19 Demand Controlled Ventilation

Table 1 – Deemed Measure Cost Details

Measure	Material Unit (Each)	Material Cost / Unit	Labor Unit (Hours)	Labor Rate/ Unit	Total Cost
DCV	1	$1,663.90	3	$96.67	$1,953.91
DCV and VFD with two speed modes (40% ventilating & 90% heating/cooling)	1	$3,025.38	4	$96.67	$3,412.06
DCV and VFD with three speed modes (40% ventilating, 75% 1st stage heating/cooling & 90% 2nd stage heating/cooling)	1	$3,487.00	4	$96.67	$3,873.68

LOADSHAPE

Commercial ventilation C23

COINCIDENCE FACTOR

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [622]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [623]

Algorithm

CALCULATION OF ENERGY SAVINGS

To determine the savings associated with the Advanced Rooftop Controls (ARC) measure we utilized the available IL TRM prototype eQuest models which were initially created by the Energy Center of Wisconsin[624] but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update). These models which were used are the most up-to-date versions and are readily available on the VEIC SharePoint site, under the TRM Reference Documents Section.

Upon examination of the ComEd building prototype models we found 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, we chose only models that: 1) utilized PSZ HVAC systems, and 2) aligned with the small commercial building type applicable to this measure. Once the ComEd baseline models were selected, we determined 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.

622 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
623 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
624 Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010

c. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

Additionally, a number of the building prototype models were found to have supply fan total static pressure modeled inputs that seem excessive and atypical for packaged single zone rooftop units – these included Convenience Store (5 in. wc), Manufacturing Facility (5 in. wc), Office Low Rise (5 in. wc), Religious Building (5 in. wc), and Restaurant (5 in. wc). The remaining models had supply fan total static pressure inputs more in line with what we would expect to find 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 ComEd prototype models as shown in the following table. Hard-coded system capacities and supply airflows can be found in the attached "Advanced Rooftop Controls_End Use Analysis_IL TRM.xlsx" spreadsheet.

Table 2 – Prototype Modifications to eQuest Keywords

Component Adjusted	eQuest Keyword	IL TR 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 in order 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. Full modeled energy end use and savings summaries can be found in the attached “Advanced Rooftop Controls_End Use Analysis_IL TRM.xlsx” spreadsheet.

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 SYSTEM:CMIN-FLOW-RATIO SYSTEM:HMIN-FLOW-RATIO SYSTEM:-MAX-FAN-RATIO	1 1 1 1	1 1 1 1	0.44* 1 1 1	0.44* 0.83** 0.83** 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 IL TRM prototype building type across the five 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

$$\Delta kWh = (tons) \times \text{Normalized Electric Energy Savings}$$

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

Normalized Electric Energy Savings

= kWh/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Electric Energy Savings Summary (kWh/ton)

Table 4 – Electric Energy Savings Summary (kWh/ton)

Building Type - IL TRM Prototype Model Name	Rockford - Zone 1			Chicago - Zone 2			Springfield - Zone 3			Mt Vernon/Belleville - Zone 4			Marion - Zone 5		
	Measure Scenario: 1 - DCV; 2 - DCV and VFD w/ 2-speed fan control; 3 - DCV and VFD w/ 3-speed fan control														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Assembly	52.0	145.8	168.7	51.4	154.6	175.5	85.2	189.0	205.8	95.7	199.7	213.7	89.7	200.8	210.4
Assisted Living	8.0	574.4	604.7	8.8	580.5	605.5	14.7	578.2	598.7	15.6	589.1	609.4	16.5	600.9	615.5
College	49.7	410.8	448.4	54.1	410.4	442.0	106.5	464.1	490.9	139.1	514.3	537.0	158.7	511.9	526.3
Conditioned Storage	1.9	339.8	393.6	3.5	355.1	404.5	5.9	346.3	388.6	9.5	349.5	384.5	10.3	349.5	371.7
Convenience Store	46.4	918.9	984.1	49.9	921.0	977.0	82.3	955.1	1,000.2	86.9	996.3	1,035.0	103.7	998.3	1,022.7
Garage	14.8	479.7	578.9	19.2	482.9	573.6	25.9	510.4	586.3	48.4	570.1	640.3	53.0	589.0	648.7
Grocery	41.8	480.1	505.1	43.9	486.5	507.6	68.1	502.8	520.4	83.2	536.1	550.6	89.7	539.8	547.9
Manufacturing Facility	7.7	773.4	824.8	9.0	761.4	807.1	19.6	771.8	809.3	30.8	801.2	832.8	34.2	784.9	802.5
Office Low Rise	15.2	1,071.2	1,147.3	17.2	1,065.8	1,131.8	23.1	1,062.2	1,115.7	30.5	1,091.4	1,137.7	31.2	1,042.2	1,071.7
Religious Building	6.5	869.4	1,016.9	6.3	894.6	1,029.6	11.1	931.0	1,047.1	15.5	1,005.4	1,108.3	15.0	1,051.1	1,134.0
Restaurant	13.8	554.0	598.2	14.9	574.2	610.8	26.4	564.5	596.6	27.7	606.3	637.2	25.8	603.5	628.3
Retail Department Store	34.0	692.6	751.0	34.4	697.7	749.0	55.4	715.0	757.7	60.8	725.4	761.1	64.3	723.2	743.8
Retail Strip Mall	30.9	739.7	782.5	32.9	734.1	770.5	50.8	748.5	776.8	55.3	761.3	784.8	60.1	755.2	768.4

For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$$\Delta Therms = (10\ tons) \times (1{,}065.8\ kWh/ton)$$

$$= 10{,}658\ kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kWssp = (tons) \times \text{Normalized Electric Peak Demand Savings} \times CFssp$$

$$\Delta kWpjm = (tons) \times \text{Normalized Electric Peak Demand Savings} \times CFpjm$$

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [625]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [626]

Normalized Electric Peak Demand Savings

= kW/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 5 – Electric Peak Demand Savings Summary (kW/ton)

[625] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[626] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

Table 5 – Electric Peak Demand Savings Summary (kW/ton)

Building Type - IL TRM Prototype Model Name	Rockford - Zone 1			Chicago - Zone 2			Springfield - Zone 3			Mt Vernon/Belleville - Zone 4			Marion - Zone 5		
	Measure Scenario: 1 - DCV 2 - DCV and VFD w/ 2-speed fan control 3 - DCV and VFD w/ 3-speed fan control														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Assembly	0.024	0.107	0.107	0.086	0.126	0.126	0.015	0.042	0.042	0.069	0.095	0.095	0.048	0.064	0.064
Assisted Living	0.021	0.116	0.116	0.021	0.075	0.075	0.018	0.086	0.086	0.021	0.092	0.092	0.024	0.081	0.081
College	0.007	0.207	0.207	0.007	0.090	0.090	0.006	0.179	0.179	0.005	0.132	0.132	0.009	0.074	0.074
Conditioned Storage	0.007	0.065	0.065	0.006	0.083	0.083	0.010	0.096	0.096	0.005	0.060	0.060	0.007	0.071	0.071
Convenience Store	0.047	0.369	0.369	0.053	0.394	0.394	0.042	0.395	0.395	0.017	0.356	0.356	0.067	0.390	0.390
Garage	0.012	0.054	0.054	0.011	0.053	0.053	0.011	0.053	0.053	0.011	0.068	0.068	0.007	0.061	0.061
Grocery	0.065	0.122	0.122	0.034	0.080	0.080	0.033	0.088	0.088	0.072	0.119	0.119	0.033	0.082	0.082
Manufacturing Facility	0.008	0.335	0.335	0.006	0.296	0.296	-0.003	0.283	0.283	0.000	0.333	0.333	0.049	0.376	0.376
Office Low Rise	0.011	0.395	0.395	0.009	0.346	0.346	0.007	0.366	0.366	0.011	0.384	0.384	0.029	0.385	0.385
Religious Building	0.000	0.462	0.465	0.000	0.406	0.409	0.000	0.461	0.461	0.000	0.456	0.457	0.000	0.464	0.467
Restaurant	0.030	0.231	0.231	0.034	0.162	0.162	0.023	0.113	0.113	0.033	0.134	0.134	0.006	0.069	0.069
Retail Department Store	0.057	0.152	0.152	0.042	0.120	0.120	0.029	0.099	0.099	0.029	0.113	0.113	0.066	0.149	0.149
Retail Strip Mall	0.046	0.171	0.171	0.046	0.191	0.191	0.042	0.189	0.189	0.020	0.158	0.158	0.066	0.178	0.178

For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes) using the Summer System Peak Coincidence Factor:

$$\Delta kW = (10\ tons) \times (0.346\ kW/ton) \times 91.3\%$$

$$= 3.159\ kW$$

NATURAL GAS SAVINGS

$$\Delta Therms = (kBtuh\ output) \times Normalized\ Gas\ Energy\ Savings$$

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 6 – Gas Energy Savings Summary (Therms/kBtuh output)

Table 6 – Gas Energy Savings Summary (Therms/kBtuh output)

Building Type - IL TRM Prototype Model Name	Rockford - Zone 1			Chicago - Zone 2			Springfield - Zone 3			Mt Vernon/Belleville - Zone 4			Marion - Zone 5		
	Measure Scenario: 1 - DCV 2 - DCV and VFD w/ 2-speed fan control 3 - DCV and VFD w/ 3-speed fan control														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Assembly	7.1	7.3	7.3	7.1	7.3	7.3	6.1	6.5	6.4	6.0	6.4	6.3	6.0	6.6	6.5
Assisted Living	1.0	0.5	0.2	0.8	0.4	0.1	0.7	0.3	0.1	0.7	0.5	0.2	0.6	0.5	0.2
College	7.2	6.8	6.6	6.3	6.0	5.8	5.3	5.0	4.9	4.3	4.2	4.0	2.8	2.7	2.6
Conditioned Storage	2.5	1.4	1.2	2.2	1.1	0.9	2.0	0.9	0.7	1.9	0.8	0.6	1.5	0.4	0.3
Convenience Store	4.8	3.8	3.6	4.3	3.3	3.1	3.7	2.8	2.7	3.5	2.7	2.5	2.9	2.2	2.0
Garage	0.5	0.4	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.4	0.3	0.2	0.4	0.3	0.3
Grocery	7.5	7.0	6.8	6.7	6.2	6.1	5.9	5.5	5.3	5.3	5.0	4.9	4.1	3.8	3.7
Manufacturing Facility	0.5	0.4	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Office Low Rise	2.8	1.2	1.0	2.5	0.9	0.7	2.0	0.8	0.6	1.8	0.6	0.5	1.3	0.2	0.2
Religious Building	0.9	1.1	1.3	0.8	0.9	1.1	0.7	0.8	0.9	0.6	0.8	0.9	0.6	0.6	0.7
Restaurant	2.9	2.2	1.9	2.5	1.8	1.6	2.2	1.6	1.4	2.0	1.6	1.3	1.7	1.3	1.1
Retail Department Store	2.5	1.5	1.4	2.3	1.3	1.1	2.0	1.1	1.0	1.8	1.1	0.9	1.5	0.9	0.8
Retail Strip Mall	2.4	1.9	1.7	2.1	1.6	1.5	1.8	1.4	1.3	1.7	1.4	1.3	1.5	1.2	1.1

For example, a rooftop unit with a 148 kBtuh output gas furnace on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$$\Delta kWh = (148\ kBtuh) \times (0.9\ Therms/kBtuh\ output)$$

$$= 133.2\ Therms$$

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ARTC-V01-190101

REVIEW DEADLINE: 1/1/2023

4.4.42 Advanced Thermostats for Small Commercial

DESCRIPTION

This measure characterizes the energy savings from the installation of an "Advanced Thermostat" for reduced heating and cooling consumption in a small commercial building. Advanced thermostats use a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.

The thermostat must be installed to control a single-zone HVAC system. This measure is limited to packaged HVAC units 5 tons or less. Systems larger will likely require more sophisticated controls to meet code requirements.

This class of products and services are relatively new, diverse, and rapidly changing. The savings associated with commercial installations of advanced thermostats have not been evaluated. In the absence of commercial specific assumptions, this TRM provides a deemed estimate based on the average residential savings. This is considered a reasonable starting assumption since the eligibility is limited to residential sized equipment and although on average commercial systems may be larger, it is predicted that reduced savings percentage will result in a similar average savings. It is highly recommended that the application of Advanced Thermostats in commercial settings be evaluated for future revisions.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known, or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be 11 years[627].

[627] Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range.

DEEMED MEASURE COST

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. If unknown then the average incremental cost for the new installation measure is assumed to be $175.

LOADSHAPE

Loadshape C05 - Commercial Electric Heating and Cooling, or

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [628]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [629]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Deemed savings are provided based upon the average savings from the Residential version of this measure. Future evaluation on savings percentages for commercial applications should be used to improve this assumption.

ΔkWh[630] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * F_e * 29.3)

ΔkWh_{cool} = %AC * ((FLH * Btu/hr * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

$\Delta kWh_{heating}$ = 0.03 * 15,678 * 0.073 * 1 * 1 + (66.1 * 0.0314 * 29.3)

= 95.1 kWh

ΔkWh_{cool} = 1.0 * ((629 * 33600 * 1/9.3) / 1000) * 0.06 * 1

= 136.4 kWh

ΔkWh = 95.1 + 136.4

[628] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year. Multiplied by 50%.

[629] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%.

[630] Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace.

= 231.5 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = %AC * (Cooling_Reduction * Btu/hr * (1/EER))/1000 * EFF_ISR * CF

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [631]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [632]

ΔkW_{SSP} = 1.0 * (0.06 * 33600 * (1/7.5))/1000 * 1.0 * 0.457

= 0.1228 kW

ΔkW_{PJM} = 1.0 * (0.06 * 33600 * (1/7.5))/1000 * 1.0 * 0.239

= 0.0642 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

For basis of values, see Residential measure 5.3.16.

ΔTherms = 0.935 * 955 * 0.073 * 1 * 1

= 65.2 Therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ADTH-V01-190101

REVIEW DEADLINE: 1/1/2020

[631] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year. Multiplied by 50%.

[632] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%.

4.4.43 Packaged RTU Sealing

DESCRIPTION

The HVAC Packaged RTU Sealing Measure targets areas of the RTU that are readily accessible and can be easily sealed. By sealing the following areas, the amount of uncontrolled infiltration will be reduced leading to increased occupant comfort and an overall reduction in energy use.

The measure seeks to target the following three areas for sealing.

1. Economizer Hood – Seal the interior and exterior seams that connect the economizer to the RTU using UL listed metal tape and/or silicone caulking.
2. RTU Curb – Seal supply and return duct seams inside of RTU with mastic along with any leaks that are found around the perimeter of the roof to RTU connection using UL listed metal tape and/or silicone caulking.
3. Non-Removable Cabinet Panels – Seal all cabinet seams that are not typically removed during basic service (i.e. control panel) using UL listed metal tape and/or silicone caulking.

Uncontrolled infiltration of non-conditioned outside air (OSA) is a known issue for packaged rooftop units (RTU). This leakage can occur thru the curb, economizer assembly connection and cabinet panels. This leakage not only influences occupant comfort but also increases energy usage by increasing the heating and cooling loads while also reducing the unit's operating energy efficiency.

Prior to a recently released laboratory and field study developed by Robert Mowris & Associates, Inc.[633] the energy effects of uncontrolled infiltration through cabinet leakage were difficult to quantify. However, this study determined that uncontrolled OSA infiltration not only increases the amount of energy to condition the excess air but also reduces the unit's operating efficiency (sensible EER) by 5.4%. By reducing the amount of uncontrolled OSA infiltration through RTU sealing the unit's operating efficiency (EER) can be increased reducing the amount of cooling energy. (Note: The referenced study quantifies improvements only from sealing the economizer hood – sealing the curb and non-access panels are recommended practice here but savings have not been quantified for these actions and may be in a future revision.)

This measure is only appropriate for packaged single zone rooftop units. Custom calculations are required for savings for built up air handling units or packaged multizone systems.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is assumed to be a packaged HVAC system that has had the economizer hood, curb and non-access cabinet panels sealed.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment condition is assumed to be an operational packaged HVAC system that has not been previously sealed. The packaged HVAC systems must be single zone and must have a functioning economizer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Because the measure targets existing packaged RTU units, the deemed lifetime of the measure is assumed to be 5 years[634].

DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available the deemed measure cost below listed below can be used. The deemed measure costs are detailed for each individual RTU.

---

[633] Robert Mowris & Associates, Inc., "Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults," California Public Utilities Commission, Feb 15, 2016 page 203

[634] Assumed to be one third of effective useful life of an RTU (15 years)

Measure	Material Unit	Material Cost / Unit	Labor Unit (Hours)	Labor Rate / Unit	Total Cost
HVAC Packaged RTU Sealing	1	$48.99	1.5	$97	$194.49

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [635]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [636]

Algorithm

CALCULATION OF ENERGY SAVINGS

To determine the savings associated with the Packaged RTU Sealing measure available IL TRM prototype eQuest models, which were initially created by the Energy Center of Wisconsin[637] but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update, were utilized. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update).

This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, only models that had the following characteristics were chosen: 1) Packaged-Single Zone (PSZ) HVAC systems; and 2) aligned with the small commercial building type applicable to this measure. Several modifications to the models were necessary in order to simulate a functioning airside economizer, which is assumed to be present in the baseline scenario for this measure:

3. 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.
    c. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

To determine the energy use associated with an unsealed RTU the prototype models were modified using the associated reduction in efficiency reported in a Robert Mowris and Associates, Inc. study[638] that was performed for the California Public Utilities Commission in 2016. For further detail on the full modeled energy end use and savings summaries, see: “Packaged RTU Sealing_End Use Analysis_IL TRM 09042018.xlsx” spreadsheet.

After analyzing the modeled cooling annual energy usage for both the baseline (unsealed) and measure (sealed) model scenarios it was determined that the building type and climate zone variables had a minimal impact on the overall energy savings associated with the measure. As a result, the overall average savings factor of 4.67% was deemed applicable for any small commercial building type across all climate zones. This single savings value used in conjunction with the energy and demand savings calculations listed in the following sections will allow the savings

[635] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

[636] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[637] Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010

[638] Robert Mowris & Associates, Inc., “Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults,” California Public Utilities Commission, Feb 15, 2016 Section 5.4

to be calculated based on the unit size and equivalent full load hours listed in the Illinois Technical Resource Manual (TRM).

ELECTRIC ENERGY SAVINGS

ΔkWh = (kBtu/hr) / EERbefore * EFLH * %Savings

Where:

kBtu/hr = rated capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 4.67%[639]

$EFLH_{cooling}$ = IL TRM v6 Equivalent Full Load Hours (EFLH) for cooling are provided in the following table

Building Type	Cooling EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Assembly	725	796	937	1,183	932
Assisted Living	1,475	1,457	1,773	2,110	1,811
College	475	481	662	746	806
Conditioned Storage (Warehouse)	357	338	422	647	533
Convenience Store	1,088	1,067	1,368	1,541	1,371
Garage	934	974	1,226	1,582	1,383
Grocery	1,033	1,000	1,236	1,499	1,286
Manufacturing Facility	1,010	1,055	1,209	1,453	1,273
Office - Low Rise	949	1,010	1,182	1,452	1,281
Religious Building	861	817	967	1,159	1,067
Restaurant	1,074	1,134	1,279	1,627	1,325
Retail - Department Store	949	889	1,124	1,367	1,157
Retail - Strip Mall	950	919	1,149	1,351	1,215

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives packaged RTU sealing:

ΔkWh = (5*12) / 12 * 949 * 4.67%

= 221.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkWssp = (kBtu/hr) / EERbefore * %Savings * CFssp

ΔkWpjm = (kBtu/hr) / EERbefore * %Savings * CFpjm

639 The average cooling energy savings for all building types and climate zones, as determined by modeling 13 small commercial building types across 5 weather zones utilizing the prototype TRM eQuest models. For additional reference on the methodology and approach to the calculation of the deemed savings factor, see "Packaged RTU Sealing_End Use Analysis_IL TRM 09042018.xlsx"

Where:

kBtu/hr = Capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 4.67%

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [640]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [641]

For example, a 12 EER 5-ton rooftop air conditioner using the Summer System Peak Coincidence Factor receives RTU sealing:

ΔkW = (5*12) / 12 * 4.67% * 91.3%

= 0.213 kW

NATURAL GAS SAVINGS

$$\Delta Therm = (kBtu/hr) / 100 / Efficiency_{before} * EFLH * \%Savings$$

Where:

kBtu/hr = rated capacity of the heating equipment actually installed in kBtu per hour

=Actual

100 = Converts kBtu/hr to Therms/hr

$Efficiency_{before}$ = Efficiency of the baseline equipment (rated)

=Actual

%Savings = Deemed savings percentages by building type and climate zone are provided in the following table

Building Type	Savings Percentage				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Assembly	2.84%	2.86%	2.86%	2.98%	2.94%
Assisted Living	4.01%	4.15%	4.35%	4.64%	5.44%
College	3.86%	3.88%	3.97%	4.09%	5.10%
Conditioned Storage (Warehouse)	0.92%	0.90%	0.87%	1.00%	1.23%
Convenience Store	3.07%	3.20%	3.43%	3.70%	4.63%

[640] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[641] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

Building Type	Savings Percentage				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Garage	0.20%	0.21%	0.22%	0.23%	0.29%
Grocery	3.38%	3.49%	3.60%	3.79%	4.57%
Manufacturing Facility	0.18%	0.16%	0.16%	0.16%	0.16%
Office - Low Rise	2.19%	2.23%	2.37%	2.46%	2.96%
Religious Building	0.28%	0.28%	0.30%	0.31%	0.37%
Restaurant	2.76%	2.83%	2.96%	3.11%	3.58%
Retail - Department Store	1.87%	1.91%	2.00%	2.14%	2.88%
Retail - Strip Mall	2.06%	2.12%	2.29%	2.46%	3.17%

$EFLH_{heating}$ = IL TRM v6 Equivalent Full Load Hours (EFLH) for heating are provided in the following table

Building Type	Heating EFLH				
	Zone 1 (Rockford)	Zone 2 (Chicago)	Zone 3 (Springfield)	Zone 4 (Belleville)	Zone 5 (Marion)
Assembly	1,787	1,831	1,635	1,089	1,669
Assisted Living	1,683	1,646	1,446	1,063	1,277
College	1,530	1,430	1,276	709	849
Conditioned Storage (Warehouse)	1,338	1,098	976	771	810
Convenience Store	1,481	1,368	1,214	871	973
Garage	985	969	852	680	752
Grocery	1,608	1,602	1,404	876	1,047
Manufacturing Facility	1,048	1,013	939	567	634
Office - Low Rise	1,428	1,425	1,132	692	793
Religious Building	1,603	1,504	1,440	1,054	1,205
Restaurant	1,350	1,354	1,216	920	1,091
Retail - Department Store	1,123	979	852	697	689
Retail - Strip Mall	1,332	1,233	1,090	751	810

For example, a packaged RTU with an 80% efficient 150-kBtu/hr gas furnace on a department store in Rockford receives packaged RTU sealing:

ΔTherm = (150 / 100) / 80% * 1,123 * 1.87%

= 39.4 Therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PRTU-V01-190101

REVIEW DEADLINE: 1/1/2023

4.4.44 Commercial Ground Source and Ground Water Source Heat Pump

DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

A. New Construction:

   i. The installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new C&I building.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

B. Time of Sale:

   i. The planned installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section C below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the building. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   iii. DHW savings are calculated based upon the fuel type and efficiency of the existing unit.

C. Early Replacement/Retrofit:

   i. The early removal of functioning electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   iii. DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs to be operational, defined as costing less than[642]:

Existing System	Maximum repair cost
Air Source Heat Pump	$263/ton
Chiller	$308/ton
Boiler (Steam)	$3.87/ kBtu
Boiler (Hot Water)	$4.25/ kBtu
Furnace	$2.49/ kBtu
Ground Source Heat Pump	$2,185/ton

      - All other conditions will be considered Time of Sale.

   The Baseline efficiency of the existing unit replaced:
      - Use actual existing efficiency whenever possible.
      - If the efficiency of the existing unit is unknown, use assumptions based on the federal minimum standards provided in tables below.
      - If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

[642] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost (defined in the Measure Costs section) it can be considered early replacement.

The installation of the GSHP should meet the following design parameters to ensure a properly sized circulation pump. If the GSHP design does not meet the following parameters, a custom calculation should be performed to account for the motor energy consumed by the circulation pump. Optimal design parameters are:

- Circulation pump is included in the manufacturer assembly of the GSHP system
  Or;
- Circulation pump flow rate less than or equal to 3.0 GPM per system ton
- Variable flow controls on pumps serving systems greater than 10 tons. Variable flow controls include one of the following:
  - A variable speed system pump controlled from differential pressure and 2-way water flow control valves on each heat pump.
  - Individual on/off pumps on each heat pump controlled by heat pump demand. The heat pumps may be decoupled from the ground heat exchanger using a separate variable speed pump controlled by differential temperature across the ground loop.
- On/off or variable flow controls on pumps for systems less than 10 tons. On/off pump controls shall operate only when heat pump(s) are running.
- System pumping head less than 80 feet. For systems 10 tons or smaller system pumping head should not exceed 40 feet.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment must be a Ground Source or Ground Water Source Heat Pump unit meeting the minimum efficiency level standards required by the program.

DEFINITION OF BASELINE EQUIPMENT

For these products, the baseline equipment includes Air Conditioning, Space Heating and Domestic Hot Water Heating.

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level as outlined in Table 2; and a Federal Standard electric hot water heater efficiency level as outlined in Table 6.

To calculate savings with a chiller/unitary cooling systems and boiler/furnace baseline, the baseline equipment is assumed to meet the minimum standard efficiencies as outlined in the Table 3 for chillers/unitary cooling systems , and Table 4 for boilers or Table 5 for furnaces. If a desuperheater is installed, the domestic hot water heater minimum standard efficiency is calculated as per Table 6 below.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

Table2: IECC 2015 ASHP Minimum Efficiency Requirements:

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	13.0 SEER[c]	14.0 SEER[c]	AHRI 210/240
			Single Package	13.0 SEER[c]	14.0 SEER[c]	
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	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 SEER	11.0 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	11.0 EER 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.8 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	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	9.3 EER 9.4 IEER	
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	7.7 HSPF[c]	8.2 HSPF[c]	AHRI 210/240
		—	Single Package	7.7 HSPF[c]	8.0 HSPF[c]	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	7.4 HSPF	
		—	Single Package	7.4 HSPF	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	6.8 HSPF	
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	3.3 COP	AHRI 340/360
			17°Fdb/15°F wb outdoor air	2.25 COP	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP	3.2 COP	
			17°Fdb/15°F wb outdoor air	2.05 COP	2.05 COP	

Table 3: IECC 2015 Electric Chillers, Air-Cooled and Water-Cooled minimum efficiencies

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015 Path A	BEFORE 1/1/2015 Path B	AS OF 1/1/2015 Path A	AS OF 1/1/2015 Path B	TEST PROCEDURE[c]
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 12.500 IPLV	NA[c]	≥ 13.700 IPLV	≥ 15,800 IPLV	AHRI 550/590
Air-cooled chillers	≥ 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
Air-cooled chillers	≥ 150 Tons	EER (Btu/W)	≥ 12.500 IPLV	NA[c]	≥ 14.000 IPLV	≥ 16.100 IPLV	AHRI 550/590
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				AHRI 550/590
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	AHRI 550/590
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 75 tons and < 150 tons	kW/ton	≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 75 tons and < 150 tons	kW/ton	≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 150 tons and < 300 tons	kW/ton	≥ 0.680 FL	≥ 0.718 FL	≥ 0.660 FL	≥ 0.680 FL	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 150 tons and < 300 tons	kW/ton	≥ 0.580 IPLV	≥ 0.540 IPLV	≥ 0.540 IPLV	≥ 0.440 IPLV	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 300 tons and < 600 tons	kW/ton	≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 300 tons and < 600 tons	kW/ton	≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 600 tons	kW/ton	≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	AHRI 550/590
Water cooled, electrically operated positive displacement	≥ 600 tons	kW/ton	≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	AHRI 550/590
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	AHRI 550/590
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 150 tons and < 300 tons	kW/ton	≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 300 tons and < 400 tons	kW/ton	≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 300 tons and < 400 tons	kW/ton	≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 400 tons and < 600 tons	kW/ton	≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 400 tons and < 600 tons	kW/ton	≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 600 Tons	kW/ton	≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	AHRI 550/590
Water cooled, electrically operated centrifugal	≥ 600 Tons	kW/ton	≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	AHRI 550/590
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	AHRI 560
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	AHRI 560
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.050 IPLV	NA[c]	≥ 1.050 IPLV	NA[c]	AHRI 560
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	AHRI 560
Absorption double effect direct fired	All capacities	COP	≥ 1.000 IPLV	NA[c]	≥ 1.050 IPLV	NA[c]	AHRI 560

Table 4: IECC 2015 Boiler minimum efficiency requirements

EQUIPMENT TYPE[a]	SUBCATEGORY OR RATING CONDITION	SIZE CATEGORY (INPUT)	MINIMUM EFFICIENCY[d, e]	TEST PROCEDURE
Boilers, hot water	Gas-fired	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	80% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	82% E_c	
	Oil-fired[c]	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	82% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	84% E_c	
Boilers, steam	Gas-fired	< 300,000 Btu/h	75% AFUE	10 CFR Part 430
	Gas-fired- all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	79% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	79% E_t	
	Gas-fired-natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	77% E_t	
		> 2,500,000 Btu/h[a]	77% E_t	
	Oil-fired[c]	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	81% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	81% E_t	

Table 5: IECC 2015 Warm-air Furnace minimum efficiency standards

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[d, e]	TEST PROCEDURE[a]
Warm-air furnaces, gas fired	< 225,000 Btu/h	—	78% AFUE or 80%E_t^c	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum capacity[c]	80%E_t^f	ANSI Z21.47
Warm-air furnaces, oil fired	< 225,000 Btu/h	—	78% AFUE or 80%E_t^c	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity[b]	81%E_t^g	UL 727
Warm-air duct furnaces, gas fired	All capacities	Maximum capacity[b]	80%E_c	ANSI Z83.8
Warm-air unit heaters, gas fired	All capacities	Maximum capacity[b]	80%E_c	ANSI Z83.8
Warm-air unit heaters, oil fired	All capacities	Maximum capacity[b]	80%E_c	UL 731

Table 6: IECC 2015 Water Heaters mininmum performance

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Water heaters, electric	≤ 12 kW[d]	Resistance	0.97 - 0.00 132V, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance	$(0.3 + 27/V_m)$, %/h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00 132*V*, EF	DOE 10 CFR Part 430
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gal	0.67 - 0.0019*V*, EF	DOE 10 CFR Part 430
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h[c]	≥ 4,000 (Btu/h)/gal and < 2 gal	0.62 - 0.00 19V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	

Table7: IECC 2018 ASHP Minimum Efficiency Requirements:

TABLE C403.3.2(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	14.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 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 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	ISO 13256-1
Water to Water: Water Loop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	

Table 7 continued:

Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	8.2 HSPF	AHRI 210/240
		—	Single Package	8.0 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	
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°Fdb/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°Fdb/15°F wb outdoor air	2.05 COP	
Water to Air: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	ISO 13256-1
Water to Air: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	
Brine to Air: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	
Water to Water: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
Water to Water: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	
Brine to Water: Ground Loop (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 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled heat pumps less than 65,000 Btu/h are regulated by NAECA. SEER and HSPF values are those set by NAECA.

Table 8: IECC 2018 Electric Chillers, Air-Cooled and Water-Cooled minimum efficiencies

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[c]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≥ 0.680 FL	≥ 0.718 FL	≥ 0.660 FL	≥ 0.680 FL	
			≥ 0.580 IPLV	≥ 0.540 IPLV	≥ 0.540 IPLV	≥ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

Table 9: IECC 2018 Boiler minimum efficiency requirements

TABLE C403.3.2(5)
MINIMUM EFFICIENCY REQUIREMENTS: GAS- AND OIL-FIRED BOILERS

EQUIPMENT TYPE[a]	SUBCATEGORY OR RATING CONDITION	SIZE CATEGORY (INPUT)	MINIMUM EFFICIENCY[d, e]	TEST PROCEDURE
Boilers, hot water	Gas-fired	< 300,000 Btu/h[f, g]	82% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	80% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	82% E_c	
	Oil-fired[c]	< 300,000 Btu/h[g]	84% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	82% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	84% E_c	
Boilers, steam	Gas-fired	< 300,000 Btu/h[f]	80% AFUE	10 CFR Part 430
	Gas-fired- all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	79% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	79% E_t	
	Gas-fired-natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	77% E_t	
		> 2,500,000 Btu/h[a]	77% E_t	
	Oil-fired[c]	< 300,000 Btu/h	82% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b]	81% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[a]	81% E_t	

Table 10: IECC 2018 Warm-air Furnace minimum efficiency standards

TABLE C403.3.2(4)
WARM-AIR FURNACES AND COMBINATION WARM-AIR FURNACES/AIR-CONDITIONING UNITS, WARM-AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[d, e]	TEST PROCEDURE[a]
Warm-air furnaces, gas fired	< 225,000 Btu/h	—	80% AFUE or 80%E_t[c]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum capacity[c]	80%E_t[f]	ANSI Z21.47
Warm-air furnaces, oil fired	< 225,000 Btu/h	—	83% AFUE or 80%E_t[c]	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity[b]	81%E_t[g]	UL 727
Warm-air duct furnaces, gas fired	All capacities	Maximum capacity[b]	80%E_c	ANSI Z83.8
Warm-air unit heaters, gas fired	All capacities	Maximum capacity[b]	80%E_c	ANSI Z83.8
Warm-air unit heaters, oil fired	All capacities	Maximum capacity[b]	80%E_c	UL 731

Table 11: IECC 2018 Water Heaters mininmum performance

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Water heaters, electric	≤ 12 kW[d]	Tabletop[e], ≥ 20 gallons and ≤ 120 gallons	0.93 - 0.00132*V*, EF	DOE 10 CFR Part 430
		Resistance ≥ 20 gallons and ≤ 55 gallons	0.960 - 0.0003*V*, EF	
		Grid-enabled[f] > 75 gallons and ≤ 120 gallons	1.061 - 0.00168V, EF	
	> 12 kW	Resistance	$(0.3 + 27/V_m)$, %/h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump > 55 gallons and ≤ 120 gallons	2.057 - 0.00113V, EF	DOE 10 CFR Part 430
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gallons and > 55 gallons	0.675 - 0.0015V, EF	DOE 10 CFR Part 430
		> 55 gallons and ≤ 100 gallons	0.8012 - 0.00078V, EF	
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t	
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h[c]	≥ 4,000 (Btu/h)/gal and < 2 gal	0.82 - 0.00 19V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t	

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the minimum standard efficiencies provided above.

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit, and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of the ground source heat pump is assumed to be 25 years[643].

The expected measure life of the ground loop field is assumed to be 50 years[644].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[645].

DEEMED MEASURE COST

New Construction and Time of Sale: Incremental costs of the Ground Source Heat Pump should be used. This would be the actual installed cost of the Ground Source Heat Pump, well drilling, building retrofit, and system commissioning costs (default of $10,923 per ton[646]), minus the assumed installation cost of the baseline equipment ($1,316 per ton for ASHP[647] or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler[648] and $1,539 per ton[649] for new baseline chiller replacement).

Early Replacement: The actual installed cost of the Ground Source Heat Pump should be used (default cost for total system retrofit provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,316 per ton for a new baseline Air Source Heat Pump, or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler and $1,539 per ton for new baseline chiller replacement. This future cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape C04 – Commercial Electric Heating (if replacing building with no existing cooling)

Loadshape C05 - Commercial Electric Heating and Cooling.

Note for the purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape C04 - Commercial Electric Heating and Loadshape C03 – Commercial Cooling respectively) can be applied.

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

643 System life of indoor components as per US DOE estimates from the Office of Energy Efficiency & Renewable Energy. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

644 U.S. DOE Office of Energy Efficiency & Renewable Energy, Energy Saver details and descriptions for Geothermal Heat Pumps

645 Assumed to be one third of effective useful life per SAG policy

646 Average calculated based on reviewing cost information received from Chicagoland GSHP installers

647 Average calculated from Energy Star and RSMeans Mechanical Cost Data 2015

648 Average calucated based on RSMeans Mechanical Cost Data 2015

649 Average calucated based on RSMeans Mechanical Cost Data 2015 for Scroll, air cooled condenser chillers

= 91.3% [650]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [651]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

Cooling Savings = ($Capacity_{cool}$ * $EFLH_{Cool}$ * (1/EER_{base} – 1/EER_{GSHP}))/1000

Heating Savings = $Elec_{Heat}$ *(($Capacity_{Heat}$ * $EFLH_{Heat}$ * (1/$HSPF_{base}$ – 1/(COP_{GSHP} * 3.412)))/1000)

DHW Savings = $Elec_{DHW}$ * (%DHW * ((1/$EF_{elecbase}$) * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1/3412))

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = ($Capacity_{cool}$ * $EFLH_{Cool}$ * (1/EER_{base} – 1/EER_{GSHP}))/1000

Heating Savings from base ASHP to GSHP = ($Capacity_{Heat}$ * $EFLH_{Heat}$ * (1/$HSPF_{ASHP}$ – 1/(COP_{GSHP} * 3.412)))/1000

DHW Savings = $Elec_{DHW}$ * (%DHW * ((1/$EF_{elecbase}$) * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1 /3412))

Early replacement (non-fuel switch only)[652]:

ΔkWH for remaining life of existing unit (1st 8 years):
= [Cooling savings] + [Heating savings] + [DHW savings]

Cooling Savings = ($Capacity_{cool}$ * $EFLH_{Cool}$ * (1/EER_{Exist} – 1/EER_{GSHP}))/1000

Heating Savings = $Elec_{Heat}$ *(($Capacity_{Heat}$ * $EFLH_{Heat}$ * (1/$HSPF_{Exist}$ – 1/(COP_{GSHP} * 3.412)))/1000)

DHW Savings = $Elec_{DHW}$ * (%DHW * ((1/ $EF_{elecbase}$) * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1/3412))

ΔkWH for remaining measure life (next 17 years):
= [Cooling savings] + [Heating savings] + [DHW savings]

---

650 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

651 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

652 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings = $Elec_{Heat} *((Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{Base} – 1/(COP_{GSHP} * 3.412)))/1000)$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))$

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):
= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{Exist} – 1/EER_{GSHP}))/1000$

Heating Savings from base ASHP to GSHP = $(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))$

ΔkWh for remaining measure life (next 17 years):
= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings from base ASHP to GSHP = $(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))$

Where:

$Capacity_{cool}$ = Cooling Capacity of Ground Source Heat Pump (Btu/hr)
= Actual installed

$EFLH_{cool}$ = Cooling Equivalent Full Load Hours
Dependent on building type, provided in section 4.4 HVAC End Use

EER_{Exist} = Energy Efficiency Ratio (EER) of existing cooling unit (kBtu/hr / kW)
= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:
$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [653]

EER_{base} = Energy Efficiency Ratio (EER) of baseline replacement cooling system
= Use minimum standard efficiencies as specified in tables in 'Definition of Baseline Equipment' section

EER_{GSHP} = Part Load Energy Efficiency Ratio efficiency of efficient GSHP unit[654]
= Actual installed

[653] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.
[654] From Res GSHP measure of the IL-TRM: As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP

$Elec_{Heat}$[655] = 1 if existing heating system is electric
= 0 if existing system is non electric

$Capacity_{Heat}$ = Heating Capacity of Ground Source Heat Pump (Btu/hr)
= Actual installed

$EFLH_{Heat}$ = Heating Equivalent Full Load Hours
Dependent on building type, provided in section 4.4 HVAC End Use

$HSPF_{Exist}$ = Heating System Performance Factor of existing electric heating system (kBtu/kWh)
= Actual

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

Existing Heating System	HSPF_base
Ground Source Heat Pump or Air Source Heat Pump	Refer to applicable tables in 'Definition of Baseline Equipment' section
Electric Resistance	3.41[656]

$HSPF_{ASHP}$ = Heating System Performance Factor of new replacement ASHP (kBtu/kWh) (for fuel switch)

= Refer to applicable tables in 'Definition of Baseline Equipment' section

COP_{GSHP} = Part Load Coefficient of Performance of efficient GSHP[657]

= Actual installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF)

$Elec_{DHW}$ = 1 if building has electric DHW
= 0 if building has non electric DHW
= 0 if one to one replacement of existing Ground Source Heat Pump

%DHW = Percentage of total DHW load that the GSHP will provide
= Actual if known
= If unknown and if desuperheater installed assume 44%[658]
= 0% if no desuperheater installed

$EF_{elecbase}$ = Energy Factor of baseline electric DHW
= Actual. If unknown or for new construction assume federal standard as defined in applicable table in 'Definition of Baseline Equipment' section

$HotWaterUse_{Gallon}$ = 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

---

[655] Applicable only for early Replacement Fuel Switch projects.
[656] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[657] As per Res GSHP measure.
[658] 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.

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[659]

Building Type[660]	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	622
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multi-Family	894

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

Where:

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

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[661]

Building Type[662]	Consumption/1,000 sq.ft.
Convenience	4,594
Education	7,285
Grocery	697

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

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

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

[662] 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[662]	Consumption/1,000 sq.ft.
Health	24,540
Large Office	1,818
Large Retail	1,354
Lodging	29,548
Other Commercial	3,941
Restaurant	44,439
Small Office	1,540
Small Retail	6,111
Warehouse	1,239
Nursing	30,503
Multi-Family	15,434

γWater = Density of water

= 8.33 pounds per gallon

T_{out} = Tank temperature

= 125°F

T_{in} = Incoming water temperature from well or municiplal system

= 54°F[663]

1 = Heat Capacity of water (1 Btu/lb*°F)

3.412 = Conversion from Btu to kWh

663 US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL

Illustrative Examples

New Construction using ASHP baseline:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4, with desuperheater installed, and with a 100 gallon electric water heater in an Assisted living building in Chicago:

ΔkWh = [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +5,357

= 17,309 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 and with da esuperheater installed in in an Assisted living building in Chicago with a 100 gallon electric water heater, replacing an existing working Air Source Heat Pump with efficiency ratings of 8.2 EER and 7.7 HSPF:

ΔkWH for remaining life of existing unit (1st 8 years):

= [120,000 * 1,457 * (1/8.2 – 1/20) / 1000] + [1,646* 120,000 * (1/7.7 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 12,580 + 12,495 +5357

= 30,432 kWh

ΔkWH for remaining measure life (next 17 years):

= [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +5,357

= 17,310 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

$\Delta kW = (Capacity_{Cool} * (1/EERbase - 1/EER_{GSHP}))/1000 * CF$

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

$= (Capacity_{Cool} * (1/EERexist - 1/EER_{GSHP}))/1000 * CF$

ΔkW for remaining measure life (next 17 years):

$= (Capacity_{Cool} * (1/EERbase - 1/EER_{GSHP}))/1000 * CF$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 91.3%%[664]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

[664] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8%[665]

New Construction or Time of Sale:

For example, a 10 ton closed loop unit with Full Load EER rating of 20:

ΔkW_{SSP} = (120,000 * (1/11 – 1/20))/1000 * 0.913

= 4.482kW

ΔkW_{PJM} = (36,000 * (1/11 – 1/20))/1000 * 0.478

= 2.347kW

Early Replacement:

For example, a 10 ton closed loop unit with Full Load 20 EER replaces an existing working Air Source Heat Pump with 8.2 EER:

ΔkW_{SSP} for remaining life of existing unit (1st 8 years):

= (120,000 * (1/8.2 – 1/20))/1000 * 0.913

= 7.883 kW

ΔkW_{SSP} for remaining measure life (next 17 years):

= (120,000 * (1/11– 1/20))/1000 * 0.913

= 4.482kW

ΔkW_{PJM} for remaining life of existing unit (1st 8 years):

= (120,000 * (1/8.2 – 1/20))/1000 * 0.478

= 4.127 kW

ΔkW_{PJM} for remaining measure life (next 17 years):

= (120,000 * (1/11 – 1/20))/1000 * 0.478

= 2.347kW

NATURAL GAS SAVINGS

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh
= (1 – ElecHeat) * ((Gas_Heating_Load/$Gas_{Effbase}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/(COP_{GSHP} * 3.412))/1000)

DHW Savings = (1 – ElecDHW) * (%DHW * (1/$EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1)/100,000

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

665 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

= (1 – ElecHeat) * ((Gas_Heating_Load/$Gas_{Effbase}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/$HSPF_{ASHP}$)/1000)

DHW Savings = (1 – ElecDHW) * (%DHW * (1/ $EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)

Early replacement for buildings with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of GSHP source kWh

= [(1 – ElecHeat) * ((Gas_Heating_Load/ $Gas_{EffExist}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/(COP_{GSHP} * 3.412))/1000)]

DHW Savings = (1 – ElecDHW) * (%DHW * (1/ $EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh
= [(1 – ElecHeat) * ((Gas_Heating_Load/ $Gas_{Effbase}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/(COP_{GSHP} * 3.412))/1000)]

DHW Savings = (1 – ElecDHW) * (%DHW * (1/ $EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of base ASHP source kWh

= (1 – ElecHeat) * ((Gas_Heating_Load/$Gas_{EffExist}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/$HSPF_{ASHP}$)/1000)

DHW Savings = (1 – ElecDHW) * (%DHW * (1/ $EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

= (1 – ElecHeat) * ((Gas_Heating_Load/$Gas_{EffBase}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/$HSPF_{ASHP}$)/1000)

DHW Savings = (1 – ElecDHW) * (%DHW * (1/ $EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)

Where:

Gas_Heating_Load = Estimate of annual heating load

= $Capacity_{heat}$ * $EFLH_{heat}$ / 100,000

$Gas_{Effbase}$ = Minimum federal standard baseline efficiency of boiler or furnace

= Refer to applicable table in 'Definition of Baseline Equipment' section

$Gas_{EffExist}$ = Existing efficiency of boiler or furnace

= Actual

kWhtoTherm = Converts source kWh to Therms

= H_{grid} / 100,000

H_{grid} = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest) [666]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses

$Capacity_{heat}$ = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual installed

$EFLH_{heat}$ = Heating Equivalent Full Load Hours

Dependent on building type, provided in section 4.4 HVAC End Use

$EF_{GasBase}$ = Energy factor of Baseline natural gas DHW heater

= Actual. If unknown or New Construction assume federal standard as defined in applicable table in 'Definition of Baseline Equipment' section

All other variabes provided above.

---

[666] These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

Illustrative Examples *[for illustrative purposes a Hgrid value of 10,000 Btu/kWh is used]*

New construction using gas boiler and air-cooled chiller, *supported by Gas utility only*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater is installed in place of a natural gas boiler and air-cooled chiller:

ΔkWH = 0

ΔTherms = [Replaced baseline gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1-0)* ((1,975/80%)-(10,000/100,000 *1,646 *120,000 *1/(4.4 *3.412))/1,000)] + [(1 - 0) * 0.44 * (1/80% * (100*672) * 8.33 * (125- 54) * 1)/100,000]

= 1,153 +219

= 1,372 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER, and desuperheater installed with natural gas existing DHW heater:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [($Capacity_{cool}$ * $EFLH_{Cool}$ * (1/EER_{Exist} – 1/EER_{GSHP}))/1000] + [($Capacity_{Heat}$ * $EFLH_{Heat}$ * (1/$HSPF_{ASHP}$ – 1/(COP_{GSHP} * 3.412)))/1000] + [$Elec_{DHW}$ * (%DHW * ((1/$EF_{elecbase}$) * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1 /3412))]

= [(120,000 * 1,457 * (1/9.5 - 1/20))/1,000] + [(120,000 * 1,646 * (1/11 - 1/(4.4 * 3.412)))/1,000] + [0 * (0.44 * ((1/0.9568) * (100*672) * 8.33 * (125 - 54) * 1 /3412))]

= 9,662 + 4,800 + 0

= 14,462 kWh

Continued on next page.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= $[(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000] + [(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000] + [Elec_{DHW} * (\%DHW * ((1/EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))]$

= [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [0 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +0

= 11,953 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced existing gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= $[(1 – ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffExist}) – (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)] + [(1 – ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]$

= [(1 - 0)*((1975/75%) - (10000/100000 * 1646 * 120,000 * 1/11)/1000)]+ [(1 - 0) *(0.44 * (1/ 80% *(100*672) * 8.33 * (125- 54) * 1) / 100000)]

= 838 + 219

= 1,057 therms

ΔTherms for remaining measure life (next 17 years):

= [Replaced baseline gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= $[(1 – ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffBase}) – (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)] + [(1 – ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]$

= [(1-0)* ((1,975/80%)-(10,000/100,000 *1,646 *120,000 *1/11)/1,000)] + [(1 - 0) * 0.44 * (1/80% * (100*672) * 8.33 * (125- 54) * 1)/100,000]

= 673 + 219

= 892 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects; changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[667]] + [DHW Savings if existing natural gas DHW]

$= [(1 - ElecHeat) * ((Gas\_Heating\_Load / Gas_{Effbase})] + [(1 - ElecDHW) * \%DHW * (1/EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)]$

ΔkWh = - [GSHP heating consumption] + [Cooling savings[668]] + [DHW savings if existing electric DHW]

$= - [(EFLH_{heat} * Capacity_{Heat} * (1/COP_{GSHP} * 3.412))/1000] + [(EFLH_{cool} * Capacity_{Cool} * (1/EER_{base} - 1/EER_{GSHP}))/1000] + [ElecDHW * \%DHW * ((1/EF_{ELEC} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)]$

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 10 ton unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms $= [(1 - ElecHeat) * ((Gas\_Heating\_Load / Gas_{Effbase})] + [(1 - ElecDHW) * \%DHW * (1/EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)]$

$= [(1-0) * (1975/0.8)] + [((1 - 0) * 0.44 * (1/0.8 * (100*672) * 8.33 * (125-54) * 1)/100000)]$

= 2,469 + 219

= 2,688 therms

ΔkWh $= - [(EFLH_{heat} * Capacity_{Heat} * (1/COP_{GSHP} * 3.412))/1000] + [(EFLH_{cool} * Capacity_{Cool} * (1/EER_{base} - 1/EER_{GSHP}))/1000] + [ElecDHW * \%DHW * ((1/EF_{ELEC} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)]$

$= - [(1646 * 120000 * (1/4.4 * 3.412))/1000] + [(1457 * 120000 * (1/11 - 1/20))/1000] + [0 * (0.44 * ((1/0.9568) * (100*672) * 8.33 * (125 - 54) * 1/3412))]$

= -153,168 + 7153 + 0

= -146,015 kWh

MEASURE CODE: CI-HVC-GSHP-V01-190101

REVIEW DEADLINE: 1/1/2021

[667] Note $Gas_{Effbase}$ in the algorithm should be replaced with $Gas_{EffExist}$ for early replacement measures.

[668] Note EER_{base} in the algorithm should be replaced with EER_{exist} for early replacement measures.

4.4.45 Adsorbent Air Cleaning

DESCRIPTION

The Adsorbent Air Cleaning (AAC) measure installs modular adsorbent air cleaning devices ("AAC modules") into commercial forced air HVAC systems. These devices pass return air through adsorbent media which remove the gas-phase contaminants carbon dioxide and species of volatile organic compounds (VOCs) from the return air, allowing it to be recirculated rather than removed from the building as exhaust and replaced with ventilation air. This allows HVAC system operators to substantially reduce the amount of outside air brought in for ventilation while still maintaining acceptable indoor air quality, resulting in heating and cooling energy savings. An energy penalty is incurred due to the operation of fans integrated within the AAC modules, as well as from integrated electric heaters used in a regeneration cycle which purges the adsorbent media of contaminants to allow them to be used again.

This measure serves the market for medium to large commercial and institutional buildings.

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

DEFINITION OF EFFICIENT EQUIPMENT

Efficient equipment is defined as a commercial HVAC system which has AAC modules installed in the return airstream, with the number of modules determined by appropriate sizing calculations. The modules allow for a substantial reduction in the volume of outside air introduced to the building compared to systems without AAC modules.

DEFINITION OF BASELINE EQUIPMENT

Two baselines are defined here. The first is a variable air volume HVAC system equipped with an integrated economizer and which recirculates a portion of its return air. The other baseline is a dedicated outside air system; that is, a system which obtains 100% of its supply air from outside air.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC applications is 20 years.[669]

DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used[670].

Table 1 – Deemed Measure Cost Details

Unit	Material Cost / Unit	Labor Cost / Unit	Total Cost / Unit ($/cfm)
cfm	$1.12	$0.50	$1.62

For example, the default deemed measure cost of installing the AAC measure in an HVAC system with a design supply air flow rate of 75,000 cfm is:

Deemed Measure Cost ($) = 75,000 cfm * $1.62/cfm = $121,500

LOADSHAPE

For buildings with gas heat:

[669] ASHRAE Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey; HVAC Service Life Database. Accessed 8/29/2018.

[670] Default measure cost is based on sales information and labor cost estimates provided by a major Original Equipment Manufacturer (OEM) of AAC units. The OEM's estimates are based on prior installation experiences and case studies.

Loadshape C03 – Commercial Cooling

For buildings with electric heat:

Loadshape C05 – Commercial Electric Heating and Cooling

Coincidence Factor

The concidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

Algorithm

Calculation of Energy Savings

To determine the savings associated with the Adsorbent Air Cleaning measure, the IL TRM prototype eQuest models were utilized. These models were developed by Seventhwave (formerly the Energy Center of Wisconsin)[671] and modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours Update. The prototype models were modified in order to simulate the following measure scenarios:

1. Commercial variable air volume HVAC system with integrated economizer and recirculated return air
    a. Natural gas heating
    b. Electric heating
2. Dedicated outside air system (100% OA), with and without energy recovery ventilation
    a. Natural gas heating
    b. Electric heating
    c. Heat pump

Three major modifications to the prototype energy models were introduced in order to simulate the AAC measure. The first was a reduction in outside air consistent with reductions previously demonstrated in field studies. The second was a reduction in supply fan static pressure to simulate the pressure contribution of the AAC modules' internal fans. The third was the introduction of an electrical load and schedule to account for the energy consumed by the AAC modules' internal fans and regeneration heater. Simulation results were normalized to the amount of outside air reduced by the AAC measure.

Electric Energy Savings

$\Delta kWh = \Delta V_{OA}$ * Normalized Electric Energy Savings

Where:

ΔV_{OA} = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= if the rate is unknown, calculate using the following equation:

$\Delta V_{OA} = V\_supply * F_{OA} * F_R$, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

F_{OA} = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, $F_{OA} = 1$. For systems which recirculate a portion of their return air, F_{OA} will vary between 0 and 1. In these cases, F_{OA} can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air

[671] Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010

damper position to outside air flow, or by using an airflow measurement station.

F_R = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default[672]

Normalized Electric Energy Savings

= ΔkWh/Δscfm savings value for the appropriate combination of HVAC system type, climate zone, and measure scenario per Table 2 – Electric Energy Savings Summary (kWh/scfm)

Table 2 – Electric Energy Savings Summary

HVAC System Type	Normalized Electricity Savings (kWh/scfm)				
	Rockford - Zone 1	Chicago - Zone 2	Springfield - Zone 3	Mt Vernon/Belleville - Zone 4	Marion - Zone 5
Variable Air Volume					
VAV with Gas Heat	4.68	4.53	5.73	6.44	5.77
VAV with Electric Heat	31.87	24.84	21.60	15.66	13.91
Dedicated Outside Air System - no energy recovery					
No humidity control					
DOAS With Gas Heat	1.99	1.56	2.28	2.38	1.65
DOAS With Electric Heat	17.60	14.90	13.71	11.84	8.12
DOAS - Heat Pump	1.98	1.63	1.76	2.38	2.33
With humidity control					
DOAS With Gas Heat	2.33	2.11	2.95	3.41	2.52
DOAS With Electric Heat	11.31	15.96	14.82	13.80	9.71
DOAS - Heat Pump	2.44	2.22	2.22	3.01	3.14
Dedicated Outside Air System - sensible and latent energy recovery					
No humidity control					
DOAS With Gas Heat	1.67	1.38	2.28	1.47	0.76
DOAS With Electric Heat	3.12	2.43	2.36	1.82	1.82
DOAS - Heat Pump	0.40	0.34	0.21	0.37	0.32
With humidity control					
DOAS With Gas Heat	1.83	1.61	1.75	2.12	1.27
DOAS With Electric Heat	3.44	3.07	2.86	3.24	3.07
DOAS - Heat Pump	0.66	0.50	0.50	0.81	0.79
Dedicated Outside Air System - sensible energy recovery					
No humidity control					
DOAS With Gas Heat	2.15	1.78	2.44	2.60	1.89
DOAS With Electric Heat	8.08	6.67	6.37	5.39	5.26
DOAS - Heat Pump	1.15	0.83	0.92	1.17	1.13
With humidity control					
DOAS With Gas Heat	2.48	2.27	3.13	3.62	2.76
DOAS With Electric Heat	8.70	7.62	7.43	7.25	7.08
DOAS - Heat Pump	1.50	1.30	1.30	1.69	1.80

[672] The default value of 0.7 for F_R is based on a survey of previous case studies which documented the field installation of AAC modules in existing HVAC systems. See references for more information.

EXAMPLE:

An office building in Climate Zone 3 is equipped with a VAV system with hot water heat, and has a design supply air flow rate of 50,000 scfm and an outdoor air ventilation rate of 5,000 scfm. Installing AAC modules will allow reduction of the outdoor air ventilation rate by 70%. In this case:

V_supply = 50,000 scfm

F_{OA} = 5,000 scfm / 50,000 scfm = 0.1

F_R = 0.7

ΔV_{OA} = V_supply * F_{OA} * F_R = 50,000 scfm * 0.1 * 0.7 = 3,500 scfm

Normalized Electric Energy Savings = 5.73 kWh/scfm

ΔkWh = ΔV_{OA} * Normalized Electric Energy Savings

= 3,500 scfm * 5.73 kWh/scfm = 20,055 kWh

= 21,665 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔV_{OA} * Normalized Electric Peak Demand Savings * CF

Where:

ΔV_{OA} = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= if the rate is unknown, calculate using the following equation:

ΔV_{OA} = V_supply * F_{OA} * F_R, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

F_{OA} = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, F_{OA} = 1. For systems which recirculate a portion of their return air, F_{OA} will vary between 0 and 1. In these cases, F_{OA} can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air damper position to outside air flow, or by using an airflow measurement station.

F_R = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default

CF = 1.0

Normalized Electric Peak Demand Savings

= ΔkW/Δscfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 3 – Electric Peak Demand Savings Summary (kW/cfm)

Table 3 – Electric Demand Savings Summary

HVAC System Type	Normalized Electric Demand Savings (kW/scfm)				
	Rockford - Zone 1	Chicago - Zone 2	Springfield - Zone 3	Mt Vernon/Belleville - Zone 4	Marion - Zone 5
Variable Air Volume					
VAV with Gas Heat	0.006	0.007	0.007	0.000	0.000
VAV with Electric Heat	0.005	0.007	0.007	0.000	0.000
Dedicated Outside Air System - no energy recovery					
No humidity control					
DOAS With Gas Heat	0.004	0.003	0.004	0.005	0.004
DOAS With Electric Heat	0.004	0.004	0.004	0.005	0.004
DOAS - Heat Pump	0.003	0.003	0.004	0.003	0.004
With humidity control					
DOAS With Gas Heat	0.005	0.004	0.005	0.006	0.004
DOAS With Electric Heat	0.005	0.005	0.005	0.007	0.005
DOAS - Heat Pump	0.005	0.005	0.005	0.004	0.005
Dedicated Outside Air System - sensible and latent energy recovery					
No humidity control					
DOAS With Gas Heat	0.002	0.001	0.002	0.002	0.002
DOAS With Electric Heat	0.001	0.000	0.002	0.002	0.002
DOAS - Heat Pump	0.001	0.000	0.001	0.001	0.001
With humidity control					
DOAS With Gas Heat	0.002	0.002	0.002	0.001	0.001
DOAS With Electric Heat	0.002	0.003	0.002	0.003	0.002
DOAS - Heat Pump	0.003	0.001	0.001	0.001	0.001
Dedicated Outside Air System - sensible energy recovery					
No humidity control					
DOAS With Gas Heat	0.004	0.002	0.005	0.005	0.004
DOAS With Electric Heat	0.003	0.003	0.003	0.004	0.003
DOAS - Heat Pump	0.001	0.002	0.002	0.002	0.002
With humidity control					
DOAS With Gas Heat	0.005	0.004	0.005	0.006	0.004
DOAS With Electric Heat	0.006	0.006	0.006	0.007	0.006
DOAS - Heat Pump	0.003	0.003	0.003	0.002	0.003

EXAMPLE:

Under the same conditions as the previous example,

Normalized Electric Demand Savings = 0.007 kW/scfm

$\Delta kWh = \Delta V_{OA}$ * Normalized Demand Energy Savings * CF

= 3,500 scfm * 0.007 kW/scfm * 1

= 24.5 kW

NATURAL GAS SAVINGS

$\Delta therms = \Delta V_{OA}$ * Normalized Gas Energy Savings

Where:

ΔV_{OA} = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= custom; if unknown, calculate using the following equation:

$\Delta V_{OA} = V\_supply * F_{OA} * F_R$, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

F_{OA} = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, F_{OA} = 1. For systems which recirculate a portion of their return air, F_{OA} will vary between 0 and 1. In these cases, F_{OA} can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air damper position to outside air flow, or by using an airflow measurement station.

F_R = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default

Normalized Gas Energy Savings

= Δtherms/Δscfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Gas Energy Savings Summary (therms/scfm)

Table 4 – Natural Gas Energy Savings Summary (therms/cfm)

HVAC System Type	Normalized Natural Gas Savings (therms/scfm)				
	Rockford - Zone 1	Chicago - Zone 2	Springfield - Zone 3	Mt Vernon/Belleville - Zone 4	Marion - Zone 5
Variable Air Volume					
VAV with Gas Heat	1.01	0.77	0.59	0.39	0.39
VAV with Electric Heat	n/a	n/a	n/a	n/a	n/a
Dedicated Outside Air System - no energy recovery					
No humidity control					
DOAS With Gas Heat	0.79	0.70	0.58	0.50	0.33
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.69	0.59	0.59	0.35	0.34
With humidity control					
DOAS With Gas Heat	0.80	0.73	0.60	0.55	0.38
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.69	0.59	0.59	0.35	0.34
Dedicated Outside Air System - sensible and latent energy recovery					
No humidity control					
DOAS With Gas Heat	0.16	0.17	0.10	0.07	0.07
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.11	0.09	0.08	0.04	0.04
With humidity control					
DOAS With Gas Heat	0.16	0.16	0.11	0.12	0.11
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.11	0.08	0.08	0.04	0.04
Dedicated Outside Air System - sensible energy recovery					
No humidity control					
DOAS With Gas Heat	0.38	0.33	0.27	0.23	0.21
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.30	0.25	0.25	0.14	0.13
With humidity control					
DOAS With Gas Heat	0.39	0.37	0.29	0.29	0.27
DOAS With Electric Heat	n/a	n/a	n/a	n/a	n/a
DOAS - Heat Pump	0.30	0.25	0.25	0.14	0.13

EXAMPLE:

Under the same conditions as the previous example,

Normalized Gas Energy Savings = 0.59 therms/scfm

Δtherms = ΔV_{OA}* Normalized Gas Energy Savings

= 3,500 scfm * 0.59 therms/scfm

= 2,065 therms

MEASURE CODE: CI-HVC-ADAC-V01-190101

REVIEW DEADLINE: 1/1/2021

4.5 Lighting End Use

The commercial lighting measures use a standard set of variables for hours or use, waste heat factors, coincident factors and HVAC interaction effects. This table has been developed based on information provided by the various stakeholders. For ease of review, the table is included here and referenced in each measure.

The building characteristics can be found in the reference table named "EFLH Building Descriptions Updated 2014-11-21.xlsx". Note a modeling subcommittee is in the process of transferring and calibrating models from eQuest to OpenStudio. The model source is provided in the table.

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.

Building/Space Type	Fixture Annual Operating Hours[673]	Screw based bulb Annual Operating hours[674]	Waste Heat Cooling Energy WHFe [675]	Waste Heat Cooling Demand WHFd	Coinci-dence Factor CF[676]	Waste Heat Gas Heating IFTherms[677]	Waste Heat Electric Resistance Heating IFkWh[678]	Waste Heat Electric Heat Pump Heating IFkWh	Model Source
Assisted Living	7,862	5,950	1.14	1.30	0.66	0.035	0.823	0.358	eQuest
Childcare/Pre-School	2,860	2,860	1.17	1.29	0.72	0.018	0.420	0.183	eQuest
College	3,395	2,588	1.06	1.39	0.63	0.020	0.462	0.201	eQuest
Convenience Store	4,672	3,650	1.09	1.26	0.76	0.035	0.828	0.360	eQuest
Elementary School	3,038	2,118	1.17	1.29	0.72	0.018	0.420	0.183	eQuest
Garage	3,401	3,540	1.00	1.00	0.92	0.000	0.000	0.000	eQuest
Garage, 24/7 lighting	8,766	8,766	1.00	1.00	1.00	0.000	0.000	0.000	eQuest
Grocery	4,650	3,650	1.05	1.22	0.73	0.022	0.511	0.222	eQuest
Healthcare Clinic	3,890	4,207	1.40	1.85	0.65	0.006	0.144	0.063	eQuest
High School	3,038	2,327	1.18	1.39	0.72	0.028	0.656	0.285	eQuest
Hospital - CAV no econ	7,616	4,207	1.11	1.29	0.76	0.022	0.527	0.229	eQuest
Hospital - CAV econ	7,616	4,207	1.06	1.27	0.75	0.023	0.533	0.232	eQuest
Hospital - VAV econ	7,616	4,207	1.37	1.79	0.70	0.010	0.241	0.105	eQuest

[673]Fixtures hours of use are based upon schedule assumptions used in the eQuest models, except for those building types where Illinois based metering results provide a statistically valid estimate (currently: College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse). Miscellaneous is a weighted average of indoor spaces using the relative area of each building type in the region (CBECS).

[674] Hours of use for screw based bulbs are derived from DEER 2008 by building type for cfls. Garage, exterior and multi-family common area values are from the Hours of Use Table in this document. Miscellaneous is an average of interior space values. Some building types are averaged when DEER has two values: these include office, restaurant and retail. Healthcare clinic uses the hospital value.

[675] The Waste Heat Factor for Energy and is developed using EQuest models for various building types base on Chicago Illinois (closest to statewide average HDD and CDD). Exterior and garage values are 1, unknown is a weighted average of the other building types.

[676]Coincident diversity factors are based on either combined IL evaluation results (College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse), case lighting projects performed over several years by Michaels Energy in Illinois and other jurisdictions (Refrigerated and Freezer Cases), or based upon schedules defined in the eQuest models described (all others).

[677] IF Therms value is developed using EQuest models consistent with methodology for Waste Heat Factor for Energy.

[678] Electric heat penalty assumptions are based on converting the IFTherm multiplier value in to kWh and then applying relative heating system efficiencies. The gas efficiency was assumed to be 78% AFUE based upon standard TRM assumption for existing unit average efficiency, and the electric resistance is assumed to be 100%, for Heat Pump is assumed to be 2.3COP:
IFElectricHeat = IFTherms * 29.3 kWh/therm * 78% (Gas Heating Equipment Efficiency) / 100% (Electric Resistance Efficiency)

Building/Space Type	Fixture Annual Operating Hours[673]	Screw based bulb Annual Operating hours[674]	Waste Heat Cooling Energy WHFe [675]	Waste Heat Cooling Demand WHFd	Coinci-dence Factor CF[676]	Waste Heat Gas Heating IFTherms[677]	Waste Heat Electric Resistance Heating IFkWh[678]	Waste Heat Electric Heat Pump Heating IFkWh	Model Source
Hospital - FCU	7,616	4,207	1.38	1.29	0.73	0.001	0.033	0.015	eQuest
Manufacturing Facility	4,618	2,629	1.02	1.04	0.81	0.012	0.270	0.117	eQuest
MF - High Rise - Common	6,138	5,950	1.14	1.32	0.64	0.025	0.596	0.259	eQuest
MF - Mid Rise - Common	5,216	5,950	1.24	1.55	0.82	0.032	0.741	0.322	OpenStudio
Hotel/Motel - Guest	2,390	777	1.18	1.36	0.28	0.020	0.463	0.201	eQuest
Hotel/Motel - Common	6,138	4,542	1.20	1.24	0.73	0.032	0.748	0.325	eQuest
Movie Theater	3,506	5,475	1.11	1.38	0.53	0.029	0.673	0.293	eQuest
Office - High Rise - CAV no econ	2,886	3,088	1.00	1.07	0.57	0.037	0.874	0.380	eQuest
Office - High Rise - CAV econ	2,886	3,088	1.00	1.07	0.57	0.039	0.905	0.394	eQuest
Office - High Rise - VAV econ	2,886	3,088	1.27	1.65	0.53	0.022	0.510	0.222	eQuest
Office - High Rise - FCU	2,886	3,088	1.35	1.56	0.59	0.015	0.346	0.150	eQuest
Office - Low Rise	2,698	3,088	1.11	1.31	0.52	0.016	0.371	0.161	eQuest
Office - Mid Rise	3,266	3,088	1.06	1.34	0.60	0.006	0.139	0.060	OpenStudio
Religious Building	2,085	1,664	1.12	1.37	0.48	0.015	0.356	0.155	eQuest
Restaurant	5,571	4,784	1.17	1.31	0.68	0.021	0.491	0.213	eQuest
Retail - Department Store	4,099	2,935	1.06	1.06	0.94	0.015	0.346	0.150	OpenStudio
Retail - Strip Mall	4,093	2,935	1.12	1.29	0.71	0.019	0.450	0.196	eQuest
Warehouse	3,135	4,293	1.02	1.17	0.85	0.016	0.378	0.164	OpenStudio
Unknown	3,379	3,612	1.09	1.36	0.58	0.022	0.522	0.227	n/a
Exterior – dusk to dawn[679]	4,303	4,303	1.00	1.00	0.00	0.000	0.000	0.000	n/a
Exterior – dusk to business close	See calculation below		1.00	1.00	0.00	0.000	0.000	0.000	n/a
Low-Use Small Business	2,954	2,954	1.31	1.53	0.66	0.023	0.524	0.262	n/a
Uncooled Building	Varies	varies	1.00	1.00	0.66	0.014	0.320	0.160	n/a
Refrigerated Cases	5,802	n/a	1.29	1.29	1.00	0.000	0.000	0.000	n/a
Freezer Cases	5,802	n/a	1.50	1.5	1.00	0.000	0.000	0.000	n/a

[679] Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd's service territory. See Navigant Memorandum 'RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017'.

Exterior Lighting Hours – dusk to business close

Hours = (6.19 * Days) + (%Adj * Days)

Where:

6.19 = Average hours per day between dusk and midnight[680]

Days = Days of business operation

= Actual

%Adj = Percent adjustment dependent on hour closing[681]

Business closes at	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12pm	1am	2am	3am
%Adj	-619%	-604%	-564%	-500%	-400%	-300%	-200%	-100%	0%	100%	200%	300%

For example a business open until 8pm, 260 days per year, would assume:

Hours = (6.19 * 260) + (-400% * 260) = 569.4 hours

[680] Calculated using the eQuest model by finding the total number of hours of exterior lighting consumption between dusk and midnight and dividing by 365 (2261 / 365 = 6.19 hours per day).
[681] See "IL TRM Ext Lighting.xlsx" for calculation.

4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.

DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a commercial location. If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[682], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[683].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours[684]) by the run hours. For example using Miscellaneous at 3,612 hours would give 2.8 years. When the number of years exceeds 2021, the number of years to that date should be used.

---

682 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.
683 Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.
684 Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.

DEEMED MEASURE COST

The incremental capital cost assumption for all bulbs under 2600 lumens is $1.20[685].

For bulbs over 2600 lumens the assumed incremental capital cost is $5.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh =((WattsBase-WattsEE)/1000) * ISR * Hours * WHFe

Where:

WattsBase = Actual (if retrofit measure) or based on lumens of CFL bulb and program year installed:

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72

685 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
1050	1489	53
750	1049	43
310	749	29
250	309	25

WattsEE = Actual wattage of CFL purchased or installed

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[686] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
71.2%[687]	14.5%	12.3%	98.0%[688]

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type[689]. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in an office and sign off form provided:

ΔkWh = (((43 - 14)/1000)* 1.0 * 3088 * 1.25

= 111.9 kWh

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

[687] 1st year in service rate is based upon review of PY4-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

[688] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[689] Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

Heating Penalty

If electrically heated building:

$\Delta kWh_{heatpenalty}$[690] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

> For example, a 14W standard CFL is installed in a heat pump heated office and sign off form provided:
>
> $\Delta kWh_{heatpenalty}$ = (((43 - 14)/1000)* 1.0*3088*-0.183
>
> = - 16.4 kWh

Deferred Installs

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

> For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen) purchased and using miscellaneous hours assumption.
>
> $\Delta kWH_{1st\ year\ installs}$ = ((43 - 14) / 1000) * 0.755 * 3612 * 1.06
>
> = 83.8 kWh
>
> $\Delta kWH_{2nd\ year\ installs}$ = ((43 - 14) / 1000) * 0.121 * 3612 * 1.06
>
> = 13.4 kWh
>
> Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.
>
> $\Delta kWH_{3rd\ year\ installs}$ = ((43 - 14) / 1000) * 0.103 * 3612 * 1.06
>
> = 11.4 kWh

Summer Coincident Peak Demand Savings

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

[690]Negative value because this is an increase in heating consumption due to the efficient lighting.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

> For example, a 14W standard CFLis installed in an office and sign off form provided:
>
> ΔkW = ((43 - 14)/1000)*1.0*1.3*0.66
>
> = 0.025kW

NATURAL GAS ENERGY SAVINGS

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

ΔTherms[691] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

> For example, a 14W standard CFL is installed in an office and sign off form provided:
>
> ΔTherms = (((43 - 14)/1000)* 1.0*3088*-0.016
>
> = - 1.4 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

Replacement Period (years)[692]	Replacement Cost[693]
= 1000 / Hours	$1.25

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

[691] Negative value because this is an increase in heating consumption due to the efficient lighting.

[692] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[693] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

MEASURE CODE: CI-LTG-CCFL-V08-190101

REVIEW DEADLINE: 1/1/2020

4.5.2 Fluorescent Delamping

DESCRIPTION

This measure addresses the permanent removal of existing 8', 4', 3' and 2' fluorescent lamps. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture. This measure is applicable when retrofitting from T12 lamps to T8 lamps or simply removing lamps from a T8 fixture. Removing lamps from a T12 fixture that is not being retrofitted with T8 lamps are not eligible for this incentive.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. A pre-approval application is required for lamp removal projects.

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

Savings are defined on a per removed lamp basis. The retrofit wattage (efficient conditioned) is therefore assumed to be zero. The savings numbers provided below are for the straight lamp removal measures, as well as the lamp removal and install reflector measures. The lamp installed/retrofit is captured in another measure.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is either a T12 or a T8 lamp with default wattages provided below. Note, if the program does not allow for the lamp type to be known, then a T12:T8 weighting of 80%:20% can be applied[694].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years per DEER 2005.

DEEMED MEASURE COST

The incremental capital cost is provided in the table below:

Measure Category	Value	Source
8-Foot Lamp Removal	$16.00	ComEd/KEMA regression[695]
4-Foot Lamp Removal	$12.00	ICF Portfolio Plan
8-Foot Lamp Removal with reflector	$30.00	KEMA Assumption
4-Foot Lamp Removal with reflector	$25.00	KEMA Assumption
2-Foot or 3-Foot Removal	$12.35	KEMA Assumption
2-Foot or 3-Foot Removal with reflector	$25.70	KEMA Assumption

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

---

694 Based on ComEd's estimate of lamp type saturation.

695 Based on the assessment of active projects in the 2008-09 ComEd Smart Ideas Program. See files "ltg costs 12-10-10.xl." and "Lighting Unit Costs 102605.doc"

Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

Calculation of Savings

Electric Energy Savings

ΔkWh =((WattsBase-WattsEE)/1000) * ISR * Hours * WHFe

Where:

WattsBase = Assume wattage reduction of lamp removed

	Wattage of lamp removed[696]		Weighted average
	T8	T12	80% T12, 20% T8
8-ft T8	38.6	60.3	56.0
4-ft T8	19.4	33.7	30.8
3-ft T8	14.6	40.0	34.9
2-ft T8	9.8	28.0	24.4

WattsEE = 0

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment permanently removed and disposed of.

Hours = Average hours of use per year are provided in Reference Table in Section 4.5. If unknown use the Miscellaneous value.

[696] Default wattage reducetion is based on averaging the savings from moving from a 2 to 1, 3 to 2 and 4 to 3 lamp fixture, as provided in the Standard Performance Contract Procedures Manual: Appendix B: Table of Standard Fixture Wattages, Version 3.0, SCE, March 2004. An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor. See ‘Delamping calculation.xls’ for details.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in an office building:

ΔkWh =((19.4 - 0)/1000) * 1.0 * 4439 * 1.25

= 107.6 kWh

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[697] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in a heat pump heated office building:

$\Delta kWh_{heatpenalty}$ =((19.4 - 0)/1000) * 1.0 * 4439 * -0.151

=-13.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔkW =((19.4 - 0)/1000) * 1.0 * 1.3 * 0.66

= 0.017 kW

NATURAL GAS ENERGY SAVINGS

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

ΔTherms[698] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by

[697]Negative value because this is an increase in heating consumption due to the efficient lighting.

[698] Negative value because this is an increase in heating consumption due to the efficient lighting.

the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔTherms =((19.4 - 0)/1000) * 1.0 * 4439 * -0.016

=-1.4 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-DLMP-V02-140601

REVIEW DEADLINE: 1/1/2021

4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps

DESCRIPTION

This measure applies to "High Performance T8" (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the "Reduced Wattage T8 lamps" or RWT8 lamps that result in re-lamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 100% Commercial and 0% Residential should be used[699].

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.

The measure applies to all commercial HPT8 installations excluding new construction and major renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for the different types of installations. Whenever possible, actual costs and hours of use should be utilized for savings calculations. Default new and baseline assumptions have been provided in the reference tables. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. HPT8 configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
This measure relates to the installation of new equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. In general, the measure will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. High-bay applications use this system paired with qualifying high ballast factor ballasts and high performance 32 w lamps. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms.	This measure relates to the replacement of existing equipment with new equipment with efficiency that exceeds that of the existing equipment. In general, the retrofit will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms. High efficiency troffers (new/or retrofit) utilizing HPT8 technology can provide even greater savings. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID high-bay fixtures, while using fewer watts; these systems typically utilize high ballast factor ballasts, but qualifying low and normal ballast factor ballasts may be used when appropriate light levels are provided and overall wattage is reduced.

[699] Based on weighted average of Final ComEd's Instant Discounts program data from PY7 and PY9. For Residential installations, hours of use assumptions from '5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture' measure should be used.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient conditions for all applications are a qualifying HP or RWT8 fixture and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products[700] and qualifying RWT8 products[701].

The definition of efficient equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
High efficiency troffers combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts. High bay fixtures must have fixture efficiencies of 85% or greater. RWT8 lamps: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table. This measure assumes a lamp only purchase.	High efficiency troffers (new or retrofit kits) combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts. High bay fixtures will have fixture efficiencies of 85% or greater. RWT8: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
The baseline is standard efficiency T8 systems that would have been installed. The baseline for high-bay fixtures is pulse start metal halide fixtures, the baseline for a 2 lamp high efficiency troffer is a 3 lamp standard efficency troffer.	The baseline is the existing system. In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v7.0 until 1/1/2020 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2020. See table C-1.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of efficient equipment varies based on the program and is defined below:

[700] Consortium for Energy Efficiency (CEE) Energy Efficiency Program Library, High-Performance T8 Specification, June 30, 2009
[701] Consortium for Energy Efficiency (CEE) Energy Efficiency Program Library, Reduced Wattage T8 Specification, July 29, 2013

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 12 years[702]. Fixture retrofits which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below. RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 12 years.[703]	Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 15 years. As per explanation above, for existing T12 fixtures, a mid life baseline shift should be applied in 2019 as described in table C-1. Note, since the fixture lifetime is deemed at 12 years, the replacement cost of both the lamp and ballast should be incorporated in to the O&M calculation.

DEEMED MEASURE COST

The deemed measure cost is found in the reference table at the end of this characterization.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[702] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[703] ibid

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

Program	Reference Table
Time of Sale	A-1: HPT8 New and Baseline Assumptions
Retrofit	A-2: HPT8 New and Baseline Assumptions
Reduced Wattage T8, time of sale or retrofit	A-3: RWT8 New and Baseline Assumptions

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

Program	Reference Table
Time of Sale	A-1: HPT8 New and Baseline Assumptions
Retrofit	A-2: HPT8 New and Baseline Assumptions
Reduced Wattage T8, time of sale or retrofit	A-3: RWT8 New and Baseline Assumptions

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours. If hours or building type are unknown, use the Miscellaneous value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[704] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

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

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
93.4%[705]	2.5%	2.1%	98.0%[706]

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[707] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

NATURAL GAS SAVINGS

ΔTherms[708] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

---

[705] Based on ComEd's Instant Incentives program data from PY7 and PY9, see "IL Commercial Lighting ISR_2018.xlsx".

[706] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[707] Negative value because this is an increase in heating consumption due to the efficient lighting.

[708] Negative value because this is an increase in heating consumption due to the efficient lighting.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See Reference tables for Operating and Maintenance Values;

Program	Reference Table
Time of Sale	B-1: HPT8 Component Costs and Lifetime
Retrofit	B-2: HPT8 Component Costs and Lifetime
Reduced Wattage T8, time of sale or retrofit	B-3: HPT8 Component Costs and Lifetime

REFERENCE TABLES

See following page

A-1: Time of Sale: HPT8 New and Baseline Assumptions[709]

EE Measure Description	Nominal Watts	$Watts_{EE}$	Baseline Description	Nominal Watt	$Watts_{BASE}$	Incremental Cost	$Watts_{SAVE}$
4-Lamp HPT8 w/ High-BF Ballast High-Bay	128	147.2	200 Watt Pulse Start Metal-Halide	200	232	$75	84.80
4-Lamp HPT8 w/ High-BF Ballast High-Bay	128	147.2	250 Watt Metal Halide	250	295	$75	147.80
6-Lamp HPT8 w/ High-BF Ballast High-Bay	192	220.8	320 Watt Pulse Start Metal-Halide	320	348.8	$75	128.00
6-Lamp HPT8 w/ High-BF Ballast High-Bay	192	220.8	400 Watt Pulse Start Metal Halide	400	455	$75	234.20
8-Lamp HPT8 w/ High-BF Ballast High-Bay	256	294.4	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	320	476	$75	181.60
8-Lamp HPT8 w/ High-BF Ballast High-Bay	256	292.4	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide	400	618	75	323.60
1-Lamp HPT8-high performance 32 w lamp	32	24.64	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	3.52
1-Lamp HPT8-high performance 28 w lamp	28	21.56	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	6.60
1-Lamp HPT8-high performance 25 w lamp	25	19.25	1-Lamp Standard F32T8 w/ Elec. Ballast	32	28.16	$15	8.91
2-Lamp HPT8 -high performance 32 w lamp	64	49.28	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	7.04
2-Lamp HPT8-high performance 28 w lamp	56	43.12	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	13.20
2-Lamp HPT8-high performance 25 w lamp	50	38.5	2-Lamp Standard F32T8 w/ Elec. Ballast	64	56.32	$18	17.82
3-Lamp HPT8-high performance 32 w lamp	96	73.92	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	10.56
3-Lamp HPT8-high performance 28 w lamp	84	64.68	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	19.80
3-Lamp HPT8-high performance 25 w lamp	75	57.75	3-Lamp Standard F32T8 w/ Elec. Ballast	96	84.48	$20	26.73
4-Lamp HPT8 -high performance 32 w lamp	128	98.56	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	14.08
4-Lamp HPT8-high performance 28 w lamp	112	86.24	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	26.40
4-Lamp HPT8-high performance 25 w lamp	100	77	4-Lamp Standard F32T8 w/ Elec. Ballast	128	112.64	$23	35.64
2-lamp High-Performance HPT8 Troffer	64	49.28	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	$100	35.20

Table developed using a constant ballast factor of .77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy

[709] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

A-2: Retrofit HPT8 New and Baseline Assumptions[710]

EE Measure Description	Nominal Watts	Ballast Factor	$Watts_{EE}$	Baseline Description	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Full Measure Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	128	1.15	147.2	200 Watt Pulse Start Metal-Halide	200	232	84.80	$200
4-Lamp HPT8 w/ High-BF Ballast High-Bay	128	1.15	147.2	250 Watt Metal Halide	250	295	147.80	$200
6-Lamp HPT8 w/ High-BF Ballast High-Bay	192	1.15	220.8	320 Watt Pulse Start Metal-Halide	320	348.8	128.00	$225
6-Lamp HPT8 w/ High-BF Ballast High-Bay	192	1.15	220.8	400 Watt Pulse Start Metal Halide	400	455	234.20	$225
8-Lamp HPT8 w/ High-BF Ballast High-Bay	256	1.15	294.4	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	320	476	181.60	$250
8-Lamp HPT8 w/ High-BF Ballast High-Bay	256	1.15	294.4	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide	400	618	323.60	$250
1-Lamp Relamp/Reballast T12 to HPT8	32	0.77	24.64	1-Lamp F34T12 w/ EEMag Ballast	34	42	17.36	$50
2-Lamp Relamp/Reballast T12 to HPT8	64	0.77	49.28	2-Lamp F34T12 w/ EEMag Ballast	68	67	17.72	$55
3-Lamp Relamp/Reballast T12 to HPT8	96	0.77	73.92	3-Lamp F34T12 w/ EEMag Ballast	102	104	30.08	$60
4-Lamp Relamp/Reballast T12 to HPT8	128	0.77	98.56	4-Lamp F34T12 w/ EEMag Ballast	136	144	45.44	$65
1-Lamp Relamp/Reballast T12 to HPT8	32	0.77	24.64	1-Lamp F40T12 w/ EEMag Ballast	40	41	16.36	$50
2-Lamp Relamp/Reballast T12 to HPT8	64	0.77	49.28	2-Lamp F40T12 w/ EEMag Ballast	80	87	37.72	$55
3-Lamp Relamp/Reballast T12 to HPT8	96	0.77	73.92	3-Lamp F40T12 w/ EEMag Ballast	120	141	67.08	$60
4-Lamp Relamp/Reballast T12 to HPT8	128	0.77	98.56	4-Lamp F40T12 w/ EEMag Ballast	160	172	73.44	$65
1-Lamp Relamp/Reballast T12 to HPT8	32	0.77	24.64	1-Lamp F40T12 w/ Mag Ballast	40	51	26.36	$50
2-Lamp Relamp/Reballast T12 to HPT8	64	0.77	49.28	2-Lamp F40T12 w/ Mag Ballast	80	97	47.72	$55
3-Lamp Relamp/Reballast T12 to HPT8	96	0.77	73.92	3-Lamp F40T12 w/ Mag Ballast	120	135	61.08	$60
4-Lamp Relamp/Reballast T12 to HPT8	128	0.77	98.56	4-Lamp F40T12 w/ Mag Ballast	160	175	76.44	$65
1-Lamp Relamp/Reballast T8 to HPT8	32	0.77	24.64	1-Lamp F32T8 w/ Elec. Ballast	32	28.16	3.52	$50
2-Lamp Relamp/Reballast T8 to HPT8	64	0.77	49.28	2-Lamp F32T8 w/ Elec. Ballast	64	56.32	7.04	$55
3-Lamp Relamp/Reballast T8 to HPT8	96	0.77	73.92	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	10.56	$60
4-Lamp Relamp/Reballast T8 to HPT8	128	0.77	98.56	4-Lamp F32T8 w/ Elec. Ballast	128	112.64	14.08	$65

[710] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, Xcel Energy Lighting Efficiency Input Wattage Guide and professional judgment.

EE Measure Description	Nominal Watts	Ballast Factor	$Watts_{EE}$	Baseline Description	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Full Measure Cost
2-lamp High-Performance HPT8 Troffer or high efficiency retrofit troffer	64	0.77	49.28	3-Lamp F32T8 w/ Elec. Ballast	96	84.48	35.20	$100

Table developed using a constant ballast factor of 0.77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

EE Measure Description	Nominal Watts	$Watts_{EE}$	EE Lamp Cost	Baseline Description	Base Lamp Cost	Nominal Watts	$Watts_{BASE}$	$Watts_{SAVE}$	Measure Cost
RW T8 - F28T8 Lamp	28	24.64	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	3.52	$2.00
RWT8 F2T8 Extra Life Lamp	28	24.64	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	3.52	$2.00
RWT8 - F32/25W T8 Lamp	25	22.00	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	6.16	$2.00
RWT8 - F32/25W T8 Lamp Extra Life	25	22.00	$4.50	F32 T8 Standard Lamp	$2.50	32	28.16	6.16	$2.00
RWT8 F17T8 Lamp - 2 ft	16	14.08	$4.80	F17 T8 Standard Lamp - 2ft	$2.80	17	14.96	0.88	$2.00
RWT8 F25T8 Lamp - 3 ft	23	20.24	$5.10	F25 T8 Standard Lamp - 3ft	$3.10	25	22.00	1.76	$2.00
RWT8 F30T8 Lamp - 6' Utube	30	26.40	$11.31	F32 T8 Standard Utube	$9.31	32	28.16	1.76	$2.00
RWT8 F29T8 Lamp - Utube	29	25.52	$11.31	F32 T8 Standard Utube	$9.31	32	28.16	2.64	$2.00
RWT8 F96T8 Lamp - 8 ft	65	57.20	$9.00	F96 T8 Standard Lamp - 8 ft	$7.00	70	61.60	4.40	$2.00

A– 3: RWT8 New and Baseline Assumptions

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

B-1: Time of Sale T8 Component Costs and Lifetime[711]

[711] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	200 Watt Pulse Start Metal-Halide	$21.00	10000	$6.67	$87.75	40000	$22.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	320 Watt Pulse Start Metal-Halide	$21.00	20000	$6.67	$109.35	40000	$22.50
8-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	Lamp HPT8 Equivalent to 320 PSMH	$21.00	20000	$6.67	$109.35	40000	$22.50
1-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp Standard F32T12 w/ Elec Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
2-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp Standard F32T12 w/ Elec Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
3-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp Standard F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
4-Lamp HPT8 – all qualifying lamps	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp Standard F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00
				$32.50									
2-lamp High-Performance HPT8 Troffer	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00

B-2: T8 Retrofit Component Costs and Lifetime[712]

[712] Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	200 Watt Pulse Start Metal-Halide	$29.00	12000	$6.67	$87.75	40000	$22.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	320 Watt Pulse Start Metal-Halide	$72.00	20000	$6.67	$109.35	40000	$22.50
8-Lamp HPT8 w/ High-BF Ballast High-Bay	$5.00	24000	$6.67	$32.50	70000	$15.00	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	$17.00	20000	$6.67	$109.35	40000	$22.50
1-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
2-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
3-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
4-Lamp Relamp/Reballast T12 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp F34T12 w/ EEMag Ballast	$2.70	20000	$2.67	$20.00	40000	$15.00
1-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	1-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
2-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	2-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
3-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
4-Lamp Relamp/Reballast T8 to HPT8	$5.00	24000	$2.67	$32.50	70000	$15.00	4-Lamp F32T8 w/ Elec. Ballast	$2.70	20000	$2.67	$20.00	70000	$15.00
2-lamp High-Performance HPT8 Troffer	$5.00	24000	$2.67	$32.50	70000	$15.00	3-Lamp F32T8 w/ Elec. Ballast	$2.50	20000	$2.67	$15.00	70000	$15.00

B-3: Reduced Wattage T8 Component Costs and Lifetime[713]

EE measure description	EE Lamp Cost	EE Lamp Life (hrs)	Baseline Description	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost
RW T8 - F28T8 Lamp	$4.50	30000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 F2T8 Extra Life Lamp	$4.50	36000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 - F32/25W T8 Lamp	$4.50	30000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 - F32/25W T8 Lamp Extra Life	$4.50	36000	F32 T8 Standard Lamp	$2.50	15000	$2.67
RWT8 F17T8 Lamp - 2 ft	$4.80	18000	F17 T8 Standard Lamp - 2ft	$2.80	15000	$2.67
RWT8 F25T8 Lamp - 3 ft	$5.10	18000	F25 T8 Standard Lamp - 3ft	$3.10	15000	$2.67
RWT8 F30T8 Lamp - 6' Utube	$11.31	24000	F32 T8 Standard Utube	$9.31	15000	$2.67
RWT8 F29T8 Lamp - Utube	$11.31	24000	F32 T8 Standard Utube	$9.31	15000	$2.67
RWT8 F96T8 Lamp - 8 ft	$9.00	24000	F96 T8 Standard Lamp - 8 ft	$7.00	15000	$2.67

[713] Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

C-1: T12 Baseline Adjustment:

For measures installed up to 1/1/2020, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2020. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

EE Measure Description	Savings Adjustment T12 EEmag ballast and 34 w lamps to HPT8	Savings Adjustment T12 EEmag ballast and 40 w lamps to HPT8	Savings Adjustment T12 mag ballast and 40 w lamps to HPT8
1-Lamp Relamp/Reballast T12 to HPT8	47%	30%	20%
2-Lamp Relamp/Reballast T12 to HPT8	53%	30%	22%
3-Lamp Relamp/Reballast T12 to HPT8	42%	38%	21%
4-Lamp Relamp/Reballast T12 to HPT8	44%	29%	23%

Measures installed in 2019 will claim full savings for one year. Savings adjustment factors will be applied to the full savings for savings starting in 1/1/2020 and for the remainder of the measure life. The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 and wattage reduction from T12 EE ballast with 40 w lamp baseline from the table 'T8 New and Baseline Assumptions'.[714]

Example: 2 lamp T8 to 2 lamp HPT8 retrofit saves 10 watts, while the T12 EE with 40 w lamp to HPT8 saves 33 watts. Thus the ratio of wattage reduced is 30%.

MEASURE CODE: CI-LTG-T8FX-V07-190101

REVIEW DEADLINE: 1/1/2020

[715] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx.

4.5.4 LED Bulbs and Fixtures

Description

This characterization provides savings assumptions for a variety of LED lamps including Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16), and fixtures including refrigerated case, recessed and outdoor/garage fixtures.

If the implementation strategy does not allow for the installation location to be known, for Residential targeted programs (e.g. an upstream retail program), a deemed split of 97% Residential and 3% Commercial assumptions should be used[715], and for Commercial targeted programs a deemed split of 98% Commercial and 2% Residential should be used[716].

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

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 becomes effective on 1/2/2017.[717]

Lamps and fixtures should be found in the reference tables below. Fixtures must be ENERGY STAR labeled or on the Design Lights Consortium qualifying fixture list.

Definition of Baseline Equipment

Refer to the baseline tables.

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) required all general-purpose light bulbs (defined as omni-directional or standard A-lamps) between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards went in to effect followed by the 75 w lamp standards in 2013 and 60 w and 40 w lamps in 2014.

Additionally, an EISA backstop provision requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Since baseline lamps have significantly lower rated lifetimes, this requires that a baseline shift reducing the annual savings is incorporated during the lifetime of the measure. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021 for omnidirectional lamps.

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in the tables below.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation.

There is however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision for specialty and directional lamps to 1/1/2024. However, TAC members

---

[715] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx.

[716] Based on final ComEd's Instant Incentives program data from PY7 and PY9. For Residential installations, hours of use assumptions from '5.5.6 LED Downlights' should be used for LED fixtures and '5.5.8 LED Screw Based Omnidirectional Bulbs' should be used for LED bulbs.

[717] ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 2.1, effective January 2, 2017

commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that if within PY2019, it becomes clear that the EISA backstop *will* apply to the specialty and directional lamps, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these specialty and directional lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and if consensus is reached apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

Deemed Lifetime of Efficient Equipment

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "LED component Costs and Lifetime." The analysis period is the same as the lifetime, capped at 15 years. (15 years from GDS Measure Life Report, June 2007).

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. Refer to reference table “LED component Cost & Lifetime” for defaults.

Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below:

For ENERGY STAR rated lamps the following lumen equivalence tables should be used:[718]

Omnidirectional Lamps - ENERGY STAR Minimum Luminous Efficacy = 80Lm/W for <90 CRI lamps and 70Lm/W for >=90 CRI lamps.

Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage[719] (WattsEE)	Baseline 2014-2020 (WattsBase)	Delta Watts 2014-2020 (WattsEE)	Baseline From 1/1/2021[720] (WattsBase)	Delta Watts From 1/1/2021 (WattsEE)
5280	6209	5745	72.9	300.0	227.1	300.0	227.1
3301	5279	4290	54.5	200.0	145.5	200.0	145.5
2601	3300	2951	37.5	150.0	112.5	65.6	28.1
1490	2600	2045	26.0	72.0	46.0	45.4	19.5
1050	1489	1270	16.1	53.0	36.9	28.2	12.1
750	1049	900	11.4	43.0	31.6	20.0	8.6
310	749	530	6.7	29.0	22.3	11.8	5.0
250	309	280	3.5	25.0	21.5	25.0	21.5

Decorative Lamps - ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps

Bulb Type	Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Baseline 2014-2023 ($Watts_{Base}$)	Delta Watts 2014-2023 (WattsEE)	Baseline From 1/1/2024 ($Watts_{Base}$)[721]	Delta Watts From 1/1/2024 (WattsEE)
3-Way[722]	250	449	350	4.4	25	20.6	7.8	3.3
	450	799	625	7.9	40	32.1	13.9	6.0
	800	1,099	950	12.1	60	47.9	21.1	9.0
	1,100	1,599	1350	17.1	75	57.9	30.0	12.9
	1,600	1,999	1800	22.8	100	77.2	40.0	17.1
	2,000	2,549	2275	28.9	125	96.1	50.5	21.7
	2,550	2,999	2775	35.2	150	114.8	61.7	26.4
Globe (medium and	90	179	135	2.1	10	7.9	3.0	0.9
	180	249	215	3.3	15	11.7	4.8	1.5

[718] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.
[719] Based on ENERGY STAR V2.0 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.
[720] Calculated as 45lm/W for all EISA non-exempt bulbs.
[721] Calculated as 45lm/W for all EISA non-exempt bulbs
[722] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

Bulb Type	Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Baseline 2014-2023 ($Watts_{Base}$)	Delta Watts 2014-2023 (WattsEE)	Baseline From 1/1/2024 ($Watts_{Base}$)[721]	Delta Watts From 1/1/2024 (WattsEE)
intermediate bases less than 750 lumens)	250	349	300	4.6	25	20.4	6.7	2.0
	350	749	550	8.5	40	31.5	12.2	3.8
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	80	1.2	10	8.8	1.8	0.5
	90	149	120	1.8	15	13.2	2.7	0.8
	150	299	225	3.5	25	21.5	5.0	1.5
	300	749	525	8.1	40	31.9	11.7	3.6
Globe (candelabra bases less than 1050 lumens)	90	179	135	2.1	10	7.9	3.0	0.9
	180	249	215	3.3	15	11.7	4.8	1.5
	250	349	300	4.6	25	20.4	6.7	2.0
	350	499	425	6.5	40	33.5	9.4	2.9
	500	1,049	775	11.9	60	48.1	17.2	5.3
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	80	1.2	10	8.8	1.8	0.5
	90	149	120	1.8	15	13.2	2.7	0.8
	150	299	225	3.5	25	21.5	5.0	1.5
	300	499	400	6.1	40	33.9	8.9	2.7
	500	1,049	775	11.9	60	48.1	17.2	5.3

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types:

Bulb Type	Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Baseline 2014-2023 ($Watts_{Base}$)	Delta Watts 2014-2023 (WattsEE)	Baseline From 1/1/2024 ($Watts_{Base}$)[723]	Delta Watts From 1/1/2024 (WattsEE)
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	446	6.6	40	33.4	9.9	3.4
	473	524	499	7.3	45	37.7	11.1	3.8
	525	714	620	9.1	50	40.9	13.8	4.7
	715	937	826	12.1	65	52.9	18.4	6.2
	938	1259	1099	16.2	75	58.8	24.4	8.3
	1260	1399	1330	19.6	90	70.4	29.6	10.0
	1400	1739	1570	23.1	100	76.9	34.9	11.8
	1740	2174	1957	28.8	120	91.2	43.5	14.7
	2175	2624	2400	35.3	150	114.7	53.3	18.0
	2625	2999	2812	41.3	175	133.7	62.5	21.1
	3000	4500	3750	55.1	200	144.9	83.3	28.2

[723] Calculated as 45lm/W for all EISA non-exempt bulbs

Bulb Type	Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Baseline 2014-2023 ($Watts_{Base}$)	Delta Watts 2014-2023 (WattsEE)	Baseline From 1/1/2024 ($Watts_{Base}$)[723]	Delta Watts From 1/1/2024 (WattsEE)
***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	400	449	425	6.2	40	33.8	9.4	3.2
	450	499	475	7.0	45	38.0	10.6	3.6
	500	649	575	8.5	50	41.5	12.8	4.3
	650	1199	925	13.6	65	51.4	20.6	7.0
***ER30, BR30, BR40, or ER40**	400	449	425	6.2	40	33.8	9.4	3.2
	450	499	475	7.0	45	38.0	10.6	3.6
	500	649	575	8.5	50	41.5	12.8	4.3
***BR30, BR40, or ER40**	650	1419	1035	15.2	65	49.8	23.0	7.8
***R20**	400	449	425	6.2	40	33.8	9.4	3.2
	450	719	585	8.6	45	36.4	13.0	4.4
***All reflector lamps below lumen ranges specified above**	200	299	250	3.7	20	16.3	5.6	1.9
	300	399	350	5.1	30	24.9	7.8	2.6

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[724] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[725]

$$\text{Wattsbase} = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

[724] ENERGY STAR Lamps Center Beam Intensity Benchmark Tool and Calculator

[725] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

Additional EISA non-exempt bulb types:

Bulb Type	Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Baseline 2014-2023 ($Watts_{Base}$)	Delta Watts 2014-2023 (WattsEE)	Baseline From 1/1/2024 ($Watts_{Base}$)[726]	Delta Watts From 1/1/2024 (WattsEE)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	749	530	6.7	29	22.3	11.8	5.0
	750	1049	900	11.4	43	31.6	20.0	8.6
	1050	1489	1270	16.1	53	36.9	28.2	12.1
	1490	2600	2045	26.0	72	46.0	45.4	19.5

Hours = Average hours of use per year are provided in the Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type. If unknown, use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

ISR = In Service Rate -the percentage of units rebated that actually get installed.

=100%[727] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
82.5%[728]	8.4%	7.1%	98.0%[729]

[726] Calculated as 45lm/W for all EISA non-exempt bulbs

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

[728] Based on ComEd's Instant Incentives program data from PY7 and PY9 and Ameren's Instant Incentives program for PY9, see "IL Commercial Lighting ISR_2018.xlsx".

[729] In the absence of any data for LEDs specifically it is assumed that the same proportion of bulbs eventually get installed as for CFLS. The 98% CFL assumption is based upon review of two evaluations:

Mid Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <310 and 3300+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

Minimum Lumens	Maximum Lumens	LED Wattage (WattsEE)	Delta Watts 2014-2020 (WattsEE)	Delta Watts From 1/1/2021 (WattsEE)	Mid Life adjustment (made from 1/1/2021) to first year savings
2601	3300	37.5	112.5	28.1	25.0%
1490	2600	26.0	46.0	19.5	42.3%
1050	1489	16.1	36.9	12.1	32.8%
750	1049	11.4	31.6	8.6	27.1%
310	749	6.7	22.3	5.0	22.6%

Since the backstop provision now applies to specialty and directional lamps, the annual savings claim for these bulbs must also be reduced within the life of the measure.

	Bulb Type	Lower Lumen Range	Upper Lumen Range	LED Wattage ($Watts_{EE}$)	Delta Watts 2014-2023 (WattsEE)	Delta Watts From 1/1/2024 (WattsEE)	Mid Life adjustment (made from 1/1/2024) to first year savings
Decorative EISA 2014 Exempt, 2020 Non-Exempt	**3-Way**	250	449	4.4	20.6	3.3	16.2%
		450	799	7.9	32.1	6.0	18.6%
		800	1,099	12.1	47.9	9.0	18.9%
		1,100	1,599	17.1	57.9	12.9	22.2%
		1,600	1,999	22.8	77.2	17.1	22.2%
		2,000	2,549	28.9	96.1	21.7	22.5%
		2,550	2,999	35.2	114.8	26.4	23.0%
	Globe (medium and intermediate bases less than 750 lumens)	90	179	2.1	7.9	0.9	11.6%
		180	249	3.3	11.7	1.5	12.5%
		250	349	4.6	20.4	2.0	10.0%
		350	749	8.5	31.5	3.8	11.9%
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and	70	89	1.2	8.8	0.5	6.2%
		90	149	1.8	13.2	0.8	6.2%
		150	299	3.5	21.5	1.5	7.1%
		300	749	8.1	31.9	3.6	11.2%

'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

	Bulb Type	Lower Lumen Range	Upper Lumen Range	LED Wattage (WattsEE)	Delta Watts 2014-2023 (WattsEE)	Delta Watts From 1/1/2024 (WattsEE)	Mid Life adjustment (made from 1/1/2024) to first year savings
	intermediate bases less than 750 lumens)						
	Globe (candelabra bases less than 1050 lumens)	90	179	2.1	7.9	0.9	11.6%
		180	249	3.3	11.7	1.5	12.5%
		250	349	4.6	20.4	2.0	10.0%
		350	499	6.5	33.5	2.9	8.7%
		500	1,049	11.9	48.1	5.3	11.0%
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	1.2	8.8	0.5	6.2%
		90	149	1.8	13.2	0.8	6.2%
		150	299	3.5	21.5	1.5	7.1%
		300	499	6.1	33.9	2.7	8.1%
		500	1,049	11.9	48.1	5.3	11.0%
Directional EISA 2014 Exempt, 2020 Non-Exempt	**R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)**	420	472	6.6	33.4	3.4	10.0%
		473	524	7.3	37.7	3.8	10.0%
		525	714	9.1	40.9	4.7	11.4%
		715	937	12.1	52.9	6.2	11.8%
		938	1259	16.2	58.8	8.3	14.0%
		1260	1399	19.6	70.4	10.0	14.2%
		1400	1739	23.1	76.9	11.8	15.3%
		1740	2174	28.8	91.2	14.7	16.1%
		2175	2624	35.3	114.7	18.0	15.7%
		2625	2999	41.3	133.7	21.1	15.8%
		3000	4500	55.1	144.9	28.2	19.5%
	***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	400	449	6.2	33.8	3.2	9.5%
		450	499	7.0	38.0	3.6	9.4%
		500	649	8.5	41.5	4.3	10.4%
		650	1199	13.6	51.4	7.0	13.5%
	***ER30, BR30, BR40, or ER40**	400	449	6.2	33.8	3.2	9.5%
		450	499	7.0	38.0	3.6	9.4%
		500	649	8.5	41.5	4.3	10.4%
	***BR30, BR40, or ER40**	650	1419	15.2	49.8	7.8	15.6%
	***R20**	400	449	6.2	33.8	3.2	9.5%
		450	719	8.6	36.4	4.4	12.1%
	***All reflector lamps below lumen ranges specified above**	200	299	3.7	16.3	1.9	11.5%
		300	399	5.1	24.9	2.6	10.6%
EISA Non-Exempt	**Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA >**	310	749	6.7	22.3	5.0	22.6%
		750	1049	11.4	31.6	8.6	27.1%
		1050	1489	16.1	36.9	12.1	32.8%
		1490	2600	26.0	46.0	19.5	42.3%

	Bulb Type	Lower Lumen Range	Upper Lumen Range	LED Wattage ($Watts_{EE}$)	Delta Watts 2014-2023 (WattsEE)	Delta Watts From 1/1/2024 (WattsEE)	Mid Life adjustment (made from 1/1/2024) to first year savings
	749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)						

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{730} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

> For example, For example, a 9W LED lamp, 450 lumens, is installed in a heat pump heated office in 2014 and sign off form provided:
>
> $\Delta kWh_{heatpenalty}$ = ((29-6.7)/1000)*1.0*3088* -0.151
>
> = - 10.4 kWh

DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

[730] Negative value because this is an increase in heating consumption due to the efficient lighting.

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔkW = ((29-6.7)/1000)* 1.0*1.3*0.66

= 0.019 kW

NATURAL GAS ENERGY SAVINGS

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

ΔTherms = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔTherms = ((29-6.7)/1000)*1.0*3088* -0.016

= - 1.10 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For fixture measures, the individual component lifetimes and costs are provided in the reference table section below[731].

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb (assumed to be 15,000/3,612 =4.2 years for commercial and 15,000/5,950 = 2.5 years for multi-family common area installations) is calculated[732]. The key assumptions used in this calculation are documented below[733]:

Lamp Type	Installation Year	Standard Incandescent	EISA Compliant Halogen	CFL
Omnidirectional	2019	$0.43	$1.25	N/A
	2020	$0.43	$1.25	N/A
	2021 & after	$0.43	N/A	$2.45
Decorative	2019	$1.74	N/A	N/A

[731] See IL LED Lighting Systems TRM Reference Tables_2018.xlsx for breakdown of component cost assumptions.
[732] See C&I LED O&M Calc_2018_SpecAdj2024.xlsx" for more information. The commercial values assume the non-residential average hours assumption of 3,612.
[733] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

Lamp Type	Installation Year	Standard Incandescent	EISA Compliant Halogen	CFL
	2020	$1.74	N/A	N/A
	2021 & after	$1.74	N/A	$2.50
Directional	2019	$3.53	N/A	N/A
	2020	$3.53	N/A	N/A
	2021 & after	$3.53	N/A	$4.50

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

Omnidirectional Lamps

Location	Lumen Level	NPV of replacement costs for period			Levelized annual replacement cost savings		
		2019	2020	2021	2019	2020	2021
Commercial	Lumens <310 or >3300 (EISA exempt)	$6.02	$6.02	$6.02	$1.47	$1.47	$1.47
	Lumens ≥ 310 and ≤ 23300 (EISA compliant)	$9.64	$6.04	$1.23	$2.35	$1.47	$0.30
Multi Family Common Areas	Lumens <310 or >3300 (non-EISA compliant)	$5.92	$5.92	$5.92	$2.37	$2.37	$2.37
	Lumens ≥ 310 and ≤ 3300 (EISA compliant)	$14.25	$8.32	$1.18	$5.70	$3.33	$0.47

Decorative Lamps

Location	NPV of replacement costs for period			Levelized annual replacement cost savings		
	2019	2020	2021	2019	2020	2021
Commercial	$24.35	$23.30	$18.01	$5.93	$5.68	$4.39
Multi Family Common Areas	$23.94	$23.94	$23.94	$9.57	$9.57	$9.57

Directional Lamps

Location	NPV of replacement costs for period			Levelized annual replacement cost savings		
	2019	2020	2021	2019	2020	2021
Commercial	$49.40	$47.22	$36.30	$12.04	$11.51	$8.85
Multi Family Common Areas	$48.56	$48.56	$48.56	$19.42	$19.42	$19.42

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[734] The replacement cycle is based on the miscellaneous hours of use. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement and CFLs after 10,000 hours.

REFERENCE TABLES

LED Bulb Assumptions

Wherever possible, actual incremental costs should be used. If unavailable assume the following incremental costs[735]:

Bulb Type	Year	LED	Incandescent	Incremental Cost
Omnidirectional	2017	$3.21	$1.25	$1.96
	2018	$3.21		$1.96
	2019	$3.11		$1.86
Directional	2017	$6.24	$3.53	$2.71
	2018-2019	$5.18		$1.65
Decorative and Globe	2017	$3.50	$1.60	$1.90
	2018-2019	$3.40	$1.74	$1.66

LED Fixture Wattage and Incremental Cost Assumptions[736]

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BAE}$	Incremental Cost	T12 Mid Life Savings Adjustment (1/1/2020)
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	Baseline LED Recessed, Surface, Pendant Downlights	54.3	$27	N/A
LED Interior Directional	LED Track Lighting	12.2	Baseline LED Track Lighting	60.4	$59	N/A
	LED Wall-Wash Fixtures	8.3	Baseline LED Wall-Wash Fixtures	17.7	$59	N/A
LED Display Case	LED Display Case Light Fixture	7.1 per ft	Baseline LED Display Case Light Fixture	36.2 per ft	$11/ft	N/A
	LED Undercabinet Shelf-Mounted Task Light Fixtures	7.1 per ft	Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures	36.2 per ft	$11/ft	N/A
	LED Refrigerated Case Light, Horizontal or Vertical	7.6 per ft	Baseline LED Refrigerated Case Light,	15.2 per ft	$11/ft	N/A

[734] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.
[735] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.Given LED prices are expected to continue declining assumed costs should be reassessed on an annual basis and replaced with IL specific LED program information when available.
[736] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Table A.1. See "LED Lighting Systems TRM Reference Tables_2018.xlsx" for more information and specific product links.

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BAE}$	Incremental Cost	T12 Mid Life Savings Adjustment (1/1/2020)
			Horizontal or Vertical (per foot)			
	LED Freezer Case Light, Horizontal or Vertical	7.7 per ft	Baseline LED Freezer Case Light, Horizontal or Vertical (per foot)	18.7 per ft	$11/ft	N/A
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	8.9	F17T8 Standard Lamp - 2 foot	15.0	$13	N/A
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	15.8	F32T8 Standard Lamp - 4 foot	28.2	$15	N/A
	T8 LED Replacement Lamp (TLED), > 2400 lumens	22.9	F32T8/HO Standard Lamp - 4 foot	41.8	$13	N/A
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	25.4	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$53	97%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	36.7	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$69	92%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	33.3	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$55	96%
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	44.8	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$76	90%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	57.2	18:82;4-Lamp 34w T12 (BF < 0.88): 4-Lamp 32w T8 (BF < 0.88)	118.3	$104	91%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	21.8	18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91)	29.5	$22	96%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	33.7	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$75	96%
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	43.3	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$83	91%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	19.5	18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91)	29.5	$10	97%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	32.1	18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	57.9	$52	96%

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BAE}$	Incremental Cost	T12 Mid Life Savings Adjustment (1/1/2020)
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	43.5	18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	88.7	$78	91%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	56.3	T5HO 2L-F54T5HO - 4'	120.0	$131	N/A
	LED Surface & Suspended Linear Fixture, > 7500 lumens	82.8	T5HO 3L-F54T5HO - 4'	180.0	$173	N/A
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	61.6	3-Lamp T8HO Low-Bay	157.0	$44	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	99.5	4-Lamp T8HO High-Bay	196.0	$137	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	140.2	6-Lamp T8HO High-Bay	294.0	$202	N/A
	LED High-Bay Fixtures, > 20,000 lumens	193.8	8-Lamp T8HO High-Bay	392.0	$264	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	12.9	25% 73 Watt EISA Inc, 75% 1L T8	42.0	$18	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	29.7	25% 146 Watt EISA Inc, 75% 2L T8	81.0	$48	N/A
	LED Ag Interior Fixtures, 4,001-6,000 lumens	45.1	25% 217 Watt EISA Inc, 75% 3L T8	121.0	$57	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	59.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	$88	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	84.9	200W Pulse Start Metal Halide	227.3	$168	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	113.9	320W Pulse Start Metal Halide	363.6	$151	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	143.7	350W Pulse Start Metal Halide	397.7	$205	N/A
	LED Ag Interior Fixtures, > 20,000 lumens	193.8	(2) 320W Pulse Start Metal Halide	727.3	$356	N/A
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	34.1	100W Metal Halide	113.6	$80	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	67.2	175W Pulse Start Metal Halide	198.9	$248	N/A

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BAE}$	Incremental Cost	T12 Mid Life Savings Adjustment (1/1/2020)
	LED Exterior Fixtures, 10,001-15,000 lumens	108.8	250W Pulse Start Metal Halide	284.1	$566	N/A
	LED Exterior Fixtures, > 15,000 lumens	183.9	400W Pulse Start Metal Halide	454.5	$946	N/A

LED Fixture Component Costs & Lifetime[737]

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	50,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Interior Directional	LED Track Lighting	50,000	$39.00	70,000	$47.50	2,500	$12.71	40,000	$11.00
	LED Wall-Wash Fixtures	50,000	$39.00	70,000	$47.50	2,500	$9.17	40,000	$27.00
LED Display Case	LED Display Case Light Fixture	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	50,000	$8.63/ft	70,000	$9.50/ft	15,000	$1.13	40,000	$8.00
	LED Freezer Case Light, Horizontal or Vertical	50,000	$7.88/ft	70,000	$7.92/ft	12,000	$0.94	40,000	$6.67
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	50,000	$5.76	70,000	$13.67	30,000	$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), > 2400 lumens	50,000	$8.57	70,000	$13.67	18,000	$6.17	40,000	$11.96

[737] Note that some measures have blended baselines (T12:T8 18:82). All values are provided to enable calculation of appropriate O&M impacts. Total costs include lamp, labor and disposal cost assumptions where applicable, see IL LED Lighting Systems TRM Reference Tables_2018.xlsx for more information.

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$78.07	70,000	$40.00	24,000	$26.33	40,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$89.23	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$96.10	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$114.37	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$137.43	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$65.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$100.44	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$108.28	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	50,000	$62.21	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$93.22	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$114.06	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$152.32	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	50,000	$183.78	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	50,000	$90.03	70,000	$62.50	18,000	$64.50	40,000	$92.50

		EE Measure				Baseline			
LED Category	EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	LED Driver Life (hrs)	Total LED Driver Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$122.59	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	50,000	$157.22	70,000	$62.50	18,000	$129.00	40,000	$117.50
	LED High-Bay Fixtures, > 20,000 lumens	50,000	$228.52	70,000	$62.50	18,000	$172.00	40,000	$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	50,000	$41.20	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$65.97	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$80.08	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$105.54	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$179.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$190.86	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$237.71	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$331.73	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	50,000	$73.80	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$124.89	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	$214.95	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Exterior Fixtures, > 15,000 lumens	50,000	$321.06	70,000	$62.50	15,000	$73.00	40,000	$132.50

MEASURE CODE: CI-LTG-LEDB-V08-190101

REVIEW DEADLINE: 1/1/2022

4.5.5 Commercial LED Exit Signs

DESCRIPTION

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Commercial building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

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 is assumed to be an exit sign illuminated by LEDs.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years[738].

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[739]

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100%[740].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

Baseline Type	$Watts_{Base}$
Incandescent	35W[741]

[738] Estimate of remaining life of existing unit being replaced.
[739] Price includes new exit sign/fixture and installation. LED exit cost cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming IL labor cost of 15 minutes @ $40/hr.
[740] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
[741] Based on review of available product.

Baseline Type	$Watts_{Base}$
CFL (dual sided)	14W[742]
CFL (single sided)	7W
Unknown	7W

WattsEE = Actual wattage if known, if unknown assume 2W for signle sided or unknown type and 4W for dual sided[743]

HOURS = Annual operating hours

= 8766

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔkWH = (35 – 2)/1000 * 8766 * 1.25

= 362 kWh

For example, replacing single sided fluorescent fixture in a hospital

ΔkWH = (7– 2)/1000 * 8766 * 1.35

= 59.2 kWh

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[744] = (((WattsBase-WattsEE)/1000) * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in a heat pump heated office

$\Delta kWh_{heatpenalty}$ = (35 – 2)/1000 * 8766 * -0.151

= -43.7 kWh

For example, replacing single sided fluorescent fixture in a heat pump heated hospital

$\Delta kWh_{heatpenalty}$ = (7 – 2)/1000 * 8766 * -0.104

= -4.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF

742 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.
743 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.
744 Negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure

= 1.0

> For example, replacing incandescent fixture in an office
>
> ΔkW = (35 – 2)/1000 * 1.3 * 1.0
>
> = 0.043 kW
>
> For example, replacing single sided fluorescent fixture in a hospital
>
> ΔkW = (7 – 2)/1000 * 1.69 * 1.0
>
> = 0.0085 kW

NATURAL GAS SAVINGS

Heating Penalty if natural gas heated building (or if heating fuel is unknown):

Δtherms = (((WattsBase-WattsEE)/1000) * 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 Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

> For example, replacing incandescent fixture in an office
>
> ΔTherms = (35 – 2)/1000 * 8766 * -0.016
>
> = -4.63 Therms
>
> For example, replacing single sided fluorescent fixture in a hospital
>
> ΔTherms = (7 – 2)/1000 * 8766 * -0.011
>
> = - 0.48 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

	Baseline Measures	
Component	Cost	Life (yrs)
Lamp	$12.45[745]	1.37 years[746]

[745] Consistent with assumption for a Standard CFL bulb ($2.45) with an estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes).

[746] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

MEASURE CODE: CI-LTG-LEDE-V03-190101

REVIEW DEADLINE: 1/1/2024

4.5.6 LED Traffic and Pedestrian Signals

DESCRIPTION

Traffic and pedestrian signals are retrofitted to be illuminated with light emitting diodes (LED) instead of incandescent lamps. Incentive applies for the replacement or retrofit of existing incandescent traffic signals with new LED traffic and pedestrian signal lamps. Each lamp can have no more than a maximum LED module wattage of 25. Incentives are not available for spare lights. Lights must be hardwired and single lamp replacements are not eligible, with the exception of pedestrian hand signals. Eligible lamps must meet the Energy Star Traffic Signal Specification and the Institute for Transportation Engineers specification for traffic signals.

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

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for efficient technology wattage and savings assumptions.

DEFINITION OF BASELINE EQUIPMENT

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for baseline efficiencies and savings assumptions.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of an LED traffic signal is 100,000 hours (manufacturer's estimate), capped at 10 years.[747] The life in years is calculated by dividing 100,000 hrs by the annual operating hours for the particular signal type.

DEEMED MEASURE COST

The actual measure installation cost should be used (including material and labor).

LOADSHAPE

Loadshape C24 - Traffic Signal - Red Balls, always changing or flashing
Loadshape C25 - Traffic Signal - Red Balls, changing day, off night
Loadshape C26 - Traffic Signal - Green Balls, always changing
Loadshape C27 - Traffic Signal - Green Balls, changing day, off night
Loadshape C28 - Traffic Signal - Red Arrows
Loadshape C29 - Traffic Signal - Green Arrows
Loadshape C30 - Traffic Signal - Flashing Yellows
Loadshape C31 - Traffic Signal - "Hand" Don't Walk Signal
Loadshape C32 - Traffic Signal - "Man" Walk Signal
Loadshape C33 - Traffic Signal - Bi-Modal Walk/Don't Walk

COINCIDENCE FACTOR[748]

The summer peak coincidence factor (CF) for this measure is dependent on lamp type as below:

Lamp Type	CF
Red Round, always changing or flashing	0.55
Red Arrows	0.90

[747] ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals
[748] Ibid

Lamp Type	CF
Green Arrows	0.10
Yellow Arrows	0.03
Green Round, always changing or flashing	0.43
Flashing Yellow	0.50
Yellow Round, always changing	0.02
“Hand” Don’t Walk Signal	0.75
“Man” Walk Signal	0.21

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (W_{base} - W_{eff}) \times HOURS / 1000$

Where:

Wbase =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

Weff =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

EFLH = annual operating hours of the lamp

= see Table ‘Traffic Signals Technology Equivalencies’

1000 = conversion factor (W/kW)

EXAMPLE

For example, an 8 inch red, round signal:

$\Delta kWh = ((69 - 7) \times 4818) / 1000$

$= 299$ kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (Wbase – Weff) \times CF / 1000$

Where:

Wbase =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

Weff =The connected load of the efficient equipment

= see Table ‘Traffic Signals Technology Equivalencies’

CF = Summer Peak Coincidence Factor for measure

EXAMPLE

For example, an 8 inch red, round signal:

$\Delta kW = ((69 – 7) \times 0.55) / 1000$

$= 0.0341$ kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

REFERENCE TABLES

Traffic Signals Technology Equivalencies[749]

Traffic Fixture Type	Fixture Size and Color	Efficient Lamps	Baseline Lamps	HOURS	Efficient Fixture Wattage	Baseline Fixture Wattage	Energy Savings (in kWh)
Round Signals	8” Red	LED	Incandescent	4818	7	69	299
Round Signals	12” Red	LED	Incandescent	4818	6	150	694
Flashing Signal[750]	8” Red	LED	Incandescent	4380	7	69	272
Flashing Signal	12” Red	LED	Incandescent	4380	6	150	631
Flashing Signal	8” Yellow	LED	Incandescent	4380	10	69	258
Flashing Signal	12” Yellow	LED	Incandescent	4380	13	150	600
Round Signals	8” Yellow	LED	Incandescent	175	10	69	10
Round Signals	12” Yellow	LED	Incandescent	175	13	150	24
Round Signals	8” Green	LED	Incandescent	3767	9	69	266
Round Signals	12” Green	LED	Incandescent	3767	12	150	520
Turn Arrows	8” Yellow	LED	Incandescent	701	7	116	76
Turn Arrows	12” Yellow	LED	Incandescent	701	9	116	75
Turn Arrows	8” Green	LED	Incandescent	701	7	116	76
Turn Arrows	12” Green	LED	Incandescent	701	7	116	76
Pedestrian Sign	12” Hand/Man	LED	Incandescent	8766	8	116	946

Reference specifications for above traffic signal wattages are from the following manufacturers:

1. 8” Incandescent traffic signal bulb: General Electric Traffic Signal Model 17325-69A21/TS
2. 12” Incandescent traffic signal bulb: General Electric Signal Model 35327-150PAR46/TS
3. Incandescent Arrows & Hand/Man Pedestrian Signs: General Electric Traffic Signal Model 19010-116A21/TS
4. 8” and 12” LED traffic signals: Leotek Models TSL-ES08 and TSL-ES12
5. 8” LED Yellow Arrow: General Electric Model DR4-YTA2-01A
6. 8” LED Green Arrow: General Electric Model DR4-GCA2-01A
7. 12” LED Yellow Arrow: Dialight Model 431-3334-001X
8. 12: LED Green Arrow: Dialight Model 432-2324-001X
9. LED Hand/Man Pedestrian Sign: Dialight 430-6450-001X

MEASURE CODE: CI-LTG-LEDT-V01-120601

REVIEW DEADLINE: 1/1/2019

[749] Technical Reference Manual for Pennsylvania Act 129 Energy Efficiency and Conservation Program and Act 213 Alternative Energy Portfolio Standards. Pennsylvania Public Utility Commission. May 2009
[750] Technical Reference Manual for Ohio, August 6, 2010

4.5.7 Lighting Power Density

Description

This measure relates to installation of efficient lighting systems in new construction or substantial renovation of commercial buildings excluding low rise (three stories or less) residential buildings. Substantial renovation is when two or more building systems are renovated, such as shell and heating, heating and lighting, etc. State Energy Code specifies a lighting power density level by building type for both the interior and the exterior. Either the Building Area Method or Space by Space method as defined in IECC 2012, 2015 or 2018, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015), can be used for calculating the Interior Lighting Power Density[751]. The measure consists of a design that is more efficient (has a lower lighting power density in watts/square foot) than code requires. The IECC applies to both new construction and renovation.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the lighting system must be more efficient than the baseline Energy Code lighting power density in watts/square foot for either the interior space or exterior space.

Definition of Baseline Equipment

The baseline is assumed to be a lighting power density that meets IECC 2012 or 2015, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

Deemed Calculation for this Measure

Annual kWh Savings

$$\Delta kWh = (WSFbase - WSFeffic)/1000 * SF * Hours * WHF_e$$

Summer Coincident Peak kW Savings

$$\Delta kW = (WSFbase - WSFeffic)/1000 * SF * CF * WHF_d$$

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[752]

Deemed Measure Cost

The actual incremental cost over a baseline system will be collected from the customer if possible or developed on a fixture by fixture basis.

Loadshape

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

---

751 Refer to the referenced code documents for specifics on calculating lighting power density using either the whole building method (IECC) or the Space by Space method (current ASHRAE 90.1).

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

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the building type.

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

$$\Delta kWh = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * WHF_e$$

Where:

WSF_{base} = Baseline lighting watts per square foot or linear foot as determined by building or space type. Whole building analysis values are presented in the Reference Tables below.[753]

WSF_{effic} = The actual installed lighting watts per square foot or linear foot.

SF = Provided by customer based on square footage of the building area applicable to the lighting design for new building.

Hours = Annual site-specific hours of operation of the lighting equipment collected from the customer. If not available, use building area type as provided in the Reference Table in Section 4.5, Fixture annual operating hours.

WHF_e = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 4.5 by buidling type. If building is not cooled WHF_e is 1.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{754} = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * -IFkWh$$

Where:

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

[753] See IECC 2012 and 2015 - Reference Code documentation for additional information.

[754] Negative value because this is an increase in heating consumption due to the efficient lighting.

by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (WSF_{base}-WSF_{effic})/1000 * SF * CF * WHF_d$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is as provided in the Reference Table in Section 4.5 by buidling type. If building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is as provided in the Reference Table in Section 4.5 by buidling type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = (WSF_{base}-WSF_{effic})/1000 * SF * Hours * - IFTherms$$

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. This value is provided in the Reference Table in Section 4.5 by buidling type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES

Lighting Power Density Values from IECC 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

Building Area Type [755]	IECC 2012 Lighting Power Density (w/ft^2)	IECC 2015 Lighting Power Density (w/ft^2)
Automotive Facility	0.9	0.80
Convention Center	1.2	1.01
Court House	1.2	1.01
Dining: Bar Lounge/Leisure	1.3	1.01
Dining: Cafeteria/Fast Food	1.4	0.9
Dining: Family	1.6	0.95
Dormitory	1.0	0.57
Exercise Center	1.0	0.84
Fire station	0.8	0.67
Gymnasium	1.1	0.94

[755] In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.

Building Area Type [755]	IECC 2012 Lighting Power Density (w/ft^2)	IECC 2015 Lighting Power Density (w/ft^2)
Healthcare – clinic	1.0	0.90
Hospital	1.2	1.05
Hotel	1.0	0.87
Library	1.3	1.19
Manufacturing Facility	1.3	1.17
Motel	1.0	0.87
Motion Picture Theater	1.2	0.76
Multifamily	0.7	0.51
Museum	1.1	1.02
Office	0.9	0.82
Parking Garage	0.3	0.21
Penitentiary	1.0	0.81
Performing Arts Theater	1.6	1.39
Police Station	1.0	0.87
Post Office	1.1	0.87
Religious Building	1.3	1.0
Retail[756]	1.4	1.26
School/University	1.2	0.87
Sports Arena	1.1	0.91
Town Hall	1.1	0.89
Transportation	1.0	0.70
Warehouse	0.6	0.66
Workshop	1.4	1.19

[756] Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the small of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.

Lighting Power Density Values from IECC 2018 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

TABLE C405.3.2(1)
INTERIOR LIGHTING POWER ALLOWANCES: BUILDING AREA METHOD

BUILDING AREA TYPE	LPD (w/ft^2)
Automotive facility	0.71
Convention center	0.76
Courthouse	0.90
Dining: bar lounge/leisure	0.90
Dining: cafeteria/fast food	0.79
Dining: family	0.78
Dormitory[a, b]	0.61
Exercise center	0.65
Fire station[a]	0.53
Gymnasium	0.68
Health care clinic	0.82
Hospital[a]	1.05
Hotel/Motel[a, b]	0.75
Library	0.78
Manufacturing facility	0.90
Motion picture theater	0.83
Multifamily[c]	0.68
Museum	1.06
Office	0.79
Parking garage	0.15
Penitentiary	0.75
Performing arts theater	1.18
Police station	0.80
Post office	0.67
Religious building	0.94
Retail	1.06
School/university	0.81
Sports arena	0.87
Town hall	0.80
Transportation	0.61
Warehouse	0.48
Workshop	0.90

a. Where sleeping units are excluded from lighting power calculations by application of Section R405.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

b. Where dwelling units are excluded from lighting power calculations by application of Section R405.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

c. Dwelling units are excluded. Neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

TABLE C405.5.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft²)
Atrium – First 40 feet in height	0.03 per ft. ht.
Atrium – Above 40 feet in height	0.02 per ft. ht.
Audience/seating area – permanent	
For auditorium	0.9
For performing arts theater	2.6
For motion picture theater	1.2
Classroom/lecture/training	1.30
Conference/meeting/multipurpose	1.2
Corridor/transition	0.7
Dining area	
Bar/lounge/leisure dining	1.40
Family dining area	1.40
Dressing/fitting room performing arts theater	1.1
Electrical/mechanical	1.10
Food preparation	1.20
Laboratory for classrooms	1.3
Laboratory for medical/industrial/research	1.8
Lobby	1.10
Lobby for performing arts theater	3.3
Lobby for motion picture theater	1.0
Locker room	0.80
Lounge recreation	0.8
Office – enclosed	1.1
Office – open plan	1.0
Restroom	1.0
Sales area	1.6[a]
Stairway	0.70
Storage	0.8
Workshop	1.60
Courthouse/police station/penetentiary	
Courtroom	1.90
Confinement cells	1.1
Judge chambers	1.30
Penitentiary audience seating	0.5
Penitentiary classroom	1.3
Penitentiary dining	1.1
BUILDING SPECIFIC SPACE-BY-SPACE TYPES	
Automotive – service/repair	0.70
Bank/office – banking activity area	1.5
Dormitory living quarters	1.10
Gymnasium/fitness center	
Fitness area	0.9
Gymnasium audience/seating	0.40
Playing area	1.40

(continued)

TABLE C405.5.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft²)
Healthcare clinic/hospital	
Corridors/transition	1.00
Exam/treatment	1.70
Emergency	2.70
Public and staff lounge	0.80
Medical supplies	1.40
Nursery	0.9
Nurse station	1.00
Physical therapy	0.90
Patient room	0.70
Pharmacy	1.20
Radiology/imaging	1.3
Operating room	2.20
Recovery	1.2
Lounge/recreation	0.8
Laundry – washing	0.60
Hotel	
Dining area	1.30
Guest rooms	1.10
Hotel lobby	2.10
Highway lodging dining	1.20
Highway lodging guest rooms	1.10
Library	
Stacks	1.70
Card file and cataloguing	1.10
Reading area	1.20
Manufacturing	
Corridors/transition	0.40
Detailed manufacturing	1.3
Equipment room	1.0
Extra high bay (> 50-foot floor-ceiling height)	1.1
High bay (25- – 50-foot floor-ceiling height)	1.20
Low bay (< 25-foot floor-ceiling height)	1.2
Museum	
General exhibition	1.00
Restoration	1.70
Parking garage – garage areas	0.2
Convention center	
Exhibit space	1.50
Audience/seating area	0.90
Fire stations	
Engine room	0.80
Sleeping quarters	0.30
Post office	
Sorting area	0.9
Religious building	
Fellowship hall	0.60
Audience seating	2.40
Worship pulpit/choir	2.40
Retail	
Dressing/fitting area	0.9
Mall concourse	1.6
Sales area	1.6[a]

(continued)

TABLE C405.5.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

BUILDING SPECIFIC SPACE-BY-SPACE TYPES	LPD (w/ft²)
Sports arena	
Audience seating	0.4
Court sports area – Class 4	0.7
Court sports area – Class 3	1.2
Court sports area – Class 2	1.9
Court sports area – Class 1	3.0
Ring sports area	2.7
Transportation	
Air/train/bus baggage area	1.00
Airport concourse	0.60
Terminal – ticket counter	1.50
Warehouse	
Fine material storage	1.40
Medium/bulky material	0.60

Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

COMMON SPACE TYPES[a]	LPD (watts/sq.ft)
Atrium	
Less than 40 feet in height	0.03 per foot in total height
Greater than 40 feet in height	0.40 + 0.02 per foot in total height
Audience seating area	
In an auditorium	0.63
In a convention center	0.82
In a gymnasium	0.65
In a motion picture theater	1.14
In a penitentiary	0.28
In a performing arts theater	2.43
In a religious building	1.53
In a sports arena	0.43
Otherwise	0.43
Banking activity area	1.01
Breakroom (See Lounge/Breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	1.34
Otherwise	1.24
Conference/meeting/multipurpose room	1.23
Copy/print room	0.72
Corridor	
In a facility for the visually impaired (and not used primarily by the staff)[b]	0.92
In a hospital	0.79
In a manufacturing facility	0.41
Otherwise	0.66
Courtroom	1.72
Computer room	1.71
Dining area	
In a penitentiary	0.96
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.9
In bar/lounge or leisure dining	1.07
In cafeteria or fast food dining	0.65
In family dining	0.89
Otherwise	0.65
Electrical/mechanical room	0.95
Emergency vehicle garage	0.56

(continued)

TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

COMMON SPACE TYPES[a]	LPD (watts/sq.ft)
Food preparation area	1.21
Guest room	0.47
Laboratory	
In or as a classroom	1.43
Otherwise	1.81
Laundry/washing area	0.6
Loading dock, interior	0.47
Lobby	
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.8
For an elevator	0.64
In a hotel	1.06
In a motion picture theater	0.59
In a performing arts theater	2.0
Otherwise	0.9
Locker room	0.75
Lounge/breakroom	
In a healthcare facility	0.92
Otherwise	0.73
Office	
Enclosed	1.11
Open plan	0.98
Parking area, interior	0.19
Pharmacy area	1.68
Restroom	
In a facility for the visually impaired (and not used primarily by the staff[b]	1.21
Otherwise	0.98
Sales area	1.59
Seating area, general	0.54
Stairway (See space containing stairway)	
Stairwell	0.69
Storage room	0.63
Vehicular maintenance area	0.67
Workshop	1.59
BUILDING TYPE SPECIFIC SPACE TYPES[a]	**LPD (watts/sq.ft)**
Facility for the visually impaired[b]	
In a chapel (and not used primarily by the staff)	2.21
In a recreation room (and not used primarily by the staff)	2.41
Automotive (See Vehicular Maintenance Area above)	
Convention Center—exhibit space	1.45
Dormitory—living quarters	0.38
Fire Station—sleeping quarters	0.22
Gymnasium/fitness center	
In an exercise area	0.72
In a playing area	1.2

(continued)

TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

BUILDING TYPE SPECIFIC SPACE TYPES[a]	LPD (watts/sq.ft)
healthcare facility	
In an exam/treatment room	1.66
In an imaging room	1.51
In a medical supply room	0.74
In a nursery	0.88
In a nurse's station	0.71
In an operating room	2.48
In a patient room	0.62
In a physical therapy room	0.91
In a recovery room	1.15
Library	
In a reading area	1.06
In the stacks	1.71
Manufacturing facility	
In a detailed manufacturing area	1.29
In an equipment room	0.74
In an extra high bay area (greater than 50′ floor-to-ceiling height)	1.05
In a high bay area (25-50′ floor-to-ceiling height)	1.23
In a low bay area (less than 25′ floor-to-ceiling height)	1.19
Museum	
In a general exhibition area	1.05
In a restoration room	1.02
Performing arts theater—dressing room	0.61
Post Office—Sorting Area	0.94
Religious buildings	
In a fellowship hall	0.64
In a worship/pulpit/choir area	1.53
Retail facilities	
In a dressing/fitting room	0.71
In a mall concourse	1.1
Sports arena—playing area	
For a Class I facility	3.68
For a Class II facility	2.4
For a Class III facility	1.8
For a Class IV facility	1.2
Transportation facility	
In a baggage/carousel area	0.53
In an airport concourse	0.36
At a terminal ticket counter	0.8
Warehouse—storage area	
For medium to bulky, palletized items	0.58
For smaller, hand-carried items	0.95

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

Lighting Power Density Values from IECC 2018 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

TABLE C405.3.2(2)
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

COMMON SPACE TYPES[a]	LPD (watts/sq.ft)
Atrium	
Less than 40 feet in height	0.03 per foot in total height
Greater than 40 feet in height	0.40 + 0.02 per foot in total height
Audience seating area	
In an auditorium	0.63
In a convention center	0.82
In a gymnasium	0.65
In a motion picture theater	1.14
In a penitentiary	0.28
In a performing arts theater	2.03
In a religious building	1.53
In a sports arena	0.43
Otherwise	0.43
Banking activity area	0.86
Breakroom (See Lounge/breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	1.34
Otherwise	0.96
Computer room	1.33
Conference/meeting/multipurpose room	1.07
Copy/print room	0.56
Corridor	
In a facility for the visually impaired (and not used primarily by the staff)[b]	0.92
In a hospital	0.92
In a manufacturing facility	0.29
Otherwise	0.66
Courtroom	1.39
Dining area	
In bar/lounge or leisure dining	0.93
In cafeteria or fast food dining	0.63
In a facility for the visually impaired (and not used primarily by the staff)[b]	2.00
In family dining	0.71
In a penitentiary	0.96
Otherwise	0.63
Electrical/mechanical room	0.43
Emergency vehicle garage	0.41
Food preparation area	1.06
Guestroom[c, d]	0.77
Laboratory	
In or as a classroom	1.20
Otherwise	1.45

Laundry/washing area	0.43
Loading dock, interior	0.58
Lobby	
For an elevator	0.68
In a facility for the visually impaired (and not used primarily by the staff)[b]	2.03
In a hotel	1.06
In a motion picture theater	0.45
In a performing arts theater	1.70
Otherwise	1.0
Locker room	0.48
Lounge/breakroom	
In a healthcare facility	0.78
Otherwise	0.62
Office	
Enclosed	0.93
Open plan	0.81
Parking area, interior	0.14
Pharmacy area	1.34
Restroom	
In a facility for the visually impaired (and not used primarily by the staff[b]	0.96
Otherwise	0.85
Sales area	1.22
Seating area, general	0.42
Stairway (see Space containing stairway)	
Stairwell	0.58
Storage room	0.46
Vehicular maintenance area	0.56
Workshop	1.14

BUILDING TYPE SPECIFIC SPACE TYPES[a]	LPD (watts/sq.ft)
Automotive (see Vehicular maintenance area)	
Convention Center—exhibit space	0.88
Dormitory—living quarters[c, d]	0.54
Facility for the visually impaired[b]	
In a chapel (and not used primarily by the staff)	1.06
In a recreation room (and not used primarily by the staff)	1.80
Fire Station—sleeping quarters[c]	0.20
Gymnasium/fitness center	
In an exercise area	0.50
In a playing area	0.82
Healthcare facility	
In an exam/treatment room	1.68
In an imaging room	1.06
In a medical supply room	0.54
In a nursery	1.00
In a nurse's station	0.81
In an operating room	2.17
In a patient room[c]	0.62
In a physical therapy room	0.84
In a recovery room	1.03
Library	
In a reading area	0.82
In the stacks	1.20
Manufacturing facility	
In a detailed manufacturing area	0.93
In an equipment room	0.65
In an extra-high-bay area (greater than 50' floor-to-ceiling height)	1.05
In a high-bay area (25-50' floor-to-ceiling height)	0.75
In a low-bay area (less than 25' floor-to-ceiling height)	0.96
Museum	
In a general exhibition area	1.05
In a restoration room	0.85
Performing arts theater—dressing room	0.36
Post office—sorting area	0.68
Religious buildings	
In a fellowship hall	0.55
In a worship/pulpit/choir area	1.53

Retail facilities	
In a dressing/fitting room	0.50
In a mall concourse	0.90
Sports arena—playing area	
For a Class I facility[e]	2.47
For a Class II facility[f]	1.96
For a Class III facility[g]	1.70
For a Class IV facility[h]	1.13
Transportation facility	
In a baggage/carousel area	0.45
In an airport concourse	0.31
At a terminal ticket counter	0.62
Warehouse—storage area	
For medium to bulky, palletized items	0.35
For smaller, hand-carried items	0.69

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

c. Where sleeping units are excluded from lighting power calculations by application of Section R405.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

d. Where dwelling units are excluded from lighting power calculations by application of Section R405.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

e. Class I facilities consist of professional facilities; and semiprofessional, collegiate, or club facilities with seating for 5,000 or more spectators.

f. Class II facilities consist of collegiate and semiprofessional facilities with seating for fewer than 5,000 spectators; club facilities with seating for between 2,000 and 5,000 spectators; and amateur league and high-school facilities with seating for more than 2,000 spectators.

g. Class III facilities consist of club, amateur league and high-school facilities with seating for 2,000 or fewer spectators.

h. Class IV facilities consist of elementary school and recreational facilities; and amateur league and high-school facilities without provision for spectators.

The exterior lighting design will be based on the building location and the applicable "Lighting Zone" as defined in IECC 2015 Table C405.5.2(1) which follows. This table is identical to IECC 2012 Table C405.62(1) and IECC 2018 Table C405.4.2(1).

TABLE C405.5.2(1)
EXTERIOR LIGHTING ZONES

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas
3	All other areas not classified as lighting zone 1, 2 or 4
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

The lighting power density savings will be based on reductions below the allowable design levels as specified in IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).

Allowable Design Levels from IECC 2012

TABLE C405.6.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

		LIGHTING ZONES			
		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.)	Uncovered Parking Areas				
	Parking areas and drives	0.04 W/ft²	0.06 W/ft²	0.10 W/ft²	0.13 W/ft²
	Building Grounds				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.14 W/ft²	0.14 W/ft²	0.16 W/ft²	0.2 W/ft²
	Stairways	0.75 W/ft²	1.0 W/ft²	1.0 W/ft²	1.0 W/ft²
	Pedestrian tunnels	0.15 W/ft²	0.15 W/ft²	0.2 W/ft²	0.3 W/ft²
	Building Entrances and Exits				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft²	0.25 W/ft²	0.4 W/ft²	0.4 W/ft²
	Sales Canopies				
	Free-standing and attached	0.6 W/ft²	0.6 W/ft²	0.8 W/ft²	1.0 W/ft²
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.25 W/ft²	0.25 W/ft²	0.5 W/ft²	0.7 W/ft²
	Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)	Building facades	No allowance	0.1 W/ft² for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length	0.15 W/ft² for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length	0.2 W/ft² for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
	Automated teller machines and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft² of covered and uncovered area	0.75 W/ft² of covered and uncovered area	0.75 W/ft² of covered and uncovered area	0.75 W/ft² of covered and uncovered area
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft² of covered and uncovered area	0.5 W/ft² of covered and uncovered area	0.5 W/ft² of covered and uncovered area	0.5 W/ft² of covered and uncovered area
	Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

Allowable Design Levels from IECC 2015

TABLE C405.5.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

		LIGHTING ZONES			
		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.)	Uncovered Parking Areas				
	Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
	Building Grounds				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
	Stairways	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
	Pedestrian tunnels	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2
	Building Entrances and Exits				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
	Sales Canopies				
	Free-standing and attached	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.25 W/ft^2	0.25 W/ft^2	0.5 W/ft^2	0.7 W/ft^2
	Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)	Building facades	No allowance	0.075 W/ft^2 of gross above-grade wall area	0.113 W/ft^2 of gross above-grade wall area	0.15 W/ft^2 of gross above-grade wall area
	Automated teller machines (ATM) and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area
	Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m^2.
W = watts.

Allowable Design Levels from IECC 2018

TABLE C405.4.2(2)
LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

	LIGHTING ZONES			
	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance	350 W	400 W	500 W	900 W
Uncovered Parking Areas				
Parking areas and drives	0.03W/ft^2	0.04 W/ft^2	0.06 W/ft^2	0.08 W/ft^2
Building Grounds				
Walkways and ramps less than 10 feet wide	0.5 W/linear foot	0.5 W/linear foot	0.6 W/linear foot	0.7 W/linear foot
Walkways and ramps 10 feet wide or greater, plaza areas, special feature areas	0.10 W/ft^2	0.10 W/ft^2	0.11 W/ft^2	0.14 W/ft^2
Dining areas	0.65 W/ft^2	0.65 W/ft^2	0.75 W/ft^2	0.95 W/ft^2
Stairways	0.6 W/ft^2	0.7 W/ft^2	0.7 W/ft^2	0.7 W/ft^2
Pedestrian tunnels	0.12 W/ft^2	0.12 W/ft^2	0.14 W/ft^2	0.21 W/ft^2
Landscaping	0.03 W/ft^2	0.04 W/ft^2	0.04 W/ft^2	0.04 W/ft^2
Building Entrances and Exits				
Pedestrian and vehicular entrances and exits	14 W/linear foot of opening	14 W/linear foot of opening	21 W/linear foot of opening	21 W/linear foot of opening
Entry canopies	0.02 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
Loading docks	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2
Sales Canopies				
Free-standing and attached	0.04 W/ft^2	0.04 W/ft^2	0.6 W/ft^2	0.7 W/ft^2
Outdoor Sales				
Open areas (including vehicle sales lots)	0.02 W/ft^2	0.02 W/ft^2	0.35 W/ft^2	0.05 W/ft^2
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	7 W/linear foot	7 W/linear foot	21 W/linear foot

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m^2.

W = watts.

TABLE C405.4.2(3)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

	LIGHTING ZONES			
	Zone 1	Zone 2	Zone 3	Zone 4
Building facades	No allowance	0.075 W/ft^2 of gross above-grade wall area	0.113 W/ft^2 of gross above-grade wall area	0.15 W/ft^2 of gross above-grade wall area
Automated teller machines (ATM) and night depositories	135 W per location plus 45 W per additional ATM per location			
Uncovered entrances and gatehouse inspection stations at guarded facilities	0.5 W/ft^2 of area			
Uncovered loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.35 W/ft^2 of area			
Drive-up windows and doors	200 W per drive through			
Parking near 24-hour retail entrances.	400 W per main entry			

For SI: For SI: 1 watt per square foot = W/0.0929 m^2.

W = watts.

MEASURE CODE: CI-LTG-LPDE-V04-190101

REVIEW DEADLINE: 1/1/2020

4.5.8 Miscellaneous Commercial/Industrial Lighting

Description

This measure is designed to calculate savings from energy efficient lighting upgrades that are not captured in other measures within the TRM. If a lighting project fits the measure description in sections 4.5.1-4.5.4, then those criteria, definitions, and calculations should be used.

Unlike other lighting measures this one applies only to RF applications (because there is no defined baseline for TOS or NC applications).

Definition of Efficient Equipment

A lighting fixture that replaces an existing fixture to provide the same or greater lumen output at a lower kW consumption.

Definition of Baseline Equipment

The definition of baseline equipment is the existing lighting fixture.

Deemed Lifetime of Efficient Equipment

The lifetime of the efficient equipment fixture is the rated fixture life divided by hours of use. If unknown the default lifetime, regardless of program type is 12 years[757].

Deemed Measure Cost

The actual cost of the efficient light fixture should be used.

Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[757] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and ballast factor (if applicable) and number of fixtures.

=Actual

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor (if applicable) (if applicable) and number of fixtures.

= Actual

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[758] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

Weigted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
75.5%759	12.1%	10.3%	98.0%760

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{761} = (((WattsBase - WattsEE)/1000) * ISR * Hours * -IFkWh$$

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

[759] 1st year in service rate is based upon review of PY4-5 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

[760] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[761] Negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference able in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

NATURAL GAS ENERGY SAVINGS

ΔTherms[762] = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 6.5 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

If there are differences between the maintenance of the efficient and baseline lighting system then they should be evaluated on a project-by-project basis.

[762] Negative value because this is an increase in heating consumption due to the efficient lighting.

MEASURE CODE: CI-LTG-MSCI-V03-190101

REVIEW DEADLINE: 1/1/2021

4.5.9 Multi-Level Lighting Switch

Description

This measure relates to the installation new multi-level lighting switches on an existing lighting system.

This measure can only relate to the adding of a new control in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015/2018).

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 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 8 years[763].

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[764].

Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

---

[763] Consistent with Occupancy Sensor control measure.
[764] Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$KW_{Controlled}$ = Total lighting load connected to the control in kilowatts.

= Actual

Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown buidling type, use the Miscellaneous value.

ESF = Energy Savings factor (represents the percentage reduction to the KWcontrolled due to the use of multi-level switching).

= Dependent on building type[765]:

Building Type	Energy Savings Factor (ESF)
Private Office	21.6%
Open Office	16.0%
Retail	14.8%
Classrooms	8.3%
Unknown, average	15%

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{766} = KW_{Controlled} * Hours * ESF * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

---

765 Based on results from “Lighting Controls Effectiveness Assessment: Final Report on Bi-Level Lighting Study” published by the California Public Utilities Commission (CPUC), prepared by ADM Associates.

766 Negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value of 0.66[767].

NATURAL GAS ENERGY SAVINGS

$$\Delta therms = KW_{Controlled} * Hours * ESF * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-MLLC-V04-190101

REVIEW DEADLINE: 1/1/2021

[767] 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.

4.5.10 Lighting Controls

Description

This measure relates to the installation of new occupancy or daylighting sensors on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling, fixture mounted or integrated controls. Passive infrared, ultrasonic detectors and fixture-mounted sensors or sensors with a combination thereof are eligible. Lighting controls required by state energy codes are not eligible. This must be a new installation and may not replace an existing lighting occupancy sensor control.

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 existing system is assumed to be manually controlled or an uncontrolled lighting system which is being controlled by one of the lighting controls systems listed above. This measure is intended for controlling interior lighting only.

A subset of occupancy sensors are those that are programmed as "vacancy" sensors. To qualify as a vacancy sensor, the control must be configured such that manual input is required to turn on the controlled lighting and the control automatically turns the lighting off. Additional savings are achieved compared to standard occupancy sensors because lighting does not automatically turn on and occupants may decide to not turn it on. Note that vacancy sensors are not a viable option for many applications where standard occupancy sensors should be used instead.

Definition of Baseline Equipment

The baseline is assumed to be a lighting system uncontrolled by occupancy.

Deemed Lifetime of Efficient Equipment

The expected measure life for all lighting controls is assumed to be 8 years[768].

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	Incremental Cost769
Wall Switch Occupancy Sensor	$55.00
Fixture-Mounted Occupancy Sensor	$67.00
Remote or Wall-Mounted Occupancy Sensor	$125.00
Fixture-Mounted Daylight Sensor	$ 50.00
Remote or Wall-Mounted Daylight Sensor	$65.00
Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens	$40.00
Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens	$40.00
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	$50.00
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	$50.00
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	$ 100.00

768 DEER 2008

769 Based on indicative product cost review as performed for Efficiency Vermont TRM.

Lighting Control Type	Incremental Cost[769]
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	$ 100.00
Exterior Occupancy Sensor	$82.00

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on location.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$Kw_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer or the default values presented below used;

Lighting Control Type[770]	Wattage Unit	Default kW Controlled
Wall Switch Occupancy Sensor	per control	0.084
Fixture-Mounted Occupancy Sensor	per fixture	0.081
Remote or Wall-Mounted Occupancy Sensor	per control	0.338
Fixture-Mounted Daylight Sensor	per fixture	0.095
or Wall-Mounted Daylight Sensor	per control	0.239

[770] Estimates of watts controlled are based on Efficency Vermont data as provided in the 2018 TRM. Future evaluation should determine appropriate assumptions based on Illinois program data.

Lighting Control Type770	Wattage Unit	Default kW Controlled
Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens	per fixture	0.031
Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens	per fixture	0.118
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	per control	0.031
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	per control	0.118
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	per control	0.031
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	per control	0.118
Exterior Occupancy Sensor	per fixture	0.086

Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown buidling type, use the Miscellaneous value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system).

Lighting Control Type	Energy Savings Factor771
Wall Switch Occupancy Sensor	24%
Fixture-Mounted Occupancy Sensor	24%
Remote or Wall-Mounted Occupancy Sensor	24%
Fixture-Mounted Daylight Sensor	28%
Remote or Wall-Mounted Daylight Sensor	28%
Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens	24%
Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens	24%
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	38%
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	38%
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	38%
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	38%
Exterior Occupancy Sensor	41%

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

[771] Interior controls % savings based on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls and exterior sensors are based upon data from "Application Assessment of Bi-Level LED Parking Lot Lighting" p6.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{772} = KW_{Controlled} * Hours * ESF * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * WHF_d * (CFbaseline - CFos)$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

CFbaseline = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66

CFos = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.[773]

NATURAL GAS ENERGY SAVINGS

$$\Delta therms = KW_{Controlled} * Hours * ESF * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OSLC-V05-190101

REVIEW DEADLINE: 1/1/2021

---

[772] Negative value because this is an increase in heating consumption due to the efficient lighting.

[773] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.

4.5.11 Solar Light Tubes

Description

A tubular skylight which is 10" to 21" in diameter with a prismatic or translucent lens is installed on the roof of a commercial facility. The lens reflects light captured from the roof opening through a highly specular reflective tube down to the mounted fixture height. When in use, a light tube fixture resembles a metal halide fixture. Uses include grocery, school, retail and other single story commercial buildings.

In order that the savings characterized below apply, the electric illumination in the space must be automatically controlled to turn off or down when the tube is providing enough light.

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 equipment is assumed to be a tubular skylight that concentrates and directs light from the roof to an area inside the facility.

Definition of Baseline Equipment

The baseline equipment for this measure is a fixture with comparable luminosity. The specifications for the baseline lamp depend on the size of the Light Tube being installed.

Deemed Lifetime of Efficient Equipment

The estimated useful life for a light tube commercial skylight is 10 years[774].

Deemed Measure Cost

If available, the actual incremental cost should be used. For analysis purposes, assume an incremental cost for a light tube commercial skylight is $500[2].

Loadshape

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)[775]

Coincidence Factor

The summer peak coincidence factor for this measure is dependent on location.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = kW_f * HOURS * WHFe$$

Where:

kW_f = Connected load of the fixture the solar tube replaces

[774] Equal to the manufacturers standard warranty

[775] The savings from solar light tubes are only realized during the sunlight hours. It is therefore appropriate to apply the single shift (8/5) loadshape to this measure.

Size of Tube	Average Lumen output for Chicago Illinois (minimum)[776]	Equivalent fixture	kW
21”	9,775 (4,179)	50% 3 x 2 32W lamp CFL (207W, 9915 lumens) 50% 4 lamp F32 w/Elec 4’ T8 (114W, 8895 lumens)	0.161
14”	4,392 (1,887)	50% 2 42W lamp CFL (94W, 4406 lumens) 50% 2 lamp F32 w/Elec 4’ T8 (59W, 4448 lumens)	0.077
10”	2,157 (911)	50% 1 42W lamp CFL (46W, 2203 lumens) 50% 1 lamp F32 w/Elec 4’ T8 (32W, 2224 lumens)	0.039
		AVERAGE	**0.092**

HOURS = Equivalent full load hours

= 2400 [777]

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{778} = kW_f * HOURS * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kW_f * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

NATURAL GAS SAVINGS

$$\Delta Therms^{779} = \Delta kW_f * HOURS * - IFTherms$$

Where:

[776] Solatube Test Report (2005). http://www.mainegreenbuilding.com/files/file/solatube/stb_lumens_datasheet.pdf
[777] Ibid. The lumen values presented in the kW table represent the average of the lightest 2400 hours.
[778] Negative value because this is an increase in heating consumption due to the efficient lighting.
[779] Negative value because this is an increase in heating consumption due to the efficient lighting.

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. Please select from the Reference Table in Section 4.5 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-STUB-V02-140601

REVIEW DEADLINE: 1/1/2020

4.5.12 T5 Fixtures and Lamps

DESCRIPTION

T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or an existing T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts.

This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 99% Commercial and 1% Residential should be used[780].

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.

The measure applies to all commercial T5 installations excluding new construction and substantial renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for various installations. Actual existing equipment wattages should be compared to new fixture wattages whenever possible while maintaining lumen equivalent designs. Default new and baseline assumptions are provided if existing equipment cannot be determined. Actual costs and hours of use should be utilized when available. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. Configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs:

Time of Sale (TOS)	Retrofit (RF) and DI
This program applies to installations where customer and location of equipment is not known, or at time of burnout of existing equipment. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 fixtures, while using fewer watts.	For installations that upgrade installations before the end of their useful life. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts and having longer life.

DEFINITION OF EFFICIENT EQUIPMENT

The definition of efficient equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and DI
4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better.	4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better.

[780] Based on weighted average of Final ComEd's BILD program data from PY5 and PY6. For Residential installations, hours of use assumptions from '5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture' measure should be used.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on the program and is defined below:

Time of Sale (TOS)	Retrofit (RF) and DI
The baseline is T8 with equivalent lumen output. In high-bay applications, the baseline is pulse start metal halide systems.	The baseline is the existing system. In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v7.0 until 1/1/2020 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2020 in years remaining in the measure life. See table C-1.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the efficient equipment fixture should be the rated life of the fixture divided by hours of use. If unknown default is, regardless of program type is 12 years[781].

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

[781] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

Program	Reference Table
Time of Sale	A-1: T5 New and Baseline Assumptions
Retrofit, DI	A-2: T5 New and Baseline Assumptions

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[782] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

Weigted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
98%[783]	0%	0%	98.0%[784]

HEATING PENALTY

If electrically heated building:

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

[783] 1st year in service rate is based upon review of PY5-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information

[784] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

$\Delta kWh_{heatpenalty}$[785] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value.

NATURAL GAS ENERGY SAVINGS

ΔTherms[786] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 4.5 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference tables for Operating and Maintenance Values

Program	Reference Table
Time of Sale	B-1: T5 Component Costs and Lifetime
Retrofit, DI	B-2: T5 Component Costs and Lifetime

REFERENCE TABLES

See following page.

785 Negative value because this is an increase in heating consumption due to the efficient lighting.
786 Negative value because this is an increase in heating consumption due to the efficient lighting.

A-1: Time of Sale: T5 New and Baseline Assumptions[787]

EE Measure Description	EE Cost	$Watts_{EE}$	Baseline Description	Base Cost	$Watts_{BASE}$	Measure Cost	$Watts_{SAVE}$
2-Lamp T5 High-Bay	$200.00	180	200 Watt Pulse Start Metal-Halide	$100.00	232	$100.00	52
3-Lamp T5 High-Bay	$200.00	180	200 Watt Pulse Start Metal-Halide	$100.00	232	$100.00	52
4-Lamp T5 High-Bay	$225.00	240	320 Watt Pulse Start Metal-Halide	$125.00	350	$100.00	110
6-Lamp T5 High-Bay	$250.00	360	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	$150.00	476	$100.00	116
1-Lamp T5 Troffer/Wrap	$100.00	32	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	$60.00	44	$40.00	12
2-Lamp T5 Troffer/Wrap	$100.00	64	3-Lamp F32T8 Equivalent w/ Elec. Ballast	$60.00	88	$40.00	24
1-Lamp T5 Industrial/Strip	$70.00	32	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	$40.00	44	$30.00	12
2-Lamp T5 Industrial/Strip	$70.00	64	3-Lamp F32T8 Equivalent w/ Elec. Ballast	$40.00	88	$30.00	24
3-Lamp T5 Industrial/Strip	$70.00	96	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	$40.00	132	$30.00	36
4-Lamp T5 Industrial/Strip	$70.00	128	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	$40.00	178	$30.00	50
1-Lamp T5 Indirect	$175.00	32	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	$145.00	44	$30.00	12
2-Lamp T5 Indirect	$175.00	64	3-Lamp F32T8 Equivalent w/ Elec. Ballast	$145.00	88	$30.00	24

[787] Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011.

A-2: Retrofit T5 New and Baseline Assumptions[788]

EE Measure Description	EE Cost	$Watts_{EE}$
3-Lamp T5 High-Bay	$200.00	180
4-Lamp T5 High-Bay	$225.00	234
6-Lamp T5 High-Bay	$250.00	358
1-Lamp T5 Troffer/Wrap	$100.00	32
2-Lamp T5 Troffer/Wrap	$100.00	64
1-Lamp T5 Industrial/Strip	$70.00	32
2-Lamp T5 Industrial/Strip	$70.00	64
3-Lamp T5 Industrial/Strip	$70.00	96
4-Lamp T5 Industrial/Strip	$70.00	128
1-Lamp T5 Indirect	$175.00	32
2-Lamp T5 Indirect	$175.00	64

Baseline Description	$Watts_{BASE}$
200 Watt Pulse Start Metal-Halide	232
250 Watt Metal-Halide	295
320 Watt Pulse Start Metal-Halide	350
400 Watt Metal-Halide	455
400 Watt Pulse Start Metal-Halide	476
1-Lamp F34T12 w/ EEMag Ballast	40
2-Lamp F34T12 w/ EEMag Ballast	68
3-Lamp F34T12 w/ EEMag Ballast	110
4-Lamp F34T12 w/ EEMag Ballast	139
1-Lamp F40T12 w/ EEMag Ballast	48
2-Lamp F40T12 w/ EEMag Ballast	82
3-Lamp F40T12 w/ EEMag Ballast	122
4-Lamp F40T12 w/ EEMag Ballast	164
1-Lamp F40T12 w/ Mag Ballast	57
2-Lamp F40T12 w/ Mag Ballast	94
3-Lamp F40T12 w/ Mag Ballast	147
4-Lamp F40T12 w/ Mag Ballast	182
1-Lamp F32T8	32
2-Lamp F32T8	59
3-Lamp F32T8	88
4-Lamp F32T8	114

[788] Ibid.

B-1: Time of Sale T5 Component Costs and Lifetime[789]

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	# Base Lamps	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	# Base Ballasts	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
3-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	200 Watt Pulse Start Metal-Halide	1.00	$21.00	10000	$6.67	1.00	$87.75	40000	$22.50
4-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	320 Watt Pulse Start Metal-Halide	1.00	$21.00	20000	$6.67	1.00	$109.35	40000	$22.50
6-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	Adjusted according to 6-Lamp HPT8 Equivalent to 320	1.36	$21.00	20000	$6.67	1.50	$109.35	40000	$22.50
1-Lamp T5 Troffer/Wrap	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$15.00	70000	$15.00
2-Lamp T5 Troffer/Wrap	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$15.00	70000	$15.00
1-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$15.00	70000	$15.00
2-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$15.00	70000	$15.00
3-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent	4.50	$2.50	20000	$2.67	1.50	$15.00	70000	$15.00
4-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	6.00	$2.50	20000	$2.67	2.00	$15.00	70000	$15.00
1-Lamp T5 Indirect	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$15.00	70000	$15.00
2-Lamp T5 Indirect	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$15.00	70000	$15.00

[789] Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011.

B-2: T5 Retrofit Component Costs and Lifetime[790]

EE Measure Description	EE Lamp Cost	EE Lamp Life (hrs)	EE Lamp Rep. Labor Cost per lamp	EE Ballast Cost	EE Ballast Life (hrs)	EE Ballast Rep. Labor Cost	Baseline Description	# Base Lamps	Base Lamp Cost	Base Lamp Life (hrs)	Base Lamp Rep. Labor Cost	# Base Ballasts	Base Ballast Cost	Base Ballast Life (hrs)	Base Ballast Rep. Labor Cost
3-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	200 Watt Pulse Start Metal-Halide	1.00	$21.00	10000	$6.67	1.00	$ 88	40000	$22.50
							250 Watt Metal Halide	1.00	$21.00	10000	$6.67	1.00	$ 92	40000	$22.50
4-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	320 Watt Pulse Start Metal-Halide	1.00	$72.00	20000	$6.67	1.00	$ 109	40000	$22.50
							400 Watt Metal Halide	1.00	$17.00	20000	$6.67	1.00	$ 114	40000	$22.50
6-Lamp T5 High-Bay	$12.00	20000	$6.67	$52.00	70000	$22.50	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	1.36	$72.00	20000	$6.67	1.50	$ 109	40000	$22.50
1-Lamp T5 Troffer/Wrap	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$ 15	70000	$15.00
2-Lamp T5 Troffer/Wrap	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$ 15	70000	$15.00
1-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$ 15	70000	$15.00
2-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$ 15	70000	$15.00
3-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	4.50	$2.50	20000	$2.67	1.50	$ 15	70000	$15.00
4-Lamp T5 Industrial/Strip	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	6.00	$2.50	20000	$2.67	2.00	$ 15	70000	$15.00
1-Lamp T5 Indirect	$12.00	20000	$2.67	$52.00	70000	$15.00	Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8	1.50	$2.50	20000	$2.67	0.50	$ 15	70000	$15.00
2-Lamp T5 Indirect	$12.00	20000	$2.67	$52.00	70000	$15.00	3-Lamp F32T8 Equivalent w/ Elec. Ballast	3.00	$2.50	20000	$2.67	1.00	$ 15	70000	$15.00

[790] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011
EPE Program Downloads. (Copy of LSF_2012_v4.04_250rows.xls). Kuiken et al, Focus on Energy Evaluation. Business Programs: Deemed Savings Manual v1.0, Kema, March 22, 2010.

C-1: T12 Baseline Adjustment:

For measures installed up to 1/1/2020, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2020. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

	watts	Equivalent T12 watts adjusted for lumen equivalency-34 w and 40 w with EEMag ballast	Equivalent T12 watts adjusted for lumen equivalency-40 w with EEMag ballast	Equivalent T12 watts adjusted for lumen equivalency-40 w with Mag ballast	Prportionally Adjusted for Lumens wattage for T8 equivalent
1-Lamp T5 Industrial/Strip	32	61	73	82	44
2-Lamp T5 Industrial/Strip	64	103	125	135	88
3-Lamp T5 Industrial/Strip	96	167	185	211	132
4-Lamp T5 Industrial/Strip	128	211	249	226	178
		Savings Factor Adjustment to the T8 baseline	Savings Factor Adjustment to the T8 baseline	Savings Factor Adjustment to the T8 baseline	
1-Lamp T5 Industrial/Strip		42%	29%	24%	
2-Lamp T5 Industrial/Strip		61%	40%	34%	
3-Lamp T5 Industrial/Strip		51%	40%	31%	
4-Lamp T5 Industrial/Strip		60%	41%	51%	

MEASURE CODE: CI-LTG-T5FX-V06-190101

REVIEW DEADLINE: 1/1/2021

4.5.13 Occupancy Controlled Bi-Level Lighting Fixtures

Description

This measure relates to replacing existing uncontrolled continuous lighting fixtures with new bi-level lighting fixtures. This measure can only relate to replacement in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015/2018).

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 system is assumed to be an occupancy controlled lighting fixture that reduces light level during unoccupied periods.

Definition of Baseline Equipment

The baseline equipment is assumed to be an uncontrolled lighting system on continuously, e.g. in stairwells and corridors for health and safety reasons.

Deemed Lifetime of Efficient Equipment

The expected measure life for all lighting controls is assumed to be 8 years[791].

Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the assumed measure cost is $274[792].

Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

---

[791] DEER 2008.

[792] Consistent with the Multi-level Fixture measure with reference to Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009. Also consistent with field experience of about $250 per fixture and $25 install labor.

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * WHF_e$

Where:

$KW_{Baseline}$ = Total baseline lighting load of the existing/baseline fixture

= Actual

Note that if the existing fixture is only being retrofit with bi-level occpuancy controls and not being replaced $KW_{Baseline}$ will equal $KW_{Controlled}$.

$KW_{Controlled}$ = Total contolled lighting load at full light output of the new bi-level fixture

= Actual

Hours = Number of hours lighting is on. This measure is limited to 24/7 operation.

= 8,766

ESF = Energy Savings factor (represents the percentage reduction to the $KW_{Controlled}$ due to the occupancy control).

= % Standby Mode * (1 - % Full Light at Standby Mode)

% Standby Mode = Represents the percentage of the time the fixture is operating in standby (i.e. low-wattage) mode.

% Full Light at Standby Mode = Represents the assumed wattage consumption during standby mode relative to the full wattage consumption. Can be achieved either through dimming or a stepped control strategy.

= Dependent on application. If participant provided or metered data is available for both or either of these inputs a custom savings factor should be calculated. If not defaults are provided below:

Application	% Standby Mode	% Full Light at Standby Mode	Energy Savings Factor (ESF)
Stairwells	78.5%[793]	50%	39.3%
		33%	52.6%
		10%	70.7%
		5%	74.6%
Corridors	50.0%[794]	50%	25.0%
		33%	33.5%

[793] Average found from the four buildings in the State of California Energy Commission Lighting Research Program Bi-Level Stairwell Fixture Performance Final Report, October 2005.

[794] Value determined from the Pacific Gas and Electric Company: Bi-Level Lighting Control Credits study for Interior Corridors of Hotels, Motels and High Rise Residential, June 2002.

Application	% Standby Mode	% Full Light at Standby Mode	Energy Savings Factor (ESF)
		10%	45.0%
		5%	47.5%
Other 24/7 Space Type	50.0%[795]	50%	25.0%
		33%	33.5%
		10%	45.0%
		5%	47.5%

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[796] = $(KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * -IFkWh$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * WHF_d * (CF_{baseline} - CF_{os})$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

$CF_{baseline}$ = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66

CF_{os} = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.[797]

NATURAL GAS HEATING PENALTY

If natural gas heating:

$\Delta therms = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * - IFTherms$

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 and provided in the Reference Table in Section 4.5 by buidling type.

[795] Conservative estimate.
[796] Negative value because this is an increase in heating consumption due to the efficient lighting.
[797] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OCBL-V03-190101

REVIEW DEADLINE: 1/1/2021

4.5.14 Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.

DESCRIPTION

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb in a commercial location.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 .[798] The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[799], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[800].

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

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5" diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps (>60W) and intermediate base lamps (>40W).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours[801]) by the run hours. For example using Miscellaneous at 3612 hours would give 2.8 years. For non-exempt bulbs, when the number of years exceeds 2021, the number of years to that date should be used.

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5[802].

---

798 ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 2.1, effective January 2, 2017

799 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112015.xls'.

800 Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.

801 Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.

802 NEEP Residential Lighting Survey, 2011

For the Retrofit measures, the full cost of $8.50 should be used plus $5 labor[803] for a total of $13.50. However actual program delivery costs should be utilized if available.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * Hours * WHFe

Where:

WattsBase = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage[804]; use 60W if unknown[805]

EISA exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals >=2601	2601	2999	150
	3000	5279	200

[803] Based on 15 minutes at $20 per hour.
[804] Based upon the ENERGY STAR specification for lamps, ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 1.1, effective August 28, 2014 and the Energy Policy and Conservation Act of 2012.
[805] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	5280	6209	300
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe (medium and intermediate bases less than 750 lumens)	90	179	10
	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60

EISA non-exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	Incandescent Equivalent Post-EISA 2007 (WattsBase)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	749	29
	750	1049	43
	1050	1489	53
	1490	2600	72

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[806].

For Directional R, BR, and ER lamp types[807]:

[806] From pg 10 of the Energy Star Specification for lamps v1.1
[807] From pg 11 of the Energy Star Specification for lamps v1.1

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40
	473	524	45
	525	714	50
	715	937	65
	938	1259	75
	1260	1399	90
	1400	1739	100
	1740	2174	120
	2175	2624	150
	2625	2999	175
	3000	4500	200
***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	400	449	40
	450	499	45
	500	649	50
	650	1199	65
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399	30

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[808] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[809]

Wattsbase =

[808] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[809] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

EISA non-exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	Incandescent Equivalent Post-EISA 2007 (WattsBase)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	749	29
	750	1049	43
	1050	1489	53
	1490	2600	72

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[810]

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[811] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

[810] An evaluation, (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting, presented to Commonwealth Edison Company by Navigant, December 2010), reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

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

Weigted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
71.2%[812]	14.5%	12.3%	98.0%[813]

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type[814]. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

ΔkWh = (((45 - 14)/1000) * 1.0 * 3088 * 1.25

= 119.7 kWh

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[815] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

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

812 1st year in service rate is based upon review of PY4-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

813The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

814 Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

815Negative value because this is an increase in heating consumption due to the efficient lighting.

lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in a heat pump heated office and sign off form provided.

$\Delta kWh_{heatpenalty}$ = (((45 - 14)/1000) * 1.0 * 3088 * -0.183

= - 17.5 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

ΔkW = ((45 - 14)/1000) * 1.0 * 1.3 * 0.66

= 0.027kW

NATURAL GAS SAVINGS

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

ΔTherms[816] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in a gas heated office and sign off form provided.

ΔTherms = (((45 - 14)/1000) * 1.0 * 3088 * -0.016

= - 1.5 Therms

[816] Negative value because this is an increase in heating consumption due to the efficient lighting.

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be (1000/HOURS) year; baseline replacement cost is assumed to be $3.5 for those bulbs types exempt from EISA and $5 for non-exempt EISA bulb types defined above[817]. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

Measure Code: **CI-LTG-SCFL-V04-190101**

Review Deadline: **1/1/2020**

[817] NEEP Residential Lighting Survey, 2011

4.5.15 LED Open Sign

Description

LED open signs must replace an existing neon open sign. LED drivers can be either electronic switching or linear magnetic, with the electronic switching supplies being the most efficient. The on/off power switch may be found on either the power line or load side of the driver, with the line side location providing significantly lower standby losses when the sign is turned off and is not operating. All new open signs must meet UL-84 (UL-844) requirements.

Replacement signs cannot use more than 20% of the input power of the sign that is being replaced.

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 product is an LED type illuminated open sign.

Definition of Baseline Equipment

The baseline equipment is a neon type illuminated open sign.

Deemed Lifetime of Efficient Equipment

The estimated useful life is 15 years. [818]

Deemed Measure Cost

The actual measure installation cost should be used (including material and labor).

Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[818] 15 years from GDS Measure Life Report, June 2007

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section in Section 4.5.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

The following equation was used to determine the energy savings from installing LED open signs:

$$\Delta kWh = (Watts_{base} – Watts_{ee}) / 1,000 * Hours * WHFe$$

Where:

$Watts_{base}$ = Wattage of neon sign with magnetic high voltage transformer

= Actual; if unknown use 46.0W[819]

$Watts_{ee}$ = Wattage of LED sign with low voltage transformer

= Actual; if unknown use 14.9W[820]

Hours = Annual hours of operation, assumed to be consistent with operating hours. Values are provided in the Reference Table in Section 4.5.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{821} = ((WattsBase-WattsEE)/1000) * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

DEMAND SAVINGS

$$\Delta kW = ((Watts_{base} – Watt_{see})/ 1000) * CF * WHF_d$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

---

[819] Measured average demand data. Southern California Edison, "Replace Neon Open Sign with LED Open Sign", Workpaper SCE13LG070, Revision 2, October 2015. Pg. 10

[820] Ibid.

[821]Negative value because this is an increase in heating consumption due to the efficient lighting.

Other variables as provided above.

Based on defaults provided above, the deemed energy savings are provided below:

Electric Energy and Coincident Peak Demand Savings

Building Types[822]	Energy Savings (kWh)	$\Delta kWh_{heatpenalty}$ (if electric heat)	Coincident Demand Savings (kW)
Convenience Store	158	-120	0.0298
Grocery	152	-74	0.0277
Healthcare Clinic	169	-17	0.0374
Hotel/Motel - Common	229	-143	0.0282
Movie Theater	121	-73	0.0227
Restaurant	203	-85	0.0277
Retail - Department Store	191	-88	0.0387
Miscellaneous	115	-55	0.0245

NATURAL GAS SAVINGS

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

ΔTherms[823] = ((WattsBase-WattsEE)/1000) * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

Based on defaults provided above, the deemed penalty is provided below:

Building Type	$\Delta Therms_{heatpenalty}$ (if gas heat)
Convenience Store	-5.1
Grocery	-3.2
Healthcare Clinic	-0.7
Hotel/Motel - Common	-6.1
Movie Theater	-3.2
Restaurant	-3.6
Retail - Department Store	-3.7
Miscellaneous	-2.3

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[822] Savings can be calculated for additional building types using the default values provided in the Reference Table in Section 4.5.
[823] Negative value because this is an increase in heating consumption due to the efficient lighting.

MEASURE CODE: CI-LTG-OPEN-V01-180101

REVIEW DEADLINE: 1/1/2022

4.5.16 LED Streetlighting

Description

Existing streetlights are retrofitted to be illuminated with light emitting diodes (LED) instead of less efficient lamps. Incentive applies for the replacement or retrofit of existing streetlights with new LED lamps.

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

Definition of Efficient Equipment

The efficient equipment is the installed streetlight illuminated by LEDs.

Definition of Baseline Equipment

The baseline equipment is the existing streetlight for the its' remaining useful life, and a new baseline High Pressure Sodium lamp for the remainder of the measure life.

Deemed Lifetime of Efficient Equipment

The assumed effective useful life (EUL) of a new LED streetlight is 12 years for standard operation or 6 years for 8766 hour lighting[824].

For early replacement, it is assumed the existing unit has a remaining useful life (RUL) of 4 years[825].

Deemed Measure Cost

The actual measure installation cost should be used (including material and labor). The assume deferred cost (after 4 years) of replacing the existing lamp with a new High Pressure Sodium lamp is assumed to be $44[826]. This cost should be discounted to present value using the nominal discount rate.

Loadshape

Loadshape C20 - Commercial Outdoor Lighting

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0 for standard usage or 1.0 for 8766 hour lighting[827].

Algorithm

Calculation of Energy Savings

Electric Energy Savings

For remaining useful life (1st 4 years) of existing equipment:

$$\Delta kWh = (W_{exist} - W_{eff}) * HOURS / 1000$$

[824] DLC streetlighting measure, PGE workpaper, and current TRM values for exterior lighting all have a measure lives in the 11-12 year range. Assuming 50,000 hours of operation, and an annual operating hours of 4,303 hours results in a lifetime of 11.6 years or 5.7 years for 8760 operation. Typical streetlighting spec sheets suggest a longer measure life than 50,000 hours so we recommend the 12 year EUL for this measure.

[825] Standard RUL assumption of a third of the EUL of the measure.

[826] High Pressure Sodium replacement cost (lamp and labor) was provided by ComEd based on their composite maintenance rate.

[827] Assuming standard operation of streetlight occurs outside the summer peak period of 1-5 PM. Coincidence Factor is assumed to equal 0.

For remaining life of measure (next 8 years):

$\Delta kWh = (W_{base} - W_{eff}) * HOURS / 1000$

Where:

W_{exist} =the connected load of the existing equipment

= actual existing equipment wattage

W_{base} =the connected load of the baseline equipment

= assume appropriate High Pressure Sodium lamp wattage for application.

W_{eff} =the connected load of the efficient equipment

= actual efficient equipment wattage

EFLH = annual operating hours of the lamp

= 4,303 hours for standard operation[828]

= 8,766 hours for always on lighting

1000 = conversion factor (W/kW)

EXAMPLE

For example, an existing 469 watts mercury vapor streetlight is replaced by an LED light of 161 watts. High Pressure Sodium equivalent is 295 watts:

ΔkWh (first four years) = ((469 - 161) * 4,303) / 1000

= 1,325.3 kWh

ΔkWh (remaining eight years) = ((295 - 161) * 4,303) / 1000

= 576.6 kWh

Therefore a midlife adjustment of 43.5% (576.6/1325.3) would be applied after 4 years.

Summer Coincident Peak Demand Savings

$\Delta kW = (W_{base} - W_{eff}) / 1000 * CF$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0 for Standard operation

= 1 for 8766 lighting

Natural Gas Savings

N/A

Water and Other Non-Energy Impact Descriptions and Calculation

N/A

[828] Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd's service territory. See Navigant Memorandum 'RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017'.

DEEMED O&M COST ADJUSTMENT CALCULATION

To calculate an O&M adjustment, in addition to the deferred HPS replacement after 4 years, assume one additional HPS replacement costing $44 in year ten for standard operation or every 2.7 years for 8,766 hour lighting[829].

MEASURE CODE: CI-LTG-STRT-V01-190101

REVIEW DEADLINE: 1/1/2022

[829] Assumes a rated life of the High Pressure Sodium lamp of 24,000 hours. High Pressure Sodium replacement cost (lamp and labor) was provided by ComEd based on their composite maintenance rate.

4.6 Refrigeration End Use

4.6.1 Automatic Door Closer for Walk-In Coolers and Freezers

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

In order for this characterization to apply, 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.[830]

DEEMED MEASURE COST

The deemed measure cost is $156.82 for a walk-in cooler or freezer.[831]

LOADSHAPE

Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor does not apply.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Savings calculations are based on values from through PG&E's Workpaper PGECOREF110.1 – Auto-Closers for Main Cooler or Freezer Doors. Savings are averaged across all California climate zones and vintages[832].

Annual Savings	kWh
Walk in Cooler	943
Walk in Freezer	2307

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Annual Savings	kW
Walk in Cooler	0.137

[830] Source: DEER 2014
[831] Ibid.
[832] Measure savings from ComEd TRM developed by KEMA. June 1, 2010

Annual Savings	kW
Walk in Freezer	0.309

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-ATDC-V02-190101

REVIEW DEADLINE: 1/1/2023

4.6.2 Beverage and Snack Machine Controls

Description

This measure relates to the installation of new controls on refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations. This measure relates to the installation of a new control on a new or existing unit. This measure should **not** be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler with 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 efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler without a control system capable of powering down lighting and refrigeration systems during periods of inactivity

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 5 years [833].

Deemed Measure Cost

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes[834]:

Refrigerated Vending Machine and Glass Front Cooler: $180.00

Non-Refrigerated Vending Machine: $80.00

Loadshape

Loadshape C52 - Beverage and Snack Machine Controls

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0[835].

---

[833] Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005.
[834] ComEd workpapers, 8—15-11.pdf
[835] Assumed that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based controls.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = WATTSbase / 1000 * HOURS * ESF

Where:

WATTSbase = connected W of the controlled equipment; see table below for default values by connected equipment type:

Equipment Type	WATTSbase[836]
Refrigerated Beverage Vending Machines	400
Non-Refrigerated Snack Vending Machines	85
Glass Front Refrigerated Coolers	460

1000 = conversion factor (W/kW)

HOURS = operating hours of the connected equipment; assumed that the equipment operates 24 hours per day, 365.25 days per year

= 8766

ESF = Energy Savings Factor; represents the percent reduction in annual kWh consumption of the equipment controlled; see table below for default values:

Equipment Type	Energy Savings Factor (ESF)[837]
Refrigerated Beverage Vending Machines	46%
Non-Refrigerated Snack Vending Machines	46%
Glass Front Refrigerated Coolers	30%

EXAMPLE

For example, adding controls to a refrigerated beverage vending machine:

ΔkWh = WATTSbase / 1000 * HOURS * ESF

=400/1000* 8766* 0.46

= 1613 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

836 USA Technologies Energy Management Product Sheets, July 2006; cited September 2009.
837 Ibid.

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-RFG-BEVM-V03-190101

Review Deadline: 1/1/2022

4.6.3 Door Heater Controls for Cooler or Freezer

DESCRIPTION

By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize significant energy savings. There are two 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 your door heaters when the relative humidity in your 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.

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 door heater control on a commercial glass door cooler or refrigerator utilizing humidity or conductivity control.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door with no controls installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years [838].

DEEMED MEASURE COST

The incremental capital cost for a humidity-based control is $300 per circuit regardless of the number of doors controlled. The incremental cost for conductivity-based controls is $200[839].

LOADSHAPE

Loadshape C51 - Door Heater Control

COINCIDENCE FACTOR[840]

The summer peak coincidence factor for this measure is assumed to be 0%[841].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWH = kWbase * NUMdoors * ESF * BF * 8766

Where:

[838] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[839] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

[840] Source partial list from DEER 2008

[841] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings from door heater controls.

kWbase[842] = connected load kW for typical reach-in refrigerator or freezer door and frame with a heater.

= If actual kWbase is unknown, assume 0.195 kW for freezers and 0.092 kW for coolers.

NUMdoors = number of reach-in refrigerator or freezer doors controlled by sensor

= Actual installed

ESF[843] = Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls.

= assume 55% for humidity-based controls, 70% for conductivity-based controls

BF[844] = 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.

Definition	Representative Evaporator Temperature Range, °F[845]	Typical Uses	BF
Low	-35 to 0	Freezers for times such as frozen pizza, ice cream, etc.	1.36
Medium	0 – 20	Coolers for items such as meat, milk, dairy, etc	1.22
High	20 – 45	Coolers for items such as floral, produce and meat preperation rooms	1.15

8766 = annual hours of operation

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[842] A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different sources for this factor. Connecticut requires site-specific information, whereas New York's characterization does not explicitly identify the kWbase. Connecticut and Vermont provide values that are very consistent, and the simple average of these two values has been used for the purposes of this characterization.

[843] A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different estimates of ESF. Vermont is the only TRM that provides savings estimates dependent on the control type. Additionally, these estimates are the most conservative of all TRMs reviewed. These values have been adopted for the purposes of this characterization.

[844] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

[845] Energy Efficiency Supermarket Refrigeration, Wisconsin Electric Power Company, July 23, 1993

MEASURE CODE: CI-RFG-DHCT-V02-190101

REVIEW DEADLINE: 1/1/2022

4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers

DESCRIPTION

This measure is applicable to the replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins.

This measure achieves savings by installing a more efficient motor, the result of which produces less waste heat that the cooling system must reject.

If applicable, savings from this measure may be claimed in combination with measure 4.6.6 Evaporator Fan Control for Electrically Commutated Motors.

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 applies to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an electronically commutated motor (ECM) with a minimum efficiency of 66%. If controls are added as part of the motor upgrade to reduce annual run time, additional savings may potentially be claimed using measure 4.6.6 Evaporator Fan Control.

DEFINITION OF BASELINE EQUIPMENT

The baseline is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[846]

DEEMED MEASURE COST

The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer. [847]

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The peak kW coincidence factor is 100%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Savings\ per\ motor * motors$$

Where:

Savings per motor = based on the motor rating of the ECM motor:

---

[846] DEER

[847] Difference in the fully installed cost ($468) for ECM motor and controller, listed in Work Paper PGE3PREF126, “ECM for Walk-In Evaporator with Fan Controller,” June 20,2012, and the measure cost specified in 4.6.6 ($291)

Evaporator Fan Motor Rating (of ECM)	Annual kWh Savings/motor
16W	408
1/15 - 1/20HP	1,064
1/5HP	1,409
1/3HP	1,994
1/2HP	2,558
3/4HP	2,782

motors = number of fan motors replaced

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/ Hours * CF * motors

Where:

ΔkWh = Gross customer annual kWh savings for the measure, as listed above

Hours = Full Load hours per year

= 8760

CF = Summer Peak Coincident Factor

= 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor)

Evaporator Fan Motor Rating (of ECM)	Peak kW Savings/motor
16W	0.047
1/15 - 1/20HP	0.121
1/5HP	0.161
1/3HP	0.228
1/2HP	0.292
3/4HP	0.318

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-ECMF-V02-180101

REVIEW DEADLINE: 1/1/2022

4.6.5 ENERGY STAR Refrigerated Beverage Vending Machine

Description

ENERGY STAR qualified new and rebuilt vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as 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, NC .

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

Definition of Efficient Equipment

The refrigerated vending machine can be new or rebuilt but must meet the ENERGY STAR specifications which include low power mode.

Definition of Baseline Equipment

The baseline vending machine is a standard unit

Deemed Lifetime of Efficient Equipment

The deemed lifetime of this measure is 14 years[848]

Deemed Measure Cost

The incremental cost of this measure is $500[849]

Loadshape

Loadshape C22 - Commercial Refrigeration

Coincidence Factor

It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings.

Algorithm

Calculation of Savings

Beverage machine savings are taken from the ENERGY STAR savings calculator and summarized in the following table. ENERGY STAR provides savings numbers for machines with and without control software. The average savings are calculated here.

Electric Energy Savings

ENERGY STAR Vending Machine Savings[850]

Vending Machine Capacity (cans)	kWh Savings Per Machine w/o software	kWh Savings Per Machine w/ software
<500	1,099	1,659
500 - 599	1,754	2,231
600 - 699	1,242	1,751

[848] ENERGY STAR
[849] ENERGY STAR
[850] Savings from ENERGY STAR Vending Machine Calculator

Vending Machine Capacity (cans)	kWh Savings Per Machine w/o software	kWh Savings Per Machine w/ software
700 - 799	1,741	2,283
800+	713	1,288
Average	1,310	1,842

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-ESVE-V03-190101

REVIEW DEADLINE: 1/1/2022

4.6.6 Evaporator Fan Control for Electrically Commutated Motors

DESCRIPTION

This measure is for the installation of controls for Electronically Commutated Motors in existing medium temperature walk-in coolers. 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 4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in 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 1/20 HP where fans operate continuously at full speed. 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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years[851]

DEEMED MEASURE COST

The measure cost is assumed to be $291[852]

LOADSHAPE

Loadshape C46 - Evaporator Fan Control

COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor does not apply.

Algorithm

CALCULATION OF SAVINGS

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association[853] 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

[851] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[852] Source: DEER
[853] See 'EC_motor_with_controller_182014.xlsx'.

equally as well to Illinois. 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

ΔkWh = Savings per motor * motors

Where:

Savings per motor = based on the motor rating of the ECM motor:

Evaporator Fan Motor Rating (of ECM)	Annual kWh Savings/motor
16W	212
1/15 - 1/20HP	315
1/5HP	920
1/3HP	1,524
1/2HP	2,283
3/4HP	3,444

motors = number of fan motors controlled

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Peak kW savings per motor (as listed in the table below) * motors (as defined above)

Evaporator Fan Motor Rating (of ECM)	Peak kW Savings/motor
16W	0.024
1/15 - 1/20HP	0.036
1/5HP	0.105
1/3HP	0.174
1/2HP	0.261
3/4HP	0.393

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-EVPF-V04-190101

REVIEW DEADLINE: 1/1/2024

4.6.7 Strip Curtain for Walk-in Coolers and Freezers

Description

This commercial measure pertains 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. The engineering assumption is that the walk-in door is open for varying durations per day based on facility type, and the strip curtain covers the entire door frame. All assumptions are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission.[854]

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 is a strip curtain at least 0.06 inches thick[855] added to a walk-in cooler or freezer. The new strip curtain must cover the entire area of the doorway when the door is opened.

Definition of Baseline Equipment

The baseline assumption is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 4 years[856].

Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening [857]

Loadshape

Loadshape C22 - Commercial Refrigeration

Coincidence Factor

The summer peak coincidence factor for this measure is 100%[858].

---

[854] The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's (CPUC) evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from shortterm monitoring of over 100 walk-in units. "Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation", CPUC, February 2010.

[855] Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

[856] DEER 2014 Effective Useful Life.

[857] The reference for incremental cost is $10.22 per square foot of door opening (includes material and labor). 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008.

[858] The summer coincident peak demand reduction is assumed as the total annual savings divided by the total number of hours per year, effectively assuming the average demand reduction is realized during the peak period. This is a reasonable assumption for refrigeration savings.

Algorithm

Calculation of Savings

Electric Energy Savings[859]

ΔkWh = ΔkWh/sq ft * A

Where:

ΔkWh/sq ft = Average annual kWh savings per square foot of infiltration barrier. Values can be found in Table 4.6.7 - 1.

A = Doorway area. If the actual doorway area in square feet is unknown, then use the values found in Table 4.6.7 - 2.

Table 4.6.7 - 1: Default Energy Savings and for Strip Curtains[860]

Type	Pre-Existing Curtains	Energy Savings ΔkWh/sq ft
Supermarket - Cooler	Yes	37
Supermarket - Cooler	No	108
Supermarket - Freezer	Yes	119
Supermarket - Freezer	No	349
Convenience Store - Cooler	Yes	5
Convenience Store - Cooler	No	20
Convenience Store - Freezer	Yes	8
Convenience Store - Freezer	No	27
Restaurant - Cooler	Yes	8
Restaurant - Cooler	No	30
Restaurant - Freezer	Yes	34
Restaurant - Freezer	No	119
Refrigerated Warehouse	Yes	254
Refrigerated Warehouse	No	729

Table 4.6.7 - 2: Default Doorway Area by Facility Type[861]

Facility Type	Doorway Area (sq ft)
Supermarket - Cooler	35
Supermarket - Freezer	35
Convenience Store - Cooler	21
Convenience Store - Freezer	21
Restaurant - Cooler	21
Restaurant - Freezer	21
Refrigerated Warehouse	80

[859] The source algorithm from which the savings per square foot values are determined is based on Tamm's equation (an application of Bernoulli's equation) [Kalterveluste durch kuhlraumoffnungen. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144;] and the ASHRAE handbook [American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6].

[860]Table 3-114 Default Energy Savings and Demand Reductions for Strip Curtains in Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

[861] Assumed Doorway area for four different facility types including supermarket, convenience store, restaurant and refrigerated warehouse. Pennsylvania Public Utility Commission 2016 TRM, chapter 3.5.9 Strip Curtains for Walk-in Frezzers and Coolers.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh / 8766 * CF$

Where:

8766 = hours per year

CF = Summer Peak Coincidence Factor for the measure

= 1.0

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-CRTN-V04-180101

REVIEW DEADLINE: 1/1/2022

4.6.8 Refrigeration Economizers

DESCRIPTION

This measure applies to commercial walk in refrigeration systems and includes two components, outside air economizers and evaporator fan controllers. Economizers save energy by bringing in outside air when weather conditions allow, rather than operating the compressor. Walk-in refrigeration systems evaporator fans run almost all the time; 24 hrs/day, 365 days/yr. This is because they must run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. However, evaporator fans are a very inefficient method of providing air circulation. Installing an evaporator fan control system will turn off evaporator fans while the compressor is not running, and instead turn on an energy-efficient 35 watt fan to provide air circulation, resulting in significant energy savings. This measure allows for economizer systems with evaporator fan controls plus a circulation fan and without a circulation fan.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an economizer is 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[862].

DEEMED MEASURE COST

The installation cost for an economizer is $2,558.[863]

LOADSHAPE

Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 0%[864].

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated based on whether evaporator fans run all

<u>With Fan Control Installed</u>

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans) – kWCirc) * Hours * DCComp * BF] – [kWEcon * DCEcon * Hours]

<u>Without Fan Control Installed</u>

ΔkWh = [HP * kWhCond] – [kWEcon * DCEcon * Hours]

---

[862] Estimated life from Efficiency Vermont TRM

[863] Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems.

[864] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings.

Where:

HP = Horsepower of Compressor

= actual installed

kWhCond = Condensing unit savings, per hp. (value from savings table) [865]

	Hermetic / Semi-Hermetic	Scroll	Discus
kWh/HP	1,256	1,108	1,051

Hours = Number of annual hours that economizer operates [866].

Region (city)	Hours
1 (Rockford)	2,376
2 (Chicago/O'Hare)	1,968
3 (Springfield)	1,728
4 (Belleview)	1,488
5 (Marion)	1,224

DCComp = Duty cycle of the compressor

= 50% [867]

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW[868]

kWCirc = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW[869]

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%[870]

BF = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)[871]

kWEcon = Connected load kW of the economizer fan

---

[865] Savings table uses Economizer Calc.xls. Assume 5HP compressor size used to develop kWh/Hp value. No floating head pressure controls and compressor is located outdoors

[866] In the source TRM (VT) this value was 2,996 hrs based on 38° F cooler setpoint, Burlington VT weather data, and 5 degree economizer deadband. The IL numbers were calculated by using weather bin data for each location (number of hours < 38F at each location is the Hours value).

[867] 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. (as referenced by the Efficiency Vermont, Technical Reference User Manual)

[868] Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

[869] 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

[870] Average of two manufacturer estimates of 50% and 75%.

[871] 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

= If known, actual installed. Otherwise assume 0.227 kW.[872]

EXAMPLE

For example, adding an outdoor air economizer and fan controls in Rockford to a 5 hp walk in refrigeration unit with 3 evaporator fans would save:

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans) – kWCirc) * Hours * DCComp * BF] – [kWEcon * DCEcon * Hours]

= [5 * 1256] + [((0.123 * 3) – 0.035) * 2376 *0.5 * 1.3] – [0.227 * 0.63 * 2376]

= 6456 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-ECON-V05-150601

REVIEW DEADLINE: 1/1/2020

[872] 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).

4.6.9 Night Covers for Open Refrigerated Display Cases

Description

This measure is the installation of fitted 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.

Definition of Efficient Equipment

Curtains or covers on top of open refrigerated or freezer display cases that are applied at least six hours (during off-hours) in a 24-hour period.

Definition of Baseline Equipment

Refrigerated and freezer, open-type display case in vertical, semi-vertical, and horizontal displays, with no night cover.

Deemed Lifetime of Efficient Equipment

The measure life is 5 years, based on DEER 2014.[873]

Deemed Measure Cost

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.[874]

Loadshape

Loadshape 22: Commercial Refrigeration

Coincidence Factor

N/A – savings occur at night only.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = ES * L$$

Where:

ES = the energy savings (ΔkWh/ft) found in table below:

[873] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

[874] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

Display Case Description	Case Temperature Range (°F)	Annual Electricity Use kWh/ft[875]	ES ΔkWh/ft reduction (= 9% reduction of electricity use[876,877])
Vertical Open, Remote Condensing, Medium Temperature	35°F to 55°F	1453	131
Vertical Open, Remote Condensing, Low Temperature	0°F to 30°F	3292	296
Vertical Open, Self-Contained Medium Temperature	35°F to 55°F	2800	252
Horizontal Open, Remote Condensing, Medium Temperature	35°F to 55°F	439	40
Horizontal Open, Remote Condensing, Low Temperature	0°F to 30°F	1007	91
Horizontal Open, Self-Contained, Medium Temperature	35°F to 55°F	1350	121
Horizontal Open, Self-Contained, Low Temperature	0°F to 30°F	2749	247

L = the length of the refrigerated case in linear feet

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Peak savings are null because savings occur at night only.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

---

[875] Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. The information required to estimate annual energy savings for refrigerated display cases is taken from the 2013-2014 U.S. Department of Energy (DOE) energy conservation standard rulemaking for Commercial Refrigerated Equipment. During the rulemaking process, DOE estimates the energy savings specific to night covers through extensive simulation and energy models that are validated by both manufacturers of night covers and refrigerated cases. The information is also referenced from a study done by Southern California Edison and testing by Technischer Uberwachungs-Verein Rheinland, which are used by DOE for the rulemaking process.

[876] Southern California Edison Refrigeration Technology and Test Center. Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case. 1997. Southern California Edison, Rancho Cucamonga, CA.

[877] Technischer Uberwachungs-Verein Rheinland E.V. Laboratory test results for energy savings on refrigerated dairy case, conducted for Econofrost.

MEASURE CODE: CI-RFG-NCOV-V01-150601

REVIEW DEADLINE: 1/1/2024

4.6.10 High Speed Rollup Doors

DESCRIPTION

This measure entails the installation of High Speed Doors in refrigerated warehouses. High speed doors can save energy by lowering infiltration through a reduction in time that cooled spaces are exposed to ambient outdoor conditions. This in turn can lower the demand on refrigeration 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

To qualify for this measure the installed equipment must be a High Speed Door installed on the loading dock doorway 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 traffic, 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.[878]

DEEMED MEASURE COST

The incremental measure cost is $150/sq.ft.[879]

LOADSHAPE

Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR

The coincidence factor is assumed to be 1.00.

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 drive on the high speed door. The following algorithms are based heavily on those derived and described in chapter 24 Refrigerated-Facility Loads of the ASHRAE Refrigeration Handbook.

$$\Delta kWh = \left(0.00008333 * q * D_f * \eta * [D_{tB}(1-E_B) - D_{tE}(1-E_E)] - D_{tM}\mathrm{M}\right) * t$$

Where:

0.00008333 = conversion from Btu/h to tons

[878] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[879] Rite Hite – Industrial High Speed Doors

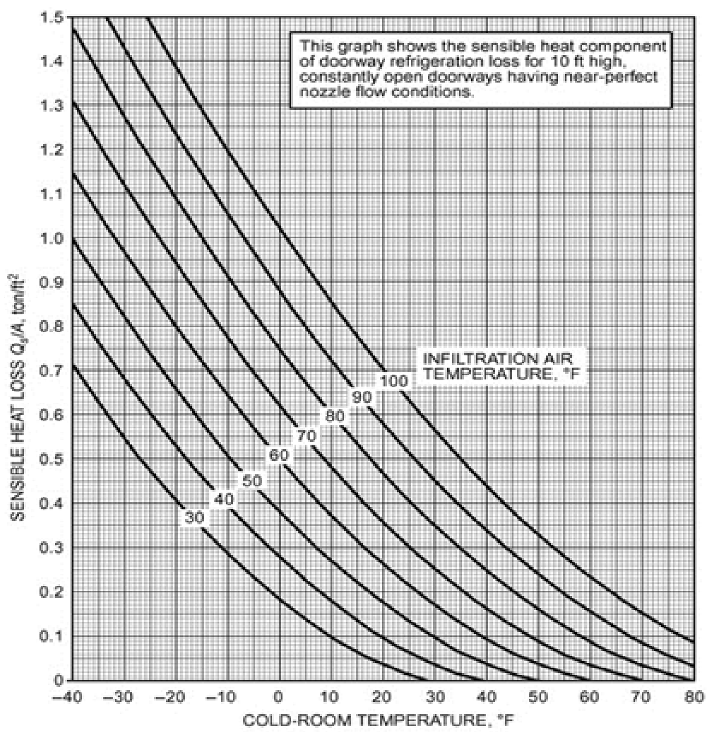
q = sensible and latent refrigeration load for fully established flow, Btu/h

$$= 3790 * W * H^{1.5} * \left(\frac{Q_s}{A}\right) * \left(\frac{1}{R_s}\right)$$

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, as read from the following figure and dependent on infiltration air temperature and cooled space temperature. If unknown, infiltration temperature can be assumed to be 50^{o} F[880], cooler temperature 35^{o}F and freezer temperature -10^{o}F[881], resulting in values of 0.06 for a cooler and 0.5 for a freezer.



R_s = Sensible heat ratio of the infiltration air heat gain, as read or interpolated from the chart below or from a psychometric 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%[882], resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.

[880] Taken to represent the overall annual average temperature in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 47.6 (Rockford) to 55.9 (Marion).

[881] Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011

[882] Taken to represent the overall annual average in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 69.1 (Springfield) to 72.1 (Rockford).

Warm Space		Cold Space at 90% rh Dry-Bulb Temperature, °F									
Temp. °F	rh, %	–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[883].

η = Efficiency of refrigeration system (kW/ton). Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton[884] for freezers.

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.

$$D_{tB} = \frac{(P\ \theta_{pB}\ +\ 60\ \theta_{oB})}{3600\ \theta_d}$$

P = Number of passages through doorway per hour.

Θ_{pB} = Door open to close time in seconds.

Θ_{oB} = Time door remains open in minutes.

Θ_d = Period of time considered in hours, 1 hr.

D_{tE} = decimal portion of time doorway is open in the efficient condition.

$$D_{tE} = \frac{(P\ \theta_{pE}\ +\ 60\ \theta_{oE})}{3600\ \theta_d}$$

883 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7

884 Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD).

P = Number of passages through doorway per hour. Custom input, assume 5.9[885] if unknown.

Θ_{pE} = Door open to close time in seconds. Custom input, assume 7.5 seconds[886] if unknown.

Θ_{oE} = Time door remains open in minutes. Custom input, assume 3 minutes[887] if unknown.

Θ_d = Period of time considered in hours, 1 hr.

D_{tM} = decimal portion of time high speed door motor is operational.

$$D_{tM} = \frac{P\ \theta_{pE}}{3600\ \theta_d}$$

Variables defined above.

E_B = effectiveness of baseline open-doorway protective device (strip curtains). Equal to 0.85[888].

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[889] if unknown.

t = hours per year when primary doors to the cooled space are open.

= Custom input, assume 2,959 hrs/yr[890] if unknown.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh / t) * CF

Where

CF = Summer peak coincidence factor for this measure

= 1.0

All other variables as defined above.

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

---

885 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.11
886 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.6
887 Professional judgement
888 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7
889 Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives.
890 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.

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[891].

Measure Code: CI-RFG-HSRD-V02-190101

Review Deadline: 1/1/2022

[891] Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets.

4.6.11 Q-Sync Motors for Reach-in Coolers/Freezers

DESCRIPTION

This measure is applicable to replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole and electronically commutated (EC) evaporator fan motors in reach-in refrigerated display cases.

This measure achieves energy savings by installing a more efficient Q-Sync motor in these scenarios (accompanied with replacement fan assembly as necessary). In addition to motor energy savings, the measure also results in less waste heat for the refrigeration equipment to reject and improves the power factor of the equipment.

This measure is limited to a typical reach-in refrigerated display case with the evaporator fan power of 9-12 Watts. In addition to the motor, replacement of the evaporator fan may be necessary to ensure matching airflow is provided (because the fan's speed has been modified). Care must be taken by the installer to ensure airflows remain within the specified range, otherwise fan performance could suffer, causing reliability issues. Q-Sync motors are commonly purchased as a kit, which includes replacement fan blades and shrouds when replacement is necessary.

This measure was developed to be applicable to the following program types: RF, NC[892].

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

DEFINITION OF EFFICIENT EQUIPMENT

The replacement unit must be a Q-Sync motor with a minimum of 73% motor efficiency (as listed by manufacturer).

DEFINITION OF BASELINE EQUIPMENT

Depending on existing conditions, one of three baselines is chosen:

Baseline 1 is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated reach-in display case.

Baseline 2 is an EC motor with no fan control operating 8760 hours continuously in a refrigerated reach-in display case.

Baseline 3 is a blended baseline, consisting of a mix of shaded-pole motors and EC motors that are assumed to be present in retrofit project where accurate counts are unknown or difficult to determine. It is assumed that existing motors have no fan control and operate 8760 hours continuously in refrigerated reach-in display cases.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is ten years.[893]

DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available, the following deemed measure cost can be used[894].

Measure	Material Unit (Each)	Material Cost / Unit	Labor Unit (Hours)	Labor Rate / Unit	Total Cost / Unit
9-12-watt Q-Sync motor (including replacement fan kit)	1	$52	0.25	$120	$82

[892] Customers should be encouraged to check with the manufacturer to determine any impact on warranty of new equipment due to installing Q-sync fan/motor assemblies.
[893] Based on communication with QM Power representative, April 16, 2018. See reference document "4.16.2018 Email.msg"
[894] Based on communication with QM Power representative, April 24, 2018. See reference document "4.24.2018 Email.msg"

Note: the unit cost is based on a large-scale retrofit project.

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

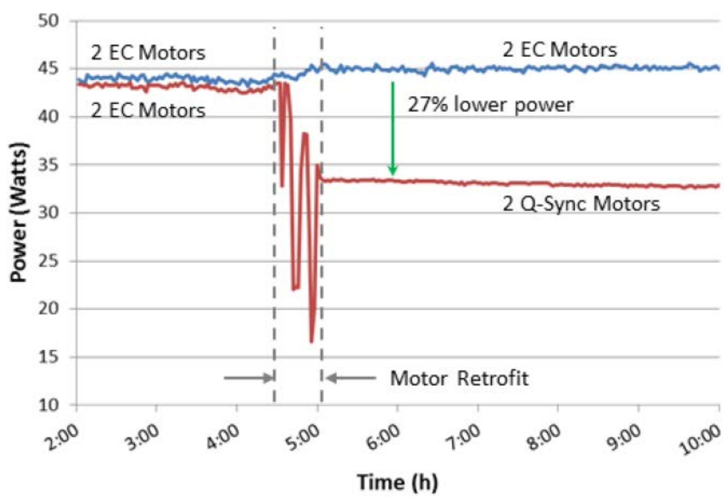
The peak kW coincidence factor is 100%

Algorithm

CALCULATION OF ENERGY SAVINGS

To determine the savings associated with the Q-Sync motor measure we utilized the field study results provided by Oak Ridge National Laboratory (ORNL)[895] and Alternative Energy Systems Consulting (AESC)[896].

In 2015, ORNL conducted a side-by-side comparison of Q-Sync motors with EC motors in a 16 ft medium-temperature vertical multi-deck refrigerated display case at an Hy-Vee Supermarket in the Kansas City metropolitan area. A retrofit was done on the display case that contained four 12 W EC evaporator fan motors, two in each 8 ft section. Two existing EC motors in one of the 8 ft sections were replaced with two 12 W Q-Sync motors. The initial results show that Q-Sync motors consumed approximately 16.4 watts per motor, and EC motors consumed approximately 22.6 watts per motor[897].



In comparison, the 2011 study by Navigant and PNNL determined that a 12 w shade-pole motor 's actual power is 60.0 watts for use in commercial refrigration equipment at design condition[898], even though some manufacturers also pointed out that "there could be significant variations in efficiency between motors of the same type but different models." In the AESC study, the field test showed that the average input power for each of the 13 shaded

[895] Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
[896] M M. Valmiki and Antonio Corradini, "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators," Alternative Energy Systems Consulting, August 2016.
[897] Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
[898] NCI (Navigant Consulting Inc.) and PNNL (Pacific Northwest National Laboratory), "Preliminary Technical Support Document (TSD): Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment," Appliances and Commercial Equipment Standards, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, Washington, D.C., 2011.

pole motors retrofitted is 41.6 watts. As a compromise between the two studies, we use 50.0 watts as a representative number for shaded pole motors in our calculation.

The electrical energy savings for replacing a shaded-pole motor with a Q-Sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours. For med-temperature cases, T is 8,760 hours. For low-temp freezer cases, T is 8,578 hours considering daily 30-minute defrost cycles during which fans are not powered[899].

Motor energy savings (Baseline 1, med-temp, per motor) = (50 w – 16.4 w) x 8760 hours / 1000 = 294.336 kWh

Motor energy savings (Baseline 1, low-temp, per motor) = (50 w – 16.4 w) x 8578 hours /1000 = 288.221 kWh

The electrical energy savings for replacing an EC motor with a Q-Sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours (8760 hours):

Motor energy savings (Baseline 2, med-temp, per motor) = (22.6 w – 16.4 w) x 8760 hours / 1000 = 54.312 kWh

Motor energy savings (Baseline 2, low-temp, per motor) = (22.6 w – 16.4 w) x 8578 hours / 1000 = 53.184 kWh

The reduced motor power will also reduce refrigeration load. Assuming the power to drive the evaporator fan is converted to heat inside the display cases at 100% rate, the reduction in refrigeration system compressor power can be calculated using the following equation:

$$\Delta kWh_{refrigeration} = \frac{\Delta kWh_{motor}}{COP},$$

where COP is the Coefficient of Performance of refrigeration systems in the supermarket display cases. For med-temperature cases, the average COP is 2.5[900]. For low-temp freezer cases, the average COP is 1.3[901].

The refrigeration energy savings can be calculated based on above numbers:

Refrigeration energy savings (Baseline 1, med-temp, per motor) = 117.734 kWh

Refrigeration energy savings (Baseline 1, low-temp, per motor) = 221.708 kWh

Refrigeration energy savings (Baseline 2, med-temp, per motor) = 21.724 kWh

Refrigeration energy savings (Baseline 2, low-temp, per motor) = 40.910 kWh

The overall energy savings are the sums of the motor energy savings and the refrigeration energy savings:

Overall energy savings (Baseline 1, med-temp, per motor) = 412.070 kWh

Overall energy savings (Baseline 1, low-temp, per motor) = 509.929 kWh

Overall energy savings (Baseline 2, med-temp, per motor) = 76.036 kWh

Overall energy savings (Baseline 2, low-temp, per motor) = 94.094 kWh

ELECTRIC ENERGY SAVINGS

If the numbers of existing shaded-pole motors and EC motors to be retrofitted are known (Baseline 1 & 2):

ΔkWh = Overall annual savings per motor * Motors

Where overall energy savings per motor can is as speficied in the following table:

[899] M M. Valmiki and Antonio Corradini, "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators," Alternative Energy Systems Consulting, August 2016.
[900] Michael Deru, et al, "U.S. Department of Energy Commercial Reference Building Models of National Building Stock," NREL Report TP-5500-46861, February 2011.
[901] Michael Deru, et al, "U.S. Department of Energy Commercial Reference Building Models of National Building Stock," NREL Report TP-5500-46861, February 2011.

Evaporator Fan Motor Rating (of Q-Sync motor)	Baseline	Annual kWh Savings/motor
9-12W	shaded-pole motor, med-temp	412.1
9-12W	shaded-pole motor, low-temp	509.9
9-12W	EC motor, med-temp	76.0
9-12W	EC motor, low-temp	94.1

Motors = number of fan motors replaced

If the numbers of existing shaded-pole motors and EC motors are unknown in a retrofit project (Baseline 3):

$\Delta kWh = [W_{med\text{-}temp} (W_{SPM} \times S_{SPM\text{-}med} + W_{ECM} \times S_{ECM\text{-}med}) + W_{low\text{-}temp} (W_{SPM} \times S_{SPM\text{-}low} + W_{ECM} \times S_{ECM\text{-}low})] * Motors$

Motors = number of fan motors replaced

S = annual energy savings per motor, by type. Savings for each different type ($S_{SPM\text{-}med}$, $S_{SPM\text{-}low}$, $S_{ECM\text{-}med}$, $S_{ECM\text{-}low}$) can be looked up from the table above.

W = weighting factors. The weights for the medium-temperature and low-temperature applications ($W_{med\text{-}temp}$ and $W_{low\text{-}temp}$) should be calculated based on the actural numbers of motors in a retrofit project, and the sum of the two weights should equal to 1. If these weights cannot be accurately obtained, the estimated weights ($W_{med\text{-}temp}$* and $W_{low\text{-}temp}$*)[902] from the table below can be used (the W_{SPM} and W_{ECM} numbers are slightly adjusted by +/-5% based on national averages in the 2015 ORNL study, reflecting some shaded pole motors may have been replaced with EC motors in the past few years)[903].

Application	WSPM	WECM	Wmed-temp*	Wlow-temp*
Supermarkets	0.6	0.4	0.68	0.32
Other Food Retail Formats	0.8	0.2	0.68	0.32
Other Retail Categories	0.7	0.3	0.68	0.32
Resturants and Bars	0.85	0.15	0.68	0.32
Beverage Vending Machines	0.85	0.15	0.68	0.32

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh / Hours * CF * motors$

Where:

ΔkWh = Gross customer annual kWh savings for the measure, as listed above

Hours = Full Load hours per year

= 8,766 (med-temp); 8,578 (low-temp)

CF = Summer Peak Coincident Factor

= 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor):

902 ASHRAE, "ASHRAE Handbook – Refrigration," ASHRAE, 2018.

903 NCI (Navigant Consulting Inc.) and PNNL (Pacific Northwest National Laboratory), "Preliminary Technical Support Document (TSD): Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment," Appliances and Commercial Equipment Standards, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, Washington, D.C., 2011.

Evaporator Fan Motor Rating (of Q-Sync motor)	Baseline	kW Savings/motor
9-12W	shaded-pole motor, med-temp	0.047
9-12W	shaded-pole motor, low-temp	0.059
9-12W	EC motor, med-temp	0.009
9-12W	EC motor, low-temp	0.011

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

There is no O&M cost adjustment for replacing shaded pole or EC motors with Q-Sync motors in reach-in refrigerated display case applications. From the 2015 ORNL study[904], the 2016 AESC study[905], and the manufacturer[906], there is no expected degradation in equipment performance after the retrofits, and therefore no O&M cost differences are expected between baseline and efficient measures.

MEASURE CODE: CI-RFG-QMF-V01-190101

REVIEW DEADLINE: 1/1/2022

[904] Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
[905] M M. Valmiki and Antonio Corradini, "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators," Alternative Energy Systems Consulting, August 2016.
[906] Based on communication with QM Power representative, August 22, 2018. See reference document "8.22.2018 Email.msg"

4.6.12 Variable Frequency Drive for Condenser Fans

DESCRIPTION

This measure is applicable to VFDs installed on condenser fan motors operating in supermarket refrigeration systems.

Where baseline condenser motor load operates at a fixed-speed, VFDs generate energy and cost savings by modulating frequency and voltage to match the load on the condensers [3]. Savings result from this resulting fan speed variation.

This measure is applicable to motors between 0.5 horsepower and 1.5 horsepower.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure applies to retrofitted installation of condenser fan motors in supermarkets where no ability to modulate frequency and voltage for fan-speed variation exits. Savings are based on the application of VFDs to baseline load conditions defined as pre-installation load compared to post-installation load.

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for VFD condenser fan applications is 15 years.[907]

DEEMED MEASURE COST

Customer costs will be used when available. For motor sizes 0.5 to 1.5 HP the default measure cost is $1,113/HP. Custom costs must be gathered for other motor sizes.

LOADSHAPE

C22-commercial refrigeration.

COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

Algorithm

CALCULATION OF ENERGY SAVINGS

Energy savings is based on a pre- and post-treatment test. The pre-treatment period being nearly three months in duration with post-treatment of a similar period. Both periods include significant average outdoor temperature (OAT) changes. Measurement of energy savings relies on regression of condenser fan energy use against ambient temperature. These estimates were made on each condenser using both pre- and post-VFD installation; comparison of the two yields savings.[908]

[907] Efficiency Vermont TRM 3/16/2015 pp 19 for motor end use-variable frequency drives.

[908] Pre- and post-VFD retrofit kWh consumption were derived from measurement of 14 condensers at 4 supermarkets in Rockford, Il. Annual savings in each Zone is the product of the number of hours in each 5-degree F Typical Meteorological Year

ELECTRIC ENERGY SAVINGS

Annual $\Delta kWh_{condenser}$ = No. fans * HP/fan * kWh savings/HP/Zone

Zone	kWh savings/HP
1 (Rockford)	1,484
2 (Chicago)	1,511
3 (Springfield)	1,448
4 (Belleville)	1,495
5 (Marion)	1,449

For example, for a condenser with 5 fans, each rated at 1.5 HP in Chicago (Zone 2):

Annual $\Delta kWh_{condenser}$ = 5 * 1.5 * 1,511

= 11,333 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Variable frequency drives, anecdotally, increase motor life because they allow for soft-start and soft shutdown. This would lead to O&M savings from replacing motors. Unfortunately there is currently insufficient evidence to quantify this savings, so no deemed O&M savings can be claimed at this time.

MEASURE CODE: CI-RFG-VSC-V01-190101

REVIEW DEADLINE: 1/1/2020

temperature bin multiplied by the mean savings across the 14 condensers measured in the study. Detailed methods, assumptions, and calculations are found in "Variable Frequency Drive Energy Savings in Supermarkets Report. Seventhwave September, 30 2018" [pending report publication by ComEd.] Once published, the report will be made available to Illinois TRM Stakeholders for reference.

4.7 Compressed Air

4.7.1 VSD Air Compressor

Description

This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls or variable displacement control. Baseline compressors choke off the inlet air to modulate the compressor output, which is not efficient. 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 as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp. Only one compressor per compressed air distribution system is eligible.

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

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

Definition of Efficient Equipment

The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

Definition of Baseline Equipment

The baseline equipment is either a modulating compressor with blow down ≤ 40 hp or an oil-free compressor with load/no load controls ≤ 40 hp.

Deemed Lifetime of Efficient Equipment

13 years[909].

Deemed Measure Cost

$$IncrementalCost (\$) = (127 \times hp_{compressor}) + 1446$$

Where:

127 and 1446[910] = compressor motor nominal hp to incremental cost conversion factor and offset

$hp_{compressor}$ = compressor motor nominal

Deemed O&M Cost Adjustments

N/A

Loadshape

Loadshape C35 - Industrial Process

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.

---

[909] Department of Energy Technical Support Document.

[910] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost, as sourced from the Efficiency Vermont Technical Reference Manual (TRM). Several Vermont vendors were surveyed to determine the cost of equipment.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.9 \times hp_{compressor} \times HOURS \times (CF_b - CF_e)$$

Where:

ΔkWh = gross customer annual kWh savings for the measure

$hp_{compressor}$ = compressor motor nominal hp

0.9[911] = compressor motor nominal hp to full load kW conversion factor

HOURS = compressor total 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

CF_b = baseline compressor factor[912]

Baseline Compressor	Compressor Factor
Modulating w/ Blowdown	0.890
Load/No Load w/ 1 Gallon/CFM	0.909
Load/No Load w/ 3 Gallon/CFM	0.831
Load/No Load w/ 5 Gallon/CFM	0.806

CF_e = efficient compressor [913]

=0.705

EXAMPLE

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

ΔkWh = 0.9 x 10 x 1976 x (0.890 – 0.705)

= 3290 kWh

---

911 Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island, as developed by DOE through a part load compressor analysis and sourced in the Efficiency Vermont TRM.

912 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.(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).

913 Ibid.

Summer Coincident Peak Demand Savings

$\Delta kW = \Delta kWh / HOURS * CF$

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0.59
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95

EXAMPLE

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

$\Delta kW = 3290/1976*0.59$

$= 0.98$ kW

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-CPA-VSDA-V02-190101

Review Deadline: 1/1/2022

4.7.2 Compressed Air 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 better efficiencies.

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 or more at element change

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

10 years [914].

DEEMED MEASURE COST

The incremental cost for this measure is estimated to be $1000 Incremental cost per filter[915]

LOADSHAPE

Loadshape C35 - Industrial Process

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

$$\Delta kWh = (kW_{typical} \times \Delta P \times SF \times Hours / HP_{typical}) \times HP_{real}$$

Where:

$kW_{typical}$ = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use Use actual compressor control type if known:

[914] Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[915] Incremental cost research found in LPDF Costs. xlsx

Compressor $kW_{typical}$

Control Type	$kW_{typical}$ [916]
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

= If the actual compressor control type is not known, then use a weighted average based on the following market assumptions:

Control Type	Share %	$kW_{typical}$ [917]
Market share estimation for load/unload control compressors	40%	74.8
Market share estimation for modulation w/unloading control compressors	40%	82.5
Market share estimation for variable displacement control compressors	20%	73.2
Weighted Average		77.6

ΔP = Reduced filter loss (psi)

=2 psi[918]

SF =1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a Savings Factor of 0.005[919]

Hours = compressor total hours of operation below depending on shift

Shift	Hours
Single shift (8/5)	1976 hours 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3952 hours 7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5928 hours 24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8320 hours 24 hours per day, 7 days a week minus some holidays and scheduled down time

$HP_{typical}$ = Nominal HP for typical compressor = 100 hp[920]

HP_{real} = Total HP of real compressors distibuting air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors

916 See "Industrial System Standard Deemed Saving Analysis.xls"
917 See "Industrial System Standard Deemed Saving Analysis.xls"
918 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
919 "Optimizing Pneumatic Systems for Extra Savings," Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.

920 Industrial System Standard Deemed Saving Analysis.xls

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / HOURS * CF$$

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0.59
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-CPA-LPDF-V02-190101

REVIEW DEADLINE: 1/1/2022

4.7.3 Compressed Air No-Loss Condensate Drains

Description

No-loss condensate drains remove condensate as needed without venting compressed air, resulting in less air demand and consequently better efficiency. Replacement or upgrades of existing no-loss drains are not eligible for the incentive.

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 installation of no-loss condensate drains.

Definition of Baseline Equipment

The baseline condition is installation of standard condensate drains (open valve, timer, or both)

Deemed Lifetime of Efficient Equipment

10 years

Deemed Measure Cost

$700 per drain [921]

Loadshape

Loadshape C35 - Industrial Process

Coincidence Factor

The coincidence factor equals 0.95[922]

Algorithm

Calculation of Savings

Electric Energy Savings

$\Delta kWh = CFM_{reduced} \times kW_{CFM} \times Hours$

Where:

$CFM_{reduced}$ = Reduced air consumption (CFM) per drain

= 3 CFM[923]

kW_{CFM} = System power reduction per reduced air demand (kw/CFM) depending on the type of compressor control:

System Power Reduction per Reduced Air Demand[924]

---

[921] Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls

[922] Efficiency Vermont Technical Reference Manual (TRM) Measure Savings Algorithms and Cost Assumptions, August 10, 2016

[923] Reduced CFM consumption is based on a timer drain opening for 10 seconds every 300 seconds as the baseline. See "Industrial System Standard Deemed Saving Analysis.xls"

[924] 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. See "Industrial System Standard Deemed Saving Analysis.xls"

Control Type	kW / CFM
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

Or if compressor control type is unknow, then a weighted average based on market share can be used:

Control Type	Share %	kW / CFM
Market share estimation for load/unload control compressors	40%	0.136
Market share estimation for modulation w/unloading control compressors	40%	0.055
Market share estimation for variable displacement control compressors	20%	0.153
Weighted Average		0.107

Hours = Compressed air system pressurized hours

=6136 hours[925]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / HOURS * CF

Where:

CF = Summer peak coincidence factor for this measure

= 0.95

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-CPA-NCLD-V02-190101

REVIEW DEADLINE: 1/1/2020

[925] US DOE, Evaluation of the Compressed Air Challenge® Training Program, Page 19

4.7.4 Efficient Compressed Air Nozzles

DESCRIPTION

This measure is for the replacement of standard air nozzle with high-efficiency air nozzle used in a compressed air system. High-efficiency air nozzles reduce the amount of air required to blow off parts or for drying. These nozzles utilize the Coandă effect to pull in free air to accomplish tasks with significantly less compressed air. High-efficiency nozzles often replace simple copper tubes. These nozzles have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

DEFINITION OF EFFICIENT EQUIPMENT

The high-efficiency air nozzle must meet the following specifications:

1. High-efficiency air nozzle must replace continuous open blow-offs
2. High-efficiency air nozzle must meet SCFM rating at 80psig less than or equal to: 1/8" 11 SCFM, 1/4" 29 SCFM, 5/16" 56 SCFM, 1/2" 140 SCFM.
3. Manufacturer's specification sheet of the high-efficiency air nozzle must be provided along with the make and model

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standArd air nozzle

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 15 years[926]

DEEMED MEASURE COST

The estimated incremental measure costs are presented in the following table[927]

Nozzle Diameter	1/8"	1/4"	5/16"	1/2"
Average IMC	$42	$57	$87	$121

LOADSHAPE

Loadshape C35 - Industrial Process

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 ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = (SCFM * SCFM%Reduced) * kW/CFM * %USE * HOURS

[926] PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission.

[927] Costs are from EXAIR's website and are an average of nozzles that meet the flow requirements. Models include Atto Super, Pico Super, Nano Super, Micro Super, Mini Super, Super and Large Super nozzles. Accessed March 20, 2014

Where:

SCFM = Air flow through standard nozzle. Use actual rated flow at 80 psi if known. If unknown, the table below includes the CFM by orifice diameter[928, 929].

Orifice Diameter	SCFM
1/8”	21
1/4”	58
5/16”	113
1/2"	280

SCFM%Reduced = Percent in reduction of air loss per nozzle. Estimated at 50%[930]

kW/CFM = System power reduction per air demand (kW/CFM) depending on the type of air compressor found in table below[931]

Air Compressor Type	ΔkW/CFM
Reciprocating – On/off Control	0.18
Reciprocating – Load/Unload	0.14
Screw – Load/Unload	0.15
Screw – Inlet Modulation	0.06
Screw – Inlet Modulation w/ Unloading	0.06
Screw – Variable Displacement	0.15
Screw - VFD	0.18

%USE = percent of the compressor total operating hours that the nozzle is in use

= Custom, if unknown assume 5%[932]

Hours = Compressed air system pressurized hours.

= Use actual hours if known, otherwise assume values in table below:

Shift	Hours
Single Shift	1976
Two Shifts	3952
Three Shifts	5928
Four Shifts or Continual Operation	8320
Unknown / Weighted average[933]	5702

---

928 Review of manufacturer’s information

929 Technical Reference Manual (TRM) for Ohio Senate Bill 221”Energy Efficiency and Conservation Program” and 09-512-GE-UNC, October 15, 2009. Pages 170-171

930 Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th
Edition, and manufacturers’ catalog.

931 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. See “Industrial System Standard Deemed Saving Analysis.xls”

932 Assumes 50% handheld air guns and 50% stationary air nozzles. 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 5 seconds of blow-off per minute of compressor run time is used.

933 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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh/HOURS * CF$$

Where:

ΔkWh = As calculated above

CF = summer peak coincidence factor

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[934]	0.89

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE CI-CPA-CNOZ-V02-190101

REVIEW DEADLINE: 1/1/2023

934 Ibid

4.7.5 Efficient Refrigerated Compressed Air 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 the warm, saturated compressed air is supplied directly into 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 of 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.[935]

DEEMED MEASURE COST

The incremental capital cost for this measure is $6 per CFM.[936]

LOADSHAPE

Loadshape C35 – Industrial Process

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

$$\Delta kWh = P_s \times (EC50_{baseline} - EC50_{efficient}) \times HOURS \times CFM$$

Where:

P_s = Full flow specific power of the dryer

[935] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[936] 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.

= 0.007 kW/CFM[937] (for both baseline and efficient equipment)

$EC50_{baseline}$ = Energy consumption ratio of baseline dryer at 50%[938] inlet load capacity as compared to fully loaded operating conditions.[939]

= 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[940]:

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	Hours	Distribution of Facilities by Hours of Operation[941]	Weighted Hours
Single Shift 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time	1,976	16%	316
Two Shifts 7AM – 11 PM, weekdays, minus some holidays and scheduled down time	3,952	23%	909
Three Shifts 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	5,702

CFM = Cubic feet per minute, rated capacity of refrigerated dryer

= Assume 100% of actual rated capacity.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh / HOURS * CF$

Where:

937 Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron.

938 Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50% capacity.

939 Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron.

940 Ibid.

941 DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.

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[933]	0.89

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-CPA-CADR-V02-190101

REVIEW DEADLINE: 1/1/2024

4.8 Miscellaneous End Use

4.8.1 Pump Optimization

DESCRIPTION

Pump improvements can be done to optimize the design and control of centrifugal water pumping systems, including water solutions with freeze protection up to 15% concentration by volume. Other fluid and gas pumps cannot use this measure calculation. The measurement of energy and demand savings for commercial and industrial applications will vary with the type of pumping technology, operating hours, efficiency, and existing and proposed controls. Depending on the specific application slowing the pump, trimming or replacing the impeller may be suitable options for improving pumping efficiency. Pumps up to 40 HP are allowed to use this energy savings calculation. Larger motors should use a custom calculation (which may result in larger savings that this measure would claim).

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is proven to be an optimized centrifugal pumping system meeting the applicable program efficiency requirements:

- Pump balancing valves no more than 15% throttled
- Balancing valves on at least one load 100% open.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 8 years[942]

DEEMED MEASURE COST

The incremental capital cost for this measure can vary considerably depending upon the strategy employed to achieve the required efficiency levels and should be determined on a site-specific basis.

DEEMED O&M COST ADJUSTMENTS

N/A

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 38%[943]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (HP_{motor} * 0.746 * LF / \eta_{motor}) * HOURS * ESF$$

[942] SCE Pump Test Final Report (2009), Summit Blue Consulting, LLC. This value is a weighted average of estimates provided by program participants.

[943] Summer Peak Coincidence Factor has been preserved from the “Technical Reference Manual” (TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC,” October 15, 2009. This is likely a conservative estimate, but is recommended for further study (as stated in the OH State TRM, page 269)

Where:

HP_{motor} = Installed nameplate motor horsepower

= Actual

0.746 = Conversion factor from horse-power to kW (kW/hp)

LF / η_{motor} = Combined as a single factor since efficiency is a function of load

= 0.65 [944]

Where:

LF = Load Factor; Ratio of the peak running load to the nameplate rating of the motor

η_{motor} = Motor efficiency at pump operating conditions

HOURS = Annual operating hours of the pump

= Actual

ESF = Energy Savings Factor; assume a value of 15%[945].

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (HP_{motor} * 0.746 * (LF / \eta_{motor})) * (ESF) * CF$$

Where:

CF = Summer Coincident Peak Factor for measure

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-PMPO-V02-190101

REVIEW DEADLINE: 1/1/2022

[944] "Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings," ACEEE 1994 Summer Study Conference, Asilomar, CA.

[945] Published estimates of typical pumping efficiency improvements range from 5 to 40%. For analysis purposes, assume 15%. United States Industrial Electric Motor Systems Market Opportunities Assessment December 2002, Table E-7, Page 18.

4.8.2 Roof Insulation for C&I Facilities

Description

Energy and demand saving are realized through reductions in the building cooling and heating loads. This measure was developed to be applicable to the following program types: RF and NC.

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

Definition of Efficient Equipment

The efficient condition is above code and should be determined by the program.

Definition of Baseline Equipment

The retrofit baseline condition is adopted from Ohio Energy Technical Reference Manual and expanded to cover all type of commercial buildings in the state of Illinois as follows.

For retrofits, the R-value for the entire assembly:

Building Type	Retrofit Assembly R-Value
Assembly	13.5
Assisted Living	13.5
College	13.5
Convenience Store	13.5
Elementary School	13.5
Garage	13.5
Grocery	13.5
Healthcare Clinic	13.5
High School	13.5
Hospital	13.5
Hotel/Motel	13.5
Manufacturing Facility	12
MF - High Rise	13.5
MF - Mid Rise	13.5
Movie Theater	13.5
Office - High Rise	13.5
Office - Low Rise	13.5
Office - Mid Rise	13.5
Religious Building	13.5
Restaurant	13.5
Retail - Department Store	13.5
Retail - Strip Mall	13.5
Warehouse	12
Unknown	13.5

For new construction use R-value from IECC 2012 or ASHRAE – 90.1 – 2010, or use IECCC 2015 or ASHRAE – 90.1 – 2013, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 (based on ASHRAE 90.1-2016) is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

R-Values: ASHRAE – 90.1 – 2010

	IL TRM Zones 1, 2, & 3 [ASHRAE/IECC Climate Zone 5 (A, B, C)]			
	Nonresidential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation Entirely Above Deck	0.048	R-20 c.i.	U-0.119	R-7.6 c.i.
Metal Building (Roof)	0.055	R-13.0 + R-13.0	U-0.083	R-13.0
Attic and Other	0.027	R-38.0	U-0.053	R-19.0

	IL TRM Zones 4 & 5 [ASHRAE/IECC Climate Zone 4 (A, B, C)]			
	Nonresidential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation Entirely Above Deck	0.048	R-20.0 c.i.	0.173	R-5.0 c.i.
Metal Building (Roof)	0.055	R-13.0 + R-13.0	0.097	R-10.0
Attic and Other	0.027	R-38.0	0.053	R-19.0

Table Notes
c.i. = continuous insulation

R-Values: ASHRAE – 90.1 – 2013 and 2016

	IL TRM Zones 1, 2, & 3 [ASHRAE/IECC Climate Zone 5 (A, B, C)]			
	Nonresidential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation Entirely Above Deck	0.032	R-30.0 c.i.	0.063	R-15 c.i.
Metal Building (Roof)	0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	0.082	R-19
Attic and Other	0.021	R-49	0.034	R-30

	IL TRM Zones 4 & 5 [ASHRAE/IECC Climate Zone 4 (A, B, C)]			
	Nonresidential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation Entirely Above Deck	0.032	R-30.0 c.i.	0.093	R-10 c.i.
Metal Building (Roof)	0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	0.082	R-19
Attic and Other	0.021	R-49	0.034	R-30

Table Notes
c.i. = continuous insulation

Ls = linear system, a continuous vapor barrier liner installed below the purlins and uninterrupted by framing members

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

Per the W017 Itron California Measure Cost Study[946], the material cost for R-30 insulation is $0.59 per square foot. The installation cost is $0.81 per square foot. The total measure cost, therefore, is $1.40 per square foot of insulation installed. However, the actual cost should be used when available.

LOADSHAPE

Loadshape C03: Commercial Cooling

COINCIDENCE FACTOR

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [947]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [948]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh\_cooling = ((1/R\_existing) - (1/R\_new)) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling} / 1{,}000 / \eta\_cooling$$

Where:

R_existing = Roof heat loss coefficient with existing insulation [(hr-^oF-ft^2)/Btu]

R_new = Roof heat loss coefficienty with new insulation [(hr-^oF-ft^2)/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^oF] during cooling season between outdoor air temperature and assumed 75^oF indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][949]	$\Delta T_{AVG,cooling}$ [°F]
1 (Rockford)	81	6
2 (Chicago)	81	6
3 (Springfield)	81	6
4 (Belleville)	82	7

[946] Measure costs are from the “2010-2012 WO017 Ex Ante Measure Cost Study”, Itron, California Public Utilities Commission, May 2014. The data is provided in a file named “MCS Results Matrix – Volume I”.
[947] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
[948] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
[949] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][949]	$\Delta T_{AVG,cooling}$ [°F]
5 (Marion)	82	7

1,000 = Conversion from Btu to kBtu

η_cooling = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh). Use actual if possible, if unknown and for planning purposes assume the following:

Year Equipment was Installed	SEER estimate
Before 2006	10
After 2006	13

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

$$\Delta kWh\_heating = [(1/R\_existing) - (1/R\_new)] * Area * EFLH_{heating} * \Delta T_{AVG,heating} / 3{,}412 / \eta\_heating$$

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 [^oF] during heating season between outdoor air temperature and assumed 55^{o}F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][950]	$\Delta T_{AVG,heating}$ [°F]
1 (Rockford)	32	23
2 (Chicago)	34	21
3 (Springfield)	35	20
4 (Belleville)	36	19
5 (Marion)	39	16

3,142 = Conversion from Btu to kWh.

η_heating = Efficiency of heating system. Use actual efficiency. If not available refer to default table below.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006	7.7	1.92
Resistance	N/A	N/A	1

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

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

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%

[950] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

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 4.4, HVAC end use

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [951]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [952]

NATURAL GAS SAVINGS

If building uses a gas furnace, the savings resulting from the insulation is calculated with the following formula.

$$\Delta Therms = ((1/R\_existing) - (1/R\_new)) * Area * EFLH_{heating} * \Delta T_{AVG,heating} / 100{,}000 / \eta\_heat$$

Where:

R_existing = Roof heat loss coefficient with existing insulation [(hr-^{o}F-ft^{2})/Btu]

R_new = Roof heat loss coefficienty with new insulation [(hr-^{o}F-ft^{2})/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{o}F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_heat = Efficiency of existing furnace. Assume 0.78 for planning purposes.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-RINS-V03-190101

REVIEW DEADLINE: 1/1/2021

[951] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[952] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

4.8.3 Computer Power Management Software

DESCRIPTION

Computer power management software is installed on a network of computers. This is software which monitors and records computer and monitor usage, as well as allows centralized control of computer power management settings.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined by the requirements listed below:

- Allow centralized control and override of computer power management settings of workstations which include both a computer monitor and CPU (i.e. a desktop or laptop computer on a distributed network)
- Be able to control on/off/sleep states on both the CPU and monitor according to the Network Administrator-defined schedules and apply power management policies to network groups
- Have capability to allow networked workstations to be remotely wakened from power-saving mode (e.g. for system maintenance or power/setting adjustments)
- Have capability to detect and monitor power management performance and generate energy savings reports
- Have capability to produce system reports to confirm the inventory and performance of equipment on which the software is installed.

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

DEFINITION OF BASELINE EQUIPMENT

Baseline is defined as a computer network without software enforcing the power management capabilities in existing computers and monitors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is five years.[953]

DEEMED MEASURE COST

The deemed measure cost is $29 per networked computer, including labor.[954]

LOADSHAPE

Loadshape C21: Commercial Office Equipment.

COINCIDENCE FACTOR

N/A

[953] The following reference uses 10 years, however, given the rapid changes in the technology industry, there is quite a lot of uncertainty about the measure life and a more conservative value was used (i.e. half the published measure life): Table VI.1: Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec, LLC).

[954] Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Wsavings * W$$

Where:

Wsavings = annual energy savings per workstation

= 200 kWh[955] for desktops, 50 kWh for laptops[956]

= If unknown assume 161 kWh (based on 74% desktop and 26% laptop[957])

W = number of desktop or laptop workstations controlled by the power management software

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

NATURAL GAS SAVING

NA

WATER IMPACT DESCRIPTIONS AND CALCULATION

NA

DEEMED O&M COST ADJUSTMENT CALCULATION

Assumed to be $2/unit [958]

MEASURE CODE: CI-MSC-CPMS-V01-150601

REVIEW DEADLINE: 1/1/2020

---

[955] Based on average energy savings/computer from the following sources:
South California Edison, Work Paper WPSCNROE0003 (200k Wh)
Surveyor Network Energy Manager Evaluation Report , NEEA (68, 100, and 128kWh)
Regional Technical Forum, UES Measures, Non-Res Network Computer Management (200 kWh)
EnergySTAR Computer Power Management Savings Calculator (~190 kWh for a mix of laptop/desktop and assuming 30% are already turned off at night) Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry (330 kWh)

[956] Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry

[957] Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.

[958] Based on Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec LLC and review of CLEARResult document providing Qualifying Software Providers for ComEd program and their licensing fees; “Qualifying Vendor Software Comparison.pdf”.

4.8.4 Modulating Commercial Gas Clothes Dryer

DESCRIPTION

This measure relates 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 properly for highest heat required in initial drying stages but is oversized for later drying stages requiring lesser heat. This causes the burner to cycle on/off frequently, resulting in less efficient drying and wasted gas. Replacing the single stage gas valve with a two-stage gas valve allows the firing rate to adjust to the changing heat demand, thereby reducing overall gas 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

A 30 to 250 pound capacity commercial gas dryer retrofitted with a two-stage modulating gas valve kit.

DEFINITION OF BASELINE EQUIPMENT

A 30 to 250 pound capacity commercial gas dryer with no modulating capabilities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life for the retrofit kit is 14 years, assumed to be equal to that of a commercial gas dryer[959].

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)[960].

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

959 Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013.
960 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.

NATURAL GAS ENERGY 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.

$$\Delta Therms = N_{Cycles} * SF$$

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[961]	1,483
Multi-family Dryers[962]	1,074
On-Premise Laundromats[963]	3,607

SF = Savings factor

= 0.18 therms/cycle[964]

If using default cycles the savings are as follows:

Application	ΔTherms
Coin- Operated Laundromats[965]	267
Multi-family Dryers[966]	193
On-Premise Laundromats[967]	649

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-MODD-V01-160601

REVIEW DEADLINE: 1/1/2023

961 From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy
962 Ibid.
963 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.
964 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.
965 From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy
966 Ibid.
967 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.

4.8.5 High Speed Clothes Washer

DESCRIPTION

This measure applies to the installation of clothes washers with extraction speeds of 200 g or greater, which is significantly higher than traditional hard-mount washers. Standard washer extractors in laundromats operate at speeds of 70-80[968] g. The high-speed extraction process in the wash cycle removes more water from each compared to standard washers, reducing operating time and gas consumption of clothes dryers. Heat exposure and mechanical action are also reduced, resulting in less linen wear.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is assumed to be a clothes washer with an extraction speed of 200 g or greater, installed in a commercial laundromat.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a clothes washer with an extraction speed of 100 g or less, installed in a commercial laundromat.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure lifetime is assumed to be the typical lifetime of a commercial clothes washer: 7 years[969].

For early replacement measures it is assumed the existing unit would last another 2.3 years[970]

DEEMED MEASURE COST[971]

The incremental cost for time of sale is $9.70/lb capacity.

The full cost of the high speed washer for early replacement applications is $164.89/lb capacity. The deferred replacement cost of the baseline unit is $155.19/lb capacity. This future cost should be discounted to present value using the real discount rate:

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

---

968 "The Real Size of a Front Load Washer", Laundromat123
969 "Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.
970 Third of expected measure life.
971 Measure costs are based on data from a quote provided by a commercial washer distributor to Franklin Energy Services.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = (Ncycles * Days * Capacity * RMC * h_e / \eta_{dryer} /100{,}000) * DryerUse * LF$$

Where:

Ncycles = Average number of washer cycles per day

= Use values from table below, depending on application

Application	Ncycles
Coin-operated Laundromats	4.3[972]
Multi-family	3.4[973]
Hotel/Motel/Hospital	10.4[974]

Days = Days per year of commercial laundromat operation

= Actual, or if unknown, assume 360 days[975]

Capacity = Clothes washer rated capacity (lb/cycle)[976]

= Actual

RMC = Retained Moisture Content (%)[977] reduction from replacing a low extraction speed washer

= Assume 25%[978]

[972] "2014-2015 State of the Self-Service Laundry Industry Report." Carlo Calma, April 13, 2015.

[973] "Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.

[974] "Laundry Planning Guide." EDRO, January 2015.

[975] Based on professional judgement, assuming closed on holidays.

[976] Clothes washer capacity is based on weight of dry clothing.

[977] The EDRO "Laundry Planning Guide" describes moisture retention as "the ratio of retained moisture weight to clean dry textile weight." The pounds of water retained by clothing at the end of a wash cycle is calculated by multiplying Capacity (lbs of dry clothing per cycle) by RMC.

[978] Using chart provided (Figure 1) and assuming a 100% nominal cotton load, the retained moisture drops from approximately 90% to 65% when a 100 g washer is replaced with a 200 g washer. Chart from "Laundry Planning Guide." EDRO, January 2015.

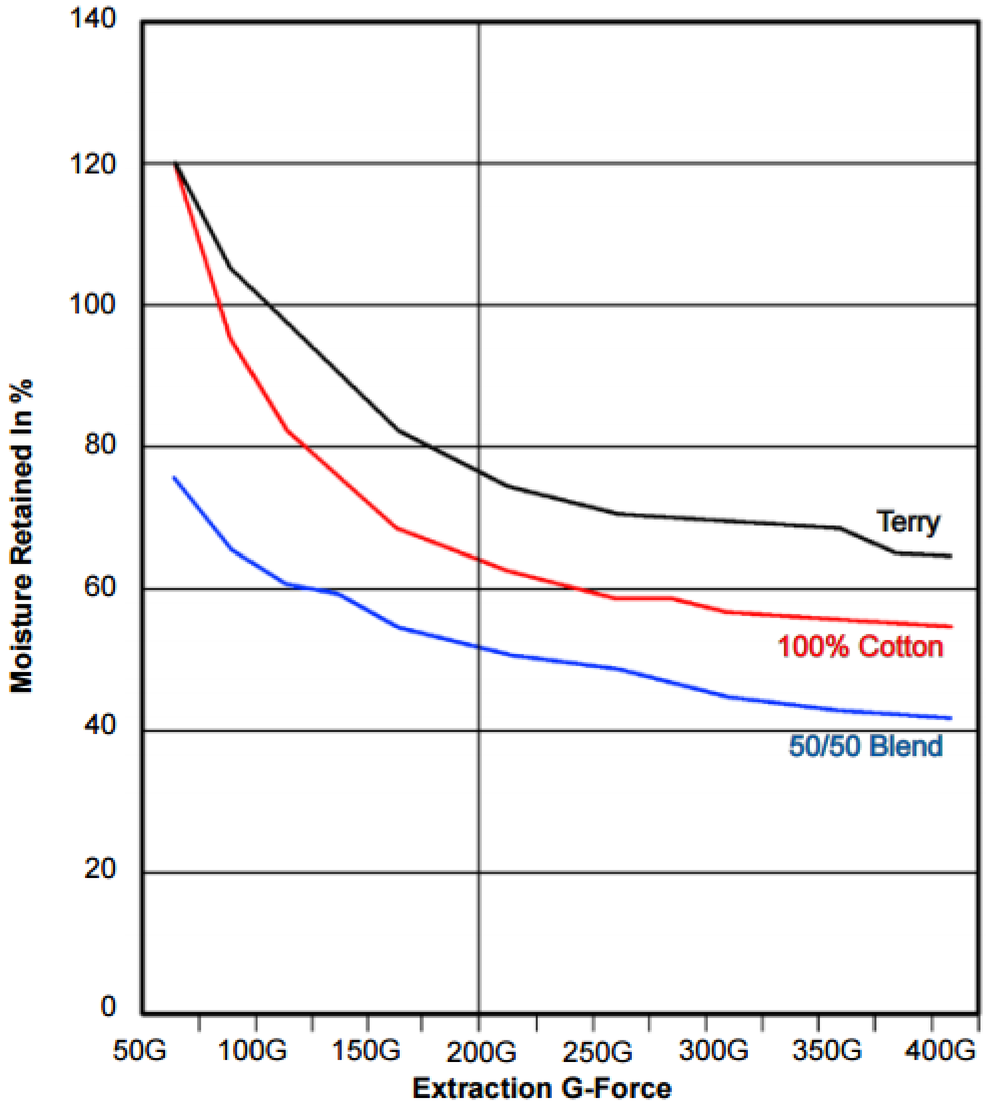


Figure 1

h_e = Heat required by a dryer to evaporate 1 lb of water

= Assume 1,200 Btu/lb[979]

η_{dryer} = Efficiency of the clothes dryer

= Actual, or if unknown, assume 60%[980]

100,000 = Converts Btus to therms

DryerUse = % of washer loads dried in the field

= Assume 91%[981]

LF = Load Factor (%) to account for the pounds per washer load, as a percentage of rated capacity

979 "Laundry Planning Guide." EDRO, January 2015.

980 ACEEE (2010), "Are We Missing Energy Savings in Clothes Dryers?" Paul Bendt (Ecos), 2010

981 "Dryer Field Study." Northwest Energy Efficiency Alliance, November 20, 2014.

= Assume 66%[982]

EXAMPLE

For example, a clothes washer with a 14 lb/cycle capacity and installed at a coin-operated laundromat, using default assumptions, would save:

ΔTherms = (Ncycles * Days * Capacity * RMC * h_e / η_{dryer} /100,000) * DryerUse * LF

= (4.3 * 360 * 14 * 0.25 * 1,200 / 0.60 /100,000) * 0.91 * 0.66

= 65 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-HSCW-V01-180101

REVIEW DEADLINE: 1/1/2021

[982] "Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.

4.8.6 ENERGY STAR Computers

DESCRIPTION

This measure estimates savings for a desktop computer with ENERGY STAR (ES) Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, and ES 6.0 with 80 PLUS Platinum PSUs.

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 efficient product is a desktop with a rating of ENERGY STAR Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, or ES 6.0 with 80 PLUS Platinum PSUs.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR qualified equipment with standard efficiency power supply

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.[983]

DEEMED MEASURE COST[984]

The incremental cost for an 80 Plus Desktop PSU is $5.
The incremental cost for an ENERGY STAR desktop PSU is $20.

LOADSHAPE

C21 Commercial Office Equipment

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[985]

$$\Delta kWh = 8760/1000 * (((Watts_{Base,Off} * \%Time_{Off}) + (Watts_{Base,Sleep} * \%Time_{Sleep}) + (Watts_{Base,Long} * \%Time_{Long}) + (Watts_{Base,Short} * \%Time_{Short})) - ((Watts_{Eff,Off} * \%Time_{Off}) + (Watts_{Eff,Sleep} * \%Time_{Sleep}) + (Watts_{Eff,Long} * \%Time_{Long}) + (Watts_{Eff,Short} * \%Time_{Short})))$$

Where (see assumptions in table below):

8760/1000 = Converts W to kWh

$Watts_{Base,Off}$ = baseline equipment power in off mode

$\%Time_{Off}$ = typical percent of time a desktop, integrated desktop or notebook is in off mode during the year

$Watts_{Base,Sleep}$ = baseline equipment power in sleep mode

[983] Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013. Page 6.
[984] Research Into Action, 80 PLUS Market Progress Evaluation Report #5, November 26, 2013. Page 24.
[985] Algorithm comes from ENERGY STAR Version 6.0 Guide

$\%Time_{Sleep}$ = typical percent time in sleep mode

$Watts_{Base,Long}$ = baseline equipment power in long idle mode

$\%Time_{Long}$ = typical percent time in long idle mode

$Watts_{Base,Short}$ = baseline equipment power in short idle mode

$\%Time_{Short}$ = typical percent time in short idle mode

$Watts_{Eff,Off}$ = efficient equipment power in off mode

$Watts_{Eff,Sleep}$ = efficient equipment power in sleep mode

$Watts_{Eff,Long}$ = efficient equipment power in long idle mode

$Watts_{Eff,Short}$ = efficient equipment power in short idle mode

Measure Annual Mode Time (%)	Off	Sleep	Long Idle	Short Idle
Duty cycle - Commercial[986]	45%	5%	15%	35%

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle
Baseline[987]	0.88	2.1	26.5	27.9
ES 6.0 Desktops[988]	0.55	1.23	24.66	26.04
ES 6.0 +20% Desktops[989]	0.52	1.63	21.33	22.58
ES 6.0 Desktops w/ 80 PLUS Gold PSUs[990]	0.50	1.50	23.08	24.38
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs[991]	0.50	1.50	22.19	23.44

Calculated energy consumption in each mode, and savings provided below:

Measure TEC by Mode (kWh) Commercial	Off	Sleep	Long Idle	Short Idle	TEC (kWh/yr)	Savings (kWh/yr)
Baseline	3.5	0.9	34.8	85.5	124.8	N/A
ES 6.0 Desktops	2.2	0.5	32.4	79.9	115.0	9.8
ES 6.0 +20% Desktops	2.0	0.7	28.0	69.2	100.0	24.7
ES 6.0 Desktops w/ 80 PLUS Gold PSUs	2.0	0.7	30.3	74.7	107.7	17.1
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs	2.0	0.7	29.2	71.9	103.7	21.1

Savings calculations can be referenced in "ENERGY STAR Desktop Analysis.xlsx"

986 ECMA 283, Appendix B, Majority Profile Study; ENERGY STAR v6.0 duty cycle. For more information, see the ENERGY STAR Program Requirements Product Specification for Computers, version 6.1, effective June 2, 2014

987 Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013

988 Analysis of current DT I2 category desktops in ENERGY STAR version 6.0 Qualified Products List (QPL).

989 Analysis of current DT I2 category desktops in ENERGY STAR version 6.0 Qualified Products List (QPL), passing with > 20% margin.

990 80 PLUS program savings calculator, additional 6.4% savings over ES v6.0 Bronze PSU levels. Based on program measurements from 80 PLUS Certified Power Supplies and Management.

991 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels.

SUMMER COINCIDENT PEAK DEMAND SAVINGS[992]

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

Where:

$Watts_{Base}$ = Assumed average baseline wattage during peak period (see table below)

$Watts_{Eff}$ = Assumed average efficient wattage during peak period (see table below)

CF = Summer Peak Coincidence Factor

= 1.0

Calculated average demand during peak period, and savings provided below:

Measure TEC by Mode (kWh) Commercial	TEC (watts)	Demand Savings
Baseline	25.2	N/A
ES 6.0 Desktops	23.4	0.0018
ES 6.0 +20% Desktops	20.3	0.0048
ES 6.0 Desktops w/ 80 PLUS Gold PSUs	21.9	0.0032
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs	21.1	0.0041

Savings calculations can be referenced in “ENERGY STAR Desktop Analysis.xlsx”

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-COMP-V01-180101

REVIEW DEADLINE: 1/1/2020

[992] It assumed that computers will not be off during peak period, and that the weighting of sleep, long idle and short idle during peak hours is consistent with the whole year. Wattage assumptions are weighted accordingly and coincidence factor is thus assumed to be 1.0 – see “ENERGY STAR Desktop Analysis.xlsx” for calculation.

4.8.7 Advanced Power Strip – Tier 1 Commercial

DESCRIPTION

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (e.g. a desk workstation) can be reduced. In a commercial office space, savings generally occur during off-hours, when connected equipment continues to consume electricity while in standby mode or when off. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

This measure 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

The efficient case is an advanced power strip with a load-sensing master plug and at least two controlled plugs.

DEFINITION OF BASELINE EQUIPMENT

The assumed baseline is a standard power strip with surge protection that does not control connected loads.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years.[993]

DEEMED MEASURE COST

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

LOADSHAPE

Loadshape C47 – Standby Losses – Commercial Office[994]

COINCIDENCE FACTOR

N/A due to no savings attributable to standby losses between 1 and 5 PM.

---

[993] This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

[994] Loadshapes were calculated from empirical studies and compared to the existing loadshape in Volume 1, Table 3.5. The studies were:

Acker, Brad *et. al,* “Office Space Plug Load Profiles and Energy Saving Interventions,” 2012 ACEEE Summer Study on Energy Efficiency in Buildings.

Sheppy, M. *et al*, “Reducing Plug Loads in Office Spaces” Hawaii and Guam Energy Improvement Technology Demonstration Project, NREL/NAVFAC (January 2014).

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh[995] = ((kW_{wkday} * (hrs_{wkday} - $hrs_{wkday\text{-}open}$)) + (kW_{wkend} * (hrs_{wkend} - $hrs_{wkend\text{-}open}$))) * weeks/year * ISR

Where:

W_{wkday} = Standby power consumption of connected electronics on weekday off-hours. If unknown, assume 0.0315 kW.

kW_{wkend} = Standby power consumption of connected electronics on weekend off-hours. If unknown, assume 0.00617 kW.

hrs_{wkday} = total hours during the work week (Monday 7:30 AM to Friday 5:30 PM)

= 106

hrs_{wkend} = total hours during the weekend (Friday 5:30 PM to Monday 7:30 AM)

= 62

$hrs_{wkday\text{-}open}$ = hours the office is open during the work week. If unknown, assume 50 hours.

$hrs_{wkend\text{-}open}$ = hours the office is open during the weekend. If unknown, assume 0 hours.

weeks/year = number of weeks per year

= 52.2

ISR = In Service Rate

= Assume 0.969 for commercial Direct Install application[996]

For example, an office open 9 hours per day (45 hours per week) on weekdays and 4 hours on Saturday:

ΔkWh = ((0.0315 * (106 - 45)) + (0.00617 * (62 - 4))) * 52.2 * 0.969

= 115 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A due to no savings attributable to standby losses between 1 and 5 PM.

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

---

[995] Savings algorithm reconstructed from weekday and weekend savings information in Sheppy *et. al*, and verified against savings in Acker *et. al* and savings in: BPA, "Smart Power Strip Energy Savings Evaluation: Ross Complex," (2011). Office stations are assumed to have zero or minimal standy losses during normal operating hours. Method shown in "Commercial Tier 1 APS Calculations – IL TRM.xlsx".

[996] Based upon review of the PY2 and PY3 ComEd Direct Install Residential program surveys. This value could be modified based upon commercial application evaluation.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-APSC-V02-190101

REVIEW DEADLINE: 1/1/2020

4.8.8 High Efficiency Transformer

DESCRIPTION

Distribution transformers are used in commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (220V or 480V) or to serve plug loads (120V).
Distribution transformers that are more efficient than the required minimum federal standard efficiency qualify for this measure. If there is no specific standard efficiency requirement, the transformer does not qualify (because we cannot define a reasonable baseline). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers (up to 333kVA single-phase and 1000kVA 3-phase), liquid-immersed distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase), and medium-voltage dry-type distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase).

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

Any transformer that is more efficient than the federal minimum standard. This includes CEE Tier II (single or three phase) and most NEMA premium efficiency rated products.

DEFINITION OF BASELINE EQUIPMENT

A transformer that meets the minimum federal efficiency requirement should be used as the baseline to calculate savings. Standards are developed by the Department of Energy and published in the Federal Register 10CFR 431[997].

(a) ***Low-Voltage Dry-Type Distribution Transformers.***

(2) The efficiency of a low-voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Low-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

Single-phase		Three-phase	
kVA	Efficiency (%)	kVA	Efficiency (%)
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1000	99.28

(b) ***Liquid-Immersed Distribution Transformers.***

[997] US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Compliance effective as of January 1, 2016.

(2) The efficiency of a liquid-immersed distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Liquid-immersed distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

Single-phase		Three-phase	
kVA	Efficiency (%)	kVA	Efficiency (%)
10	98.70	15	98.65
15	98.82	30	98.83
25	98.95	45	98.92
37.5	99.05	75	99.03
50	99.11	112.5	99.11
75	99.19	150	99.16
100	99.25	225	99.23
167	99.33	300	99.27
250	99.39	500	99.35
333	99.43	750	99.40
500	99.49	1000	99.43
667	99.52	1500	99.48
833	99.55	2000	99.51
		2500	99.53

(c) ***Medium-Voltage Dry-Type Distribution Transformers.***

(2) The efficiency of a medium- voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA and BIL rating in the table below. Medium-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

1				Three-phase			
kVA	BIL*			kVA	BIL		
	20-45 kV	46-95 kV	≥96 kV		20-45 kV	46-95 kV	≥96 kV
	Efficiency (%)	Efficiency (%)	Efficiency (%)		Efficiency (%)	Efficiency (%)	Efficiency (%)
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.13	
75	98.73	98.57	98.53	112.5	98.52	98.36	
100	98.82	98.67	98.63	150	98.65	98.51	
167	98.96	98.83	98.80	225	98.82	98.69	98.57
250	99.07	98.95	98.91	300	98.93	98.81	98.69
333	99.14	99.03	98.99	500	99.09	98.99	98.89
500	99.22	99.12	99.09	750	99.21	99.12	99.02
667	99.27	99.18	99.15	1000	99.28	99.20	99.11
833	99.31	99.23	99.20	1500	99.37	99.30	99.21
				2000	99.43	99.36	99.28
				2500	99.47	99.41	99.33

Deemed Lifetime of Efficient Equipment

30 years[998]

Deemed Measure Cost

Actual incremental costs should be used.

Loadshape

Use custom loadshape based on application; default loadshape is Loadshape C53 – Flat.

Coincidence Factor

Coincidence Factor for distribution transformers is 1.0 by definition. By including the load factor in the demand savings calculation, the load profile is accounted for.

Algorithm

Calculation of Energy Savings

Savings are determined by metering equipment

Electric Energy Savings

$$\Delta kWh = Losses_{base} - Losses_{EE}$$

Where:

$$Losses_{base} = \text{PowerRating} * \text{LF} * \text{PF} * \left(\frac{1}{EFF_{base}} - 1\right) * 8766$$

$$Losses_{EE} = \text{PowerRating} * \text{LF} * \text{PF} * \left(\frac{1}{EFF_{EE}} - 1\right) * 8766$$

PowerRating = kVA rating of the transformer (in units of kVA)

EFF_{base} = baseline total efficiency rating of federal minimum standard transformer (refer to baseline tables above based on kVA, voltage, and type of transformer)

EFF_{EE} = actual total efficiency rating of the transformer as calculated by the appropriate DOE test method[999]

LF = Load Factor for the transformer. Ratio of average transformer load to peak load rating over a period of one year. Use actual load factor for the network segment served based on historical data. If unknown, use 22% for commercial load and 45% for industrial load.[1000]

PF = Power Factor for the load being served by the transformer. Ratio of real power to apparent power supplied to the transformer. Use actual power factor for the network segment served. If unknown, use 1.0 (unity) by default.[1001]

---

[998] US DOE lists lifetime at 32 years. For consistency with efficiency measure evaluated lifetimes, 30 years is the recommended maximum deemed lifetime. US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Effective as of January 1, 2016.

[999] Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

[1000] Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013

[1001] Unity power factor for used as default value, as used in the test procedures provided by US DOE. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = PowerRating * \ LF * PF * \left(\frac{1}{Eff_{base}} - \frac{1}{Eff_{EE}}\right)$$

Variables as provided above.

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-TRNS-V01-180101

REVIEW DEADLINE: 1/1/2021

4.8.9 High Frequency Battery Chargers

DESCRIPTION

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers have a greater system efficiency.

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

DEFINITION OF EFFICIENT EQUIPMENT

High frequency battery charger systems with minimum Power Conversion Efficiency of 90% and a minimum 8-hour shift operation five days per week.

DEFINITION OF BASELINE EQUIPMENT

SCR or ferroresonant battery charger systems with minimum 8-hour shift operation five days per week.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

15 years[1002]

DEEMED MEASURE COST

The deemed incremental measure cost is $400[1003]

LOADSHAPE

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

COINCIDENCE FACTOR

The coincidence factor is assumed to be 0.0 for 1 and 2-shift operation and 1.0 for 3 and 4-shift operation. [1004]

Algorithm

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (CAP * DOD) * CHG * (CR_B / PC_B - CR_{EE} / PC_{EE})$$

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh[1005]

DOD = Depth of Discharge

[1002] Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 45
[1003] Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 42
[1004] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.
[1005] 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

= Use actual depth of discharge, otherwise use a default value of 80%.[1006]

CHG = Number of Charges per year

= Use actual number of annual charges, if unknown use values below based on the type of operations[1007]

Standard Operations	Number of Charges per year
1-shift (8 hrs/day – 5 days/week)	520
2-shift (16 hrs/day – 5 days/week)	1040
3-shift (24 hrs/day – 5 days/week)	1560
4-shift (24 hrs/day – 7 days/week)	2184

CR_B = Baseline Charge Return Factor

= 1.2485[1008]

PC_B = Baseline Power Conversion Efficiency

= 0.84[1009]

CR_{EE} = Efficient Charge Return Factor

= 1.107[1010]

PC_{EE} = Efficient Power Conversion Efficiency

= 0.89[1011]

Default savings using defaults provided above are provided below:

Standard Operations	ΔkWh
1-shift (8 hrs/day – 5 days/week)	3,531
2-shift (16 hrs/day – 5 days/week)	7,061
3-shift (24 hrs/day – 5 days/week)	10,592
4-shift (24 hrs/day – 7 days/week)	14,829

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (PF_B/PC_B - PF_{EE}/PC_{EE}) * Volts_{DC} * Amps_{DC} / 1000 * CF$$

Where:

PF_B = Power factor of baseline charger

= 0.9095[1012]

[1006] 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

[1007] 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

[1008] 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)

[1009] Ibid.

[1010] Ibid.

[1011] Ibid.

[1012] Ibid.

PF_{EE} = Power factor of high frequency charger

= 0.9370[1013]

$Volts_{DC}$ = 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.[1014]

$Amps_{DC}$ = 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.[1015]

1,000 = watt to kilowatt conversion factor

CF = Summer Coincident Peak Factor for this measure

= 0.0 (for 1 and 2-shift operation)[1016]

= 1.0 (for 3 and 4-shift operation)[1017]

Other variables as provided above.

Default savings using defaults provided above are provided below:

Standard Operations	ΔkW
1-shift (8 hrs/day – 5 days/week)	0
2-shift (16 hrs/day – 5 days/week)	0
3-shift (24 hrs/day – 5 days/week)	0.1165
4-shift (24 hrs/day – 7 days/week)	0.1165

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-BACH-V01-180101

REVIEW DEADLINE: 1/1/2021

1013 Ibid.

1014 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.

1015 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.

1016 Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.

1017 Ibid.

4.8.10 Commercial Clothes Dryer Moisture Sensor

DESCRIPTION

This measure applies to moisture sensing controllers installed on new or existing commercial natural gas clothes dryers controlled electronically. Moisture controllers detect when the load is dry, which will stop the cycle from consuming additional energy. Some new commercial dryers utilize moisture sensors, but the majority of older dryers, as well as many new models, still do not utilize moisture sensors. In a commercial dyer, when a load is drying, the heat will run completely on in the early stages. Then, it begins to cycle on and off more frequently as the load becomes drier. Traditional moisture sensors use a conductivity strip in the dryer drum. The wet load will contact the strip that completes the circuit. When the load is dry, the circuit is shorted that completes the drying cycle. Instead, this technology is a "plug and play" retrofit controller that uses patent-pending software to determine when the load is dry. When the load is dry, it overrides the existing controls to end the cycle, which shuts the drying cycle. This measure does not apply to mechanical timer dryers or to dryers with modulating valves installed.

Natural gas energy savings will be achieved by reduced drying times and correspondingly reduced natural gas consumption. Electric savings will also be achieved by reduced operating times.

This measure was developed to be applicable to following facility types:

- Hotel/Motel
- Miscellaneous - Fitness and Recreational Sports Centers
- Hospital
- Assisted Living Facilities
- Miscellaneous - Dry cleaning
- Multifamily

Moisture sensing controller retrofits could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries); however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.) capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

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 retrofit moisture controlling technology is added to new or existing commercial natural gas clothes dryers. Existing facilities must be able to confirm that they do not have moisture sensors (conductive strip type) or modulating gas valves installed on clothes dryers already before proceeding with the installation of this technology.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a conventional natural gas clothes dryer without a moisture sensor or a modulating gas valve installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The equipment effective useful life (EUL) is 14 years based on manufacturer claims, assumed to be equal to that of a commercial dryer.[1018]

[1018] Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013.

Deemed Measure Cost

The full retrofit cost is assumed to be $600, including the material cost for the basic moisture control retrofit ($500) and the associated labor for installation ($100).[1019]

Loadshape

Loadshape C55; Commercial Clothes Washer

Coincidence Factor

The coincidence factor for this measure is dependent on the application:

Application	Coincidence Factor[1020]
Multi-family Dryers	0.15
On-Premise Laundromats	0.52

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Electric energy savings are per retrofitted dryer.

$\Delta kWh = N_{Cycles} * SF$

Where:

N_{Cycles} = Number of dryer cycles per year. Refer to the table below if this value is not directly available from the facility.

Application	Cycles per Dryer Per Year
Multi-family Dryers[1021]	1,074
On-Premise Laundromats[1022]	3,607

SF = Savings factor

= 0.16 kWh/cycle[1023]

If using default cycles the savings are as follows:

Application	ΔkWh per Dryer
Multi-family Dryers	171.8
On-Premise Laundromats	577.1

[1019] Based on Gas Technology Institute's analysis of cost data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017.

[1020] In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications).

[1021] From DOE's Federal Register Notices - found here: http://energy.gov/eere/buildings/recent-federal-register-notices

[1022] 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.

[1023] Savings factor based on engineering analysis of savings data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017 and "Advanced Commercial Clothes Dryer Technologies Field Test," prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh / Hours * CF$

Where:

Hours = Assumed Run hours of Clothes Dryer[1024]

Application	Hours
Multi-family Dryers	806
On-Premise Laundromats	2,705

CF = Summer Peak Coincidence Factor for measure.

Application	Coincidence Factor[1025]
Multi-family Dryers	0.15
On-Premise Laundromats	0.52

If using default cycles the savings are as follows:

Application	ΔkW per Dryer
Multi-family Dryers	0.0320
On-Premise Laundromats	0.1109

NATURAL GAS SAVINGS

Natural gas savings are per retrofitted dryer.

$\Delta Therms = N_{Cycles} * SF$

Where:

SF = Savings factor

= 0.15 therms/cycle[1026]

If using default cycles the savings are as follows:

Application	ΔTherms per Dryer
Multi-family Dryers	161
On-Premise Laundromats	541

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-CDMS-V01-190101

REVIEW DEADLINE: 1/1/2023

1024 Estimate based on 45 minutes per cycle.

1025 In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications).

1026 Savings factor based on engineering analysis of savings data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017 and "Advanced Commercial Clothes Dryer Technologies Field Test," prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018.

4.8.11 Efficient Thermal Oxidizers

DESCRIPTION

Thermal Oxidizers are used to destroy volatile organic compounds (VOCs) from process exhausts, before emitting the treated air to the environment. VOC emissions are precursors to the formation of ground-level ozone pollution, and its control is mandated by the U.S. EPA. Some VOC constituents are individually toxic and require efficient destruction. Some waste streams have high enough concentrations to present an explosion hazard. Other waste streams merely present nuisance odors that need to be mitigated.

A facility may be required to utilize a Thermal Oxidizer by a state regulatory agency air quality permit. Some permits may require a VOC destruction efficiency that must be demonstrated with periodic emissions testing. Other permits merely require maintaining an oxidizer chamber temperature. A facility may also choose to utilize a Thermal Oxidizer for other purposes (nuisance odors), without a regulatory requirement.

The Efficient Thermal Oxidizer measure seeks to evaluate natural gas savings from utilizing more efficient means for VOC destruction with the use of a recuperative or regenerative thermal oxidizer. The heat recovery (either Recuperative or Regenerative) is used to pre-heat the inlet process air stream. This primary heat recovery is used within the thermal oxidizer process and the only heat recovery that is covered in this measure protocol. Natural gas savings will result from reduced burner firing. There is a “secondary” form of heat recovery that recovers heat from the combustion exhaust stack for other purposes like space heating, DHW heating, etc.

DEFINITION OF EFFICIENT EQUIPMENT

Two Thermal Oxidizer technologies can be considered as efficient equipment: Recuperative and Regenerative.

Recuperative Thermal Oxidizer

In a Recuperative Thermal Oxidizer, the exhaust air stream is sent through a heat exchanger to indirectly pre-heat the inlet air stream coming from the process. The heat exchanger efficiency[1027] for a recuperator is typically 50-70%. The chamber temperature is typically 1400 ^{o}F to 1500 ^{o}F.

Regenerative Thermal Oxidizer

A Regenerative Thermal Oxidizer utilizes a two-chamber ceramic bed as its heat exchanger system. The exhaust air passes through one bed, imparting its heat onto the ceramic media, while the intake air passes through the other bed, capturing the waste heat from the previous cycle. The flow reverses every few minutes so that the intake bed becomes the exhausted bed and vice versa. The heat exchanger efficiency of a regenerative system is much higher than a recuperative system. These efficiencies[1028] can reach 85% to 97%. However, the ceramic media needs to be periodically cleaned or replaced. The chamber temperatures in Regenerative Thermal Oxidizers are typically 1,500 ^{o}F to 1,600 ^{o}F (depending on VOC requirements).

DEFINITION OF BASELINE EQUIPMENT

Depending on the facility process, there may be two baseline selection options: incinerator or recuperator.

The baseline Thermal Oxidizer with no heat recovery is referred to as an Incinerator. This baseline is recommended for selection if it currently exists on site or in new construction when there is a specific process that cannot practically utilize a recuperator due to VOCs coating or clogging the heat exchanger. This system employs a burner to provide direct fire to a process exhaust air stream. Typical operative temperatures are 1400 ^{o}F to 2200 ^{o}F. The advantage of an afterburner is a quick startup and shutdown time that is ready on demand. The equipment cost is lower than the efficient equipment, but the fuel consumption is much higher.

[1027] Presentation on the “Operating Cost Reduction Strategies for Oxidizers”, presented by Rich Grzanka, during the Chem Show Technology Exposition on October 31, 2007.
[1028] Ibid.

In all other cases, (existing equipment is recuperative or new construction/ expansion of manufacturing process), a recuperative thermal oxidizer is recommended as the appropriate baseline.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected useful life of any thermal oxidizer system is assumed to 20 years.[1029]

DEEMED MEASURE COST

The cost[1030] of any thermal oxidizer is dependent on various variables such as air flow capacity, destruction efficiency, heat exchanger efficiency, etc. Shown below is an example of a system for 20,000 CFM.

Recuperative Thermal Oxidizer costs, based on their heat recovery efficiency, is detailed in the table below.

Heat Recovery Efficiency	Equipment Cost
0%	$106,042
35%	$174,193
50%	$203,801
70%	$253,801
Average	$184,317

Regenerative Thermal Oxidizer, at 95% heat recovery, have a deemed cost of $546,000.

Incinerator cost is treated as 0% heat recovery in the Recuperative Cost summary table above, and has a deemed cost of $106,042.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

Energy savings from thermally efficient equipment are entirely natural gas related. There are no electricity savings nor peak demand savings, as the blower fans and valve actuators are assumed to operate the same in all conditions.

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = ((Baseline QT Air Pollution Control Device - Proposed QT Air Pollution Control Device) x Hours) / LHV

Where:

[1029] EPA Air Pollution Control Cost Manual, Chapter 2, November 2017. The system capital recovery cost is based on an estimated 20-year equipment life. This estimate of oxidizer equipment life is consistent with information available to EPA and is consistent with statements from large vendors for incinerators and oxidizers.
[1030] U.S. Environmental Protection Agency, Incinerators and Oxidizers, Chapter 2, November 2017

LHV = Latent Heat of Vaporization

= If the post is regenerative thermal oxidizer, LHV = 0.953.

= If the post is recuperative thermal oxidizer, LHV = 1.

Regenerative or Recuperative: A baseline or proposed Regenerative or Recuperative Air Pollution Control Device can each be modeled in the following heat balance equation[1031]:

QT (BTU/hr) = QI + QCC + QRL – QVOC

Incinerator: A baseline incinerator Air Pollution Control Device can be modeled as the following heat balance equation:

QT (BTU/hr) = QI + QCC + QRL

Where:

QT = Total Energy Input

QI = Energy used to raise the temperature of process air (FI) in BTU/hr

QCC = Heat used to raise the temperature of combustion air (FCC)

QRL = Radiation heat loss from RTO (BTU/hr)

QVOC = Heat release provided by VOC combustion

Hours = Annual hours per year that Oxidizer is used

Where:

QI = FI X 1.08 x (TO – TI)

TO = Average stack outlet temperature (°F) (actual trended average or use efficiency equation below to solve for TO under assumed conditions)

TO = TC - (N X (TC - TI) X FI / (FI + FCC)

TC = Combustion chamber temperature (°F), trended or design value provided by the manufacturer

N = Thermal Efficiency of Heat Exchanger

Thermal Oxidizer	Efficiency
Regenerative	97%
Recuperative	70%
Incinerator	0%

TI = Inlet air temperature (°F), this is the temperature of the air coming from the process

FI = Process air (CFM), actual loading or use maximum design value

1.08 = Conversion Factor

= 60 (min/hr) x 0.07489 (lb/ft^3, density air at standard conditions) x 0.2404 Btu/°F-lb, (specific heat of air), where 0.2404 is average heat capacity of intake air

Where:

QCC = FCC X 1.08 X (TO – TA)

FCC = Additional combustion air CFM at provided FI value

[1031] ICAC Guidance Method for Estimation of Gas Consumption in a Regenerative Thermal Oxidizer (RTO), July 2002.

= If unknown, assume 3% of design value[1032]

TO = Average outlet temperature (°F) (same as above)

TA = Combustion intake air temperature (°F)

= Indoor: Actual, or assume 70 °F year-round

= Outdoor: Actual annual average found near the facility, or assume TMY3 annual averages:

Region / Area	Average Outdoor Air Temperature
Chicago O'Hare	50.0 °F
Chicago Midway	52.5 °F
Rockford Airport	47.6 °F

Where:

QRL = SA x BTU/hr radiant loss

SA = Surface Area (provided by the manufacturer or rough measurements taken)

BTU/hr radiant loss = Assume 240 BTU/hr if installed outdoors, otherwise, 0 BTU/hr for indoor installation since the waste heat provides space heating and offset gas-fired space heating equipment

Where:

QVOC = VOC X HC X (% Dest / 100)

VOC = Average lbs/hr from process to oxidizer

HC = Btu/lb, weighted average for the heat of combustion of VOCS

= Site-specific, lookup table

% Destruction = Destruction efficiency of VOCs provided by the manufacturer, or use:

Hours = Annual hours of operation of the air pollution control device, assume customer production schedule or hours of occupancy

LHV = Lower heating value of natural gas

= 983 BTU/CF[1033]

HHV = High heating value of natural gas

= 1,031 BTU/CF[1034]

0.953 = LHV / HHV conversion factor

To calculate the natural gas savings by upgrading from an incinerator to an Efficient Thermal Oxidizer system, the new temperatures must be considered. The addition of heat recovery (either Recuperative or Regenerative) will increase the inlet temperature, TI, above that found in the facility.

The calculation should consider changes in the inlet temperature. First, the key temperature required for 99.99% destruction efficiency of various VOC compounds must be determined. The U.S. EPA's Innovative Strategies and Economics Group produced some guidance on the key temperatures[1035] for the following compounds:

[1032] Ibid.
[1033] Biomass Energy Data Book, 2011, Appendix A: Lower and Higher Heating Values of Gas, Liquid, and Solid Fuels
[1034] Heat content of natural gas delivered to consumers per the Energy Information Administration, Independent Statistics & Analysis, 2018
[1035] U.S. Environmental Protection Agency, Incinerators and Oxidizers, Chapter 2, November 2017

VOC Compound	Key Destruction Temperature (°F)
Acrylonitrile	1,344
Allyl chloride	1,276
Benzene	1,350
Chlorobenzene	1,407
1,2 – dichloromethane	1,368
Methyl chloride	1,596
Toluene	1,341
Vinyl chloride	1,369

For VOC compounds not listed above, the Key Destruction Temperature should be determined through product literature, equipment vendors, Material Data Safety Sheets (MSDS), or some other source.

When employing heat recovery, either Recuperative or Regenerative, the increased outlet temperature is limited to the heat exchanger efficiency. This efficiency, or in other words how much heat can be recovered, is limited to the auto-ignition temperatures of the VOCs in the air stream. Regenerative Thermal Oxidizers offer the advantage of recovering more heat as the combustion can occur within the heat exchanger, whereas with Recuperative Thermal Oxidizers, the heat exchanger efficiency is much lower to prevent premature combustion in the stack of the recuperator.

While the VOCs in the waste air stream have some heating value that contributes to reaching the required chamber temperature, such contributions do not have as high of an impact in the overall energy consumption calculation when compared to the heat exchanger efficiency.

Water and Other Non-Energy Impact Descriptions and Calculation

Thermal oxidizer operations will have no impact on water or other resources. There may be some safety issues with potential burning hazards from deploying this equipment at high temperatures. There may also be some potential issues with installing outdoor natural gas piping to the location of the Thermal Oxidizers. In terms of physical sizing, regenerative thermal oxidizers are much larger, thus requiring larger physical space at the site of installation.

Deemed O&M Cost Adjustment Calculation

The ceramic media in the regenerative thermal oxidizer requires regular servicing and may need to be considered as a regular part of facility O&M.

Measure Code: CI-MSC-ETOX-V01-190101

Review Deadline: 1/1/2023