Illinois Statewide Technical Reference Manual for Energy Efficiency

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Volume 2: Commercial and Industrial Measures

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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

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

$$= 78.39\% * 87\ days * 84.23\% * 7.765\ Hr/Day * 1.5\ kW - 5.46\ kWh$$

$$= 664\ kWh$$

[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

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: RS-APL-ESDH-V01-120601

REVIEW DEADLINE: 1/1/2019

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[3].

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 s useful life.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[4].

Deemed Measure Cost

The incremental capital cost for the fans are as follows[5]:

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 therefor a coincidence factor is not applied.

Algorithm

Calculation of Savings

Electric Energy Savings [6]

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	6577

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

Fan Diameter Size (feet)	kWh Savings
22	8543
24	10018

SUMMER COINCIDENT PEAK DEMAND SAVINGS[7]

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-V01-120601

REVIEW DEADLINE: 1/1/2019

[7] 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 criteria[8].

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[9].

DEEMED MEASURE COST

The incremental capital cost for all fan sizes is $150[10].

LOADSHAPE

Loadshape C34 - Industrial Motor

COINCIDENCE FACTOR

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [11]

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

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

Diameter of Fan (inches)	kWh
24 through 35	372
36 through 47	625
48 through 71	1122

SUMMER COINCIDENT PEAK DEMAND SAVINGS[12]

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_-V01-120601

REVIEW DEADLINE: 1/1/2019

[12] Ibid.

4.1.4 Live Stock 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.

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[13].

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[14].

Deemed Measure Cost

The incremental capital cost for the waters are $787.50:[15]

Loadshape

Loadshape C04 - Non-Residential Electric Heating

Coincidence Factor

The measure has deemed kW savings therefor a coincidence factor is not applied

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Algorithm

Calculation of Savings

Electric Energy Savings [16]

The annual electric savings from this measure is a deemed value and assumed to be 1592.85 kWh.

Summer Coincident Peak Demand Savings

The annual kW savings from this measure is a deemed value and assumed to be 0.525 kW. [17]

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

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-V01-120601

REVIEW DEADLINE: 6/1/2018

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.[18]

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	≤ 200P+6,511	≥ 41
	Convection Mode	≤ 150P+5,425	≥ 56
Electric	Steam Mode	≤ 0.133P+0.6400	≥ 55
	Convection Mode	≤ 0.080P+0.4989	≥ 76

Note: P = Pan capacity as defined in Section 1.S, of the Commercial Ovens Program Requirements Version 2.1[19]

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.[20]

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[21]:

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

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[18] ENERGY STAR Commercial Ovens Key Product Criteria
http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens

[19] 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.
http://www.energystar.gov/products/specs/system/files/Commercial%20Ovens%20Program%20Requirements%20V2%201.pdf?965d-c5ec&3b06-d2f5

[20] http://www.fishnick.com/saveenergy/tools/calculators/gcombicalc.php

[21] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

Location	CF
Pizza	0.46
Full Service Limited Menu	0.51
Full Service Expanded Menu	0.36
Cafeteria	0.36

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

The algorithm below applies to electric combination ovens only.[22]

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

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

[22] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

	Base	EE
$ElecEFF_{Conv}$	72%	76%
$ElecEFF_{Steam}$	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[23]:

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

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

[23] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is 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

The algorithm below applies to natural gas combination ovens only.[24]

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

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

[24] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

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 vertical solid or glass door refrigerator or freezer or vertical chest freezer meeting the minimum ENERGY STAR efficiency level standards.

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be an existing solid or glass door refrigerator or freezer meeting the minimum federal manufacturing standards as specified by the Energy Policy Act of 2005.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years [25].

Deemed Measure Cost

The incremental capital cost for this measure is provided below[26].

Type	Refrigerator incremental Cost, per unit	Freezer Incremental Cost, per unit
Solid or Glass Door		
0 < V < 15	$143	$142
15 ≤ V < 30	$164	$166
30 ≤ V < 50	$164	$166
V ≥ 50	$249	$407

Loadshape

Loadshape C23 - Commercial Refrigeration

[25] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf

[26] Estimates of the incremental cost of commercial refrigerators and freezers varies widely by source. Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002, indicates that incremental cost is approximately zero. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010, assumed incremental cost ranging from $75 to $125 depending on equipment volume. ACEEE notes that incremental cost ranges from 0 to 10% of the baseline unit cost <http://www.aceee.org/ogeece/ch5_reach.htm>. For the purposes of this characterization, assume and incremental cost adder of 5% on the full unit costs presented in 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 assumed to be 0.937.[27]

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[28]
Solid Door Refrigerator	0.10 * V + 2.04
Glass Door Refrigerator	0.12 * V + 3.34
Solid Door Freezer	0.40 * V + 1.38
Glass Door Freezer	0.75 * V + 4.10

kWhee[29] = 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.

Type	Refrigerator kWhee	Freezer kWhee
0 < V < 15	≤ 0.089V + 1.411	≤ 0.250V + 1.250
15 ≤ V < 30	≤ 0.037V + 2.200	≤ 0.400V – 1.000
30 ≤ V < 50	≤ 0.056V + 1.635	≤ 0.163V + 6.125
V ≥ 50	≤ 0.060V + 1.416	≤ 0.158V + 6.333
Glass Door		
0 < V < 15	≤ 0.118V + 1.382	≤ 0.607V + 0.893
15 ≤ V < 30	≤ 0.140V + 1.050	≤ 0.733V – 1.000
30 ≤ V < 50	≤ 0.088V + 2.625	≤ 0.250V + 13.500
V ≥ 50	≤ 0.110V + 1.500	≤ 0.450V + 3.500

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

= Actual installed

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

[28] Energy Policy Act of 2005. Accessed on 7/7/10. <http://www.epa.gov/oust/fedlaws/publ_109-058.pdf>

[29] ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 2.0, U.S. Environmental Protection Agency, Accessed on 7/7/10. < http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req.pdf>

365.25 = days per year

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

$\Delta kWh = (3.54 - 2.76) * 365.25$

$= 285$ kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh / HOURS * CF$

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

$\Delta kW = 285 / 8766 * .937$

$= 0.030$ 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-V01-120601

REVIEW DEADLINE: 1/1/2019

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[30]

DEEMED MEASURE COST

The incremental capital cost for this measure is $998[31] for a natural gas steam cooker or $2490[32] 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[33]:

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

[30] California DEER 2008 which is also used by both the Food Service Technology Center and ENERGY STAR®.
[31] Source for incremental cost for efficient natural gas steamer is RSG Commercial Gas Steamer Workpaper, January 2012.
[32] 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.
[33] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is 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	0.36
Unknown	0.40

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%[34]

$IDLE_{Base}$ = Idle Energy Rate of Base Steamer[35]

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[36]

Number of Pans	PC_{BASE}, gas (lbs/hr)	PC_{BASE}, electric (lbs/hr)
3	65	70
4	87	93

[34]Food Service Technology Center 2011 Savings Calculator
[35]Food Service Technology Center 2011 Savings Calculator
[36]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.

Number of Pans	PC_{BASE}, gas (lbs/hr)	PC_{BASE}, electric (lbs/hr)
5	108	117
6	130	140

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[37] (gas steamers) or 0.0308[8] (electric steamers)

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

=15%[38] (gas steamers) or 26%[9] (electric steamers)

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

Type of Food Service	Hoursday[39]
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[40]
Custom	Varies

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[41]

$CSM_{\%ENERGYSTAR}$ = ENERGY STAR Steamer's Time in Manual Steam Mode (% of time)[42]

= 0%

$IDLE_{ENERGYSTAR}$ = Idle Energy Rate of ENERGY STAR®[43]

Number of Pans	$IDLE_{ENERGY\ STAR}$ – gas, (Btu/hr)	$IDLE_{ENERGY\ STAR}$ – electric, (kW)
3	6250	0.40
4	8333	0.53
5	10417	0.67

[37] Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC.

[38] 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.

[39] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.

[40] Unknown is average of other locations

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

[42] 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® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC for efficient steamer. Both baseline & efficient steamer mode values should be considered for users in Illinois market.

[43] Food Service Technology Center 2011 Savings Calculator

Number of Pans	$IDLE_{ENERGY\ STAR}$ – gas, (Btu/hr)	$IDLE_{ENERGY\ STAR}$ – electric, (kW)
6	12500	0.80

PC_{ENERGY} = Production Capacity of ENERGY STAR® Steamer[44]

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%[45] (gas steamer) or 50%[15] (electric steamer)

PRE_{number} = Number of preheats per day

=1[46] (if unknown, use 1)

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

Where:

PRE_{number} = Number of Preheats per Day

=1[47](if unknown, use 1)

PRE_{heat} = Preheat energy savings per preheat

= 11,000 Btu/preheat[48] (gas steamer) or 0.5 kWh/preheat[49] (electric steamer)

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

Where:

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

=15%[50] (gas steamer) or 26%[28] (electric steamer)

---

[44]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.

[45]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 and http://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Steam_Cookers_Program_Requirements.pdf?7010-36eb

[46]Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC and Food

[47]Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC and Food

[48]Ohio TRM which references 2002 Food Service Technology Center "Commercial Cooking Appliance Technology Assessment" Chapter 8: Steamers. This is time also used by ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC. 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

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

[50] 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.

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

=38%[51] (gas steamer) or 50%[23] (electric steamer)

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[52]

E_{FOOD} = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food[53]

E_{FOOD} - gas(Btu/lb)	E_{FOOD} (kWh/lb)
105[54]	0.0308[55]

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

[51] Ibid.
[52]Amount used by both Food Service Technology Center and ENERGY STAR® savings calculator
[53]Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC.
[54]Ibid.
[55]Ibid.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

This is only applicable to the electric steam cooker.

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

Where:

CF =Summer Peak Coincidence Factor for measure is provided below for different locations[56]:

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

$Days_{Year}$ =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:

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

$= (13{,}649/ (6 * 365.25)) * 0.36$

$= 2.24$ kW

WATER IMPACT DESCRIPTIONS AND CALCULATION

This is applicable to both gas and electric steam cookers.

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

Where

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

= 40[57]

$W_{ENERGYSTAR}$ = Water Consumption Rate of ENERGY STAR® Steamer look up[58]

CEE Tier	gal/hr
Tier 1A	15
Tier 1B	4

[56] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.

[57] FSTC (2002). Commercial Cooking Appliance Technology Assessment. Chapter 8: Steamers.

[58] 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.

CEE Tier	gal/hr
Avg Efficient	10
Avg Most Efficient	3

$Days_{Year}$ =Annual Days of Operation

=custom or 365.25 days a year[59]

EXAMPLE

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

ΔWater = (40 -10) * 7 * 365.25

= 76,703 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-STMC-V04-160601

REVIEW DEADLINE: 1/1/2023

[59]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.[60]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1800[61].

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

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

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 884 Therms[62].

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

[62] 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[63]

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[64]

Deemed Measure Cost

The incremental capital cost for this measure is $50[65]

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

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

[64] Lifetime from ENERGY STAR commercial griddle which cites reference as "FSTC research on available models, 2009" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[65]Measure cost from ENERGY STAR which cites reference as "EPA research on available models using AutoQuotes, 2010" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[66] Algorithms and assumptions derived from ENERGY STAR Oven Commercial Kitchen Equipment Savings Calculator.http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

ΔTherms = (ΔDailyIdle Energy + ΔDailyPreheat Energy + ΔDailyCooking Energy) * Days /100000

Where:

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[67]

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:[68]

[67] Lifetime from ENERGY STAR Commerical Kitchen Equipment Savings Calculator which cites reference as "EPA/FSTC research on available models, 2013"
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[68] 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
Low Temp	Under Counter	$50
	Stationary Single Tank Door	$0
	Single Tank Conveyor	$0
	Multi Tank Conveyor	$970
High Temp	Under Counter	$120
	Stationary Single Tank Door	$770
	Single Tank Conveyor	$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[69]:

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

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.

$$\Delta \text{kWh}^{70} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy}^{71} + \Delta \text{IdleEnergy}$$

Where:

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

$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}413)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}413)]$

ΔBoosterEnergy = Annual electric energy consumption of booster water heater

[69] Values taken from Minnesota Technical Reference Manual, ‘Electric Oven and Range’ measure and is based upon “Project on Restaurant Energy Performance-End-Use Monitoring and Analysis”, Appendixes I and II, Claar, et. al., May 1985

[70]Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

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

= $[(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}413)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3{,}413)]$

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

3,413 = 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 ÷ 3,413)] - [(0.86 * 75 * 365.25) * (70 *1.0 * 8.2 ÷ 0.98 ÷ 3,413)]

= 1,081 kWh

ΔBoosterEnergy = [(1.09 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,413)] - [(0.86 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,413)]

= 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 = 1,081 + 618 + 1,472

= 3,171 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).

<u>Electric building and electric booster water heating</u>

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
	Under Counter	12,363	9,191	3,173

Dishwasher type		kWh_{Base}	kWh_{ESTAR}	ΔkWh
High Temp	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
	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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/ AnnualHours * CF

Where:

AnnualHours = Hours * Days

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

CF = Summer Peak Coincidence Factor

= dependent on restaurant type[72]:

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

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

NATURAL GAS ENERGY SAVINGS

$$\Delta \text{Therms}^{73} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy}$$

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

[72] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985
[73] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

= 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

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
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:

$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$

$\Delta Water = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)$

= 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-V03-180101

REVIEW DEADLINE: 1/1/2023

4.2.7 ENERGY STAR Fryer

DESCRIPTION

This measure applies to natural gas fired ENERGY STAR fryer 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 fryer with a heavy load cooking efficiency ≥ 50% utilizing ASTM standard F1361 or F2144.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[74]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1200.[75]

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[76]

Custom calculation below, otherwise use deemed value of 505 Therms.

ΔTherms = (ΔDailyIdle Energy + ΔDailyPreheat Energy + ΔDailyCooking Energy) * Days /100000

[74]Lifetime from ENERGY STAR commercial griddle which cites reference as "FSTC research on available models, 2009" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
[75]Measure cost from ENERGY STAR which cites reference as "EPA research on available models using AutoQuotes, 2010" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
[76] Algorithms and assumptions derived from ENERGY STAR fryer Commercial Kitchen Equipment Savings Calculator.http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

Where:

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 16 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 150 pounds
EffENERGYSTAR	= Cooking Efficiency ENERGY STAR
	= custom or if unknown, use 50%
EffBase	= Cooking Efficiency Baseline
	= custom or if unknown, use 35%
PCENERGYSTAR	= Production Capacity ENERGY STAR
	= custom or if unknown, use 65 pounds/hr
PCBase	= Production Capacity base
	= custom or if unknown, use 60 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 62000 btu/h
PreheatRateBase	= preheat energy rate baseline
	= custom or if unknown, use 64000 btu/h
IdleENERGYSTAR	= Idle energy rate
	= custom or if unknown, use 9000 btu/h
IdleBase	= Idle energy rate
	= custom or if unknown, use 14000 btu/h

IdleENERGYSTARTime	= ENERGY STAR Idle Time
	= HOURsday-LB/PCENERGYSTAR –PreHeatTimeENERGYSTAR/60
	=Custom or if unknown, use
	=16 – 150/65-15/60
	=13.44 hours
IdleBaseTime	= BASE Idle Time
	= HOURsday-LB/PCbase –PreHeatTimeBase/60
	=Custom or if unknown, use
	=16 – 150/60-15/60
	=13.25 hours
EFOOD	= ASTM energy to food
	= 570 btu/pound

EXAMPLE

For example, an ENERGY STAR fryer with a tested heavy load cooking energy efficiency of 50% and an idle energy rate of 120,981 btu and an Idle Energy Consumption Rate 9000 btu would save.

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

Where:

ΔDailyIdleEnergy	=(18550*13.25)- (120981 * 13.44)
	= 64519 btu
ΔDailyPreheatEnergy	= (1 * 15 / 60 *64000) – (1 * 15 / 60 *62000)
	= 500 btu
ΔDailyCookingEnergy	= (150 * 570/ .35) - (150 * 570/ .5)
	=73286 btu
ΔTherms	= (64519+500+73286)* 365.25 /100000
	=508 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-ESFR-V01-120601

REVIEW DEADLINE: 1/1/2019

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[77]

DEEMED MEASURE COST

The incremental capital cost for this measure is $0 for and electric griddle and $60 for a gas griddle.[78]

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[79]:

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

[77] Lifetime from ENERGY STAR commercial griddle which cites reference as "FSTC research on available models, 2009" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
[78] Measure cost from ENERGY STAR which cites reference as "EPA research on available models using AutoQuotes, 2010" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
[79]Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is 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 [80]

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

[80] Algorithms and assumptions derived from ENERGY STAR Griddle Commercial Kitchen Equipment Savings Calculator.http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

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 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 * 0.36

= 0.22 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-V02-160601

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[81]

DEEMED MEASURE COST

The incremental capital cost for this measure is[82]

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[83]:

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

[81] Lifetime from ENERGY STAR HFHC which cites reference as "FSTC research on available models, 2009" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[82] Measure cost from ENERGY STAR which cites reference as "EPA research on available models using AutoQuotes, 2010" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[83]Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is 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[84]

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

[84] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

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)* .36

=0 .61 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-V02-160601

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.

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 10 years[85].

Deemed Measure Cost

The incremental capital cost for this measure is provided below.[86]

Harvest Rate (H)	Incremental Cost
100-200 lb ice machine	$296
201-300 lb ice machine	$312
301-400 lb ice machine	$559
401-500 lb ice machine	$981
501-1000 lb ice machine	$1,485
1001-1500 lb ice machine	$1,821
>1500 lb ice machine	$2,194

Loadshape

Loadshape C23 - Commercial Refrigeration

Coincidence Factor

The Summer Peak Coincidence Factor is assumed to equal 0.937

[85] DEER 2008

[86] These values are from electronic work papers prepared in support of San Diego Gas & Electric's "Application for Approval of Electric and Gas Energy Efficiency Programs and Budgets for Years 2009-2011", SDGE, March 2, 2009. Accessed on 7/7/10 <http://www.sdge.com/regulatory/documents/ee2009-2011Workpapers/SW-ComB/Food%20Service/Food%20Service%20Electic%20Measure%20Workpapers%2011-08-05.DOC>.

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.

Ice Machine Type	kWhbase[87]	kWhee[88]
Ice Making Head (H < 450)	10.26 - 0.0086*H	9.23 - 0.0077*H
Ice Making Head (H ≥ 450)	6.89 – 0.0011*H	6.20 - 0.0010*H
Remote Condensing Unit, without remote compressor (H < 1000)	8.85 – 0.0038*H	8.05 - 0.0035*H
Remote Condensing Unit, without remote compressor (H ≥ 1000)	5.1	4.64
Remote Condensing Unit, with remote compressor (H < 934)	8.85 – 0.0038*H	8.05 - 0.0035*H
Remote Condensing Unit, with remote compressor (H ≥ 934)	5.3	4.82
Self Contained Unit (H < 175)	18 - 0.0469*H	16.7 - 0.0436*H
Self Contained Unit (H ≥ 175)	9.8	9.11

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[89]

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

= Actual installed

[87]Baseline reflects federal standards which apply to units manufactured on or after January 1, 2010 <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div6&view=text&node=10:3.0.1.4.17.8&idno=10>.

[88]ENERGY STAR Program Requirements for Commercial Ice Machines, Partner Commitments, U.S. Environmental Protection Agency, Accessed on 7/7/10 <http://www.energystar.gov/ia/partners/product_specs/program_reqs/ice_machine_prog_req.pdf>

[89]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 < http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Ice_Machines.xls> 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.

365.35 = days per year

> For example an ice machine with an ice making head producing 450 pounds of ice would save
>
> ΔkWH = [(6.4 – 5.8) / 100] * (0.57 * 450) * 365.25
>
> = 562 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / (HOURS * DC) * CF

Where:

HOURS = annual operating hours

= 8766[90]

CF = 0.937

> For example an ice machine with an ice making head producing 450 pounds of ice would save
>
> ΔkW = 562/(8766 * 0.57) * .937
>
> = 0.105 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[91] 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-V01-120601

REVIEW DEADLINE: 1/1/2019

[90]Unit is assumed to be connected to power 24 hours per day, 365.25 days per year.
[91]AHRI Certification Directory, Accessed on 7/7/10. <http://www.ahridirectory.org/ahridirectory/pages/home.aspx>

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.[92] 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[93]

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[94] may be assumed.

Loadshape

Loadshape C01 - Commercial Electric Cooking

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[92] 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)

[93] 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."

[94] 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 = ΔGallons * 8.33 * 1 * (Tout - Tin) * (1/EFF_Elec) /3,413 * FLAG

Where:

ΔGallons = 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[95]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[96]

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

=custom, otherwise assume 97%[97]

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) /3,413 x 1

= 5,341kWh

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) /3,413 x 1

=8309 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[95] 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

[96] 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.

[97] 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.

NATURAL GAS ENERGY SAVINGS

ΔTherms = ΔGallons * 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%[98]

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[99]

ΔGallons = (FLObase - FLOeff) * 60 * HOURSday * DAYSyear

Where:

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

Time of Sale	Retrofit, Direct Install
1.6 gal/min[100]	1.9 gal/min[101]

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

Time of Sale	Retrofit, Direct Install
1.06 gal/min[102]	1.06 gal/min[103]

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

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

[100]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. www1.eere.energy.gov/femp/pdfs/spec_prerinsesprayvavles.pdf.

[101] 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)

[102]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.

[103]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

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise[104]:

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

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-SPRY-V04-180101

REVIEW DEADLINE: 1/1/2023

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.

[104] 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.

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 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 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[105]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2173[106]

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.[107]

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

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

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

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

107 Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment, http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

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

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[108]

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[109]

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%[110]

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

[108] Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3
[109] Typical preheat time from FSTC Broiler Technology Assessment.
[110] 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[111]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2665[112]

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)

[111]Lifecycle determined from Food Service Technology Center Gas Oven Life-Cycle Cost Calculator.
[112]See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

= Custom of if unknown, use 90,000 Btu/hr[113]

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

= Custom of if unknown, use 50,000 Btu/hr[114]

Duty = Duty cycle of rotisserie oven (%)

= Custom or if unknown, use 60%[115]

Hours = Typical operating hours of rotisserie oven

= Custom or if unknown, use 2,496 hours[116]

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

[113] Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7.2 http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

[114] 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.

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

[116] 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[117]

Deemed Measure Cost

The incremental capital cost for this measure is $1000[118]

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.

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

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

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

Where:

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

= 38,500 Btu/hr[119]

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

= Custom or if unknown, use 24,750 Btu/hr[120]

Duty = Duty cycle of salamander broiler (%)

= Custom or if unknown, use 70%[121]

Hours = Typical operating hours of salamander broiler

= Custom or if unknown, use 2,496 hours[122]

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

[119] Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

[120] 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%

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

[122] 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[123]

DEEMED MEASURE COST

The incremental capital cost for this measure is $4400[124]

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.

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

[123] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.
[124]See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

Where:

$InputRate_{Base}$	= Rated energy input rate of baseline upright broiler (Btu/hr)
	= 144,000 Btu/hr[125]
$InputRate_{EE}$	= Rated energy input rate of infrared upright broiler (Btu/hr)
	= Custom or if unknown, use 90,000 Btu/hr[126]
Duty	= Duty cycle of upright broiler (%)
	= Custom or if unknown, use 70%[127]
Hours	= Typical operating hours of upright broiler
	= Custom or if unknown, use 2,496 hours[128]
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

[125] 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%

[126] Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

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

[128] 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.[129]

DEEMED MEASURE COST

The incremental capital cost for this measure is[130]

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.

[129] PG&E Workpaper: Commercial Kitchen Demand Ventilation Controls-Electric, 2004 - 2005
[130] Ibid.

Electric Energy Savings

kWh savings are assumed to be 4966 kWh per horsepower of the fan[131]

Summer Coincident Peak Demand Savings

kW savings are assumed to be 0.68 kW per horsepower of the fan[132]

Natural Gas Energy Savings

$$\Delta Therms = CFM * HP * Annual\ Heating\ Load / (Eff(heat) * 100{,}000)$$

Where:

CFM = the average airflow reduction with ventilation controls per hood

= 430 cfm/HP[133]

HP = actual if known, otherwise assume 7.75 HP[134]

Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air, Btu/cfm dependent on location[135]:

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%[136]

100,000 = conversion from Btu to Therm

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

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

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

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

135 Food Service Technology Center Outside Air Load Calculator, http://www.fishnick.com/ventilation/oalc/oac.php, 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.

136 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

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

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[137].

Deemed Measure Cost

The incremental capital cost for this measure is $2400[138].

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[139].

Water Impact Descriptions and Calculation

N/A

[137]See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.
[138]Ibid.
[139] 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.[140]

DEEMED MEASURE COST

The incremental capital cost for this measure is $3000.[141]

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.[142]

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

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

[142] Assumptions derived from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator, FSTC Oven Technology Assessment (http://www.fishnick.com/equipment/techassessment/7_ovens.pdf), and from FSTC Gas Double Rack Oven Test Reports.

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

Where:

InputRate	= Input energy rate of rack oven – double oven
	= Custom or if unknown, 275,000 Btu/hr[143]
$BakingEfficiency_{EE}$	= Baking efficiency of energy efficiency rack oven – double oven
	= Custom or if unknown, use 55%[144]
$BakingEfficiency_{Base}$	= 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%[145]
Hours	= Average daily hours of operation
	= Custom or if unknown, use 3,744 hours[146]
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

[143] Median rated energy input for rack ovens from FSTC Oven Technology Assessment, http://www.fishnick.com/equipment/techassessment/7_ovens.pdf
[144] Average baking efficiency of double rack oven from FSTC Gas Double Rack Oven Test Reports.
[145] Duty cycle from FSTC Gas Double Rack Oven Test Reports on various double rack ovens.
[146] 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.[147]

Deemed Measure Cost

The incremental cost for this measure is assumed to be $800 for half size units and $1000 for full size[148]

Loadshape

Loadshape C01 - Commercial Electric Cooking

Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[149]:

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

[147] Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php

[148] Based on data from the Regional Technical Forum for the Northwest Council (http://rtf.nwcouncil.org/measures/com/ComCookingConvectionOven_v2_0.xlsm) using actual list prices for 23 units from 2012, see “ComCookingConvectionOven_v2_0.xlsm”.

[149]Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls, http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech. Unknown 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	$HOURS_{DAY}$ [150]
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[151]
Custom	Varies

DAYS = Days per year of operation

= Actual, default = 365[152]

PRE_{TIME} = Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on
= 15 min/day[153]

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

= 0.0732[154]

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

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[150] Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls, http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech
[151] Unknown is average of other locations
[152] Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php
[153] Food Service Technology Center (2002). *Commercial Cooking Appliance Technology Assessment*. Prepared by Don Fisher. Chapter 7: Ovens
[154] American Society for Testing and Materials. Industry standard for Commercial Ovens

= Actual, default = 100[155]

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.

Performance Metrics: Baseline and Efficient Values

Metric	Baseline Model [156]	Energy Efficient Model [157]
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)

155 Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php

156 Food Service Technology Center (FSTC). Default values from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php

157 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.

CF = 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	0.36
Unknown	0.40

EXAMPLE

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

$$\Delta kW = (2200 / (6 * 365)) * 0.40$$

$$= 0.40$$

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-VO1-150601

REVIEW DEADLINE: 1/1/2022

[158] Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls, http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech. Unknown is an average of other location types

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.

Equipment Type	Sub Category	Federal Standard Minimum Efficiency[159]
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.675 – (0.0015 * Rated Storage Volume in Gallons) EF
	>55 gallon tanks	0.8012 – (0.00078 * Rated Storage Volume in Gallons) EF
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	80% E_t Standby Loss: $(Q/800 + 110\sqrt{V})$
Electric Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.96 – (0.0003 * rated volume in gallons) EF
	>55 gallon tanks [160]	2.057 – (0.00113 * rated volume in gallons) EF
Electric Water Heaters > 75,000 Btu/h	≤12 kW	0.97 – (0.00132 * rated volume in gallons) EF
	> 12kW	Standby Loss: $0.30 + 27/V_m$ (%/hr)

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[161]

DEEMED MEASURE COST

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available[162]:

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

[159] ≤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.

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

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

[162] 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	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

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 [164].

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:

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

Where:

T_{OUT} = Tank temperature

= 125°F

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

= 54°F [165]

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

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

[165] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

$HotWaterUse_{Gallon}$ = 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:[166]

Building Type[167]	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:[168]

[166] 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%.

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

[168] 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[169]	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 Energy Factor (EF);

Equipment Type	Sub Category	Federal Standard Minimum Efficiency[170]
Electric Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.96 – (0.0003 * rated volume in gallons) EF
	>55 gallon tanks [171]	2.057 – (0.00113 * rated volume in gallons) EF
Electric Water Heaters > 75,000 Btu/h	≤12 kW	0.97 – (0.00132 * rated volume in gallons) EF
	> 12kW	N/A (For >12 kW Units see below)

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

= Actual

3412 = Converts Btu to kWh

For example, for a 200,000 Btu/h, 150 gallon, 90% Thermal Efficiency storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft² 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%.

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

[170] ≤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.

[171] 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 [172]

CF = Summer Peak Coincidence Factor for measure

= 0.925 [173]

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.

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

Where:

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

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

100,000 = Converts Btu to Therms

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

Equipment Type	Sub Category	Federal Standard Minimum Efficiency[174]
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.675 – (0.0015 * Rated Storage Volume in Gallons) EF
	>55 gallon tanks	0.8012 – (0.00078 * Rated Storage Volume in Gallons) EF
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	80% E_t

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% Thermal Efficiency 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) – 1079) * 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

[174] ≤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.

MEASURE CODE: CI-HWE-STWH-V03-180101

REVIEW DEADLINE: 1/1/2019

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[175]. 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 9 years.[176]

DEEMED MEASURE COST

The full install cost (including labor) for this measure is $8[177] or program actual. For LFRs, The incremental cost is $14.27[178] 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.

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[175] Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

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

[177] 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)

[178] 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[179].

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[180] or custom based on metering studies[181] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[182]

Baseline for LFRs[183]: = 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[184] or custom based on metering studies[185] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[186]

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179 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.

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

181 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.

182 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

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

184 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.

185 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.

186 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

For LFRs[187]: = 2.2 * 0.95 = 2.09

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[188] (A)	Unit	Estimated % hot water from Faucets [189] (B)	Multiplier [190] (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

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

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

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

[190] 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.

= 86F for Bath, 93F for Kitchen 91F for Unknown[191], 110F for health care facilities[192]

SupplyTemp = Assumed temperature of water entering building

= 54.1°F [193]

RE_electric = Recovery efficiency of electric water heater

= 98% [194]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below[195]

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

Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh / Hours) * CF

Where:

ΔkWh = calculated value above on a per faucet basis

Hours = Annual electric DHW recovery hours for faucet use

= (Usage * 0.545[196])/GPH

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

[191] 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.

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

[193] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

[194] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[195] 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 http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd%20EPY2%20Evaluation%20Reports/ComEd_All_Electric_Single_Family_HEP_PY2_Evaluation_Report_Final.pdf

[196] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90°F mixed faucet water.

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[197]

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

[197] 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% [198]

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

Other variables as defined above.

[198] 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.

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

Δgallons = ((GPM_base - GPM_low)/GPM_base) * Usage * ISR

Variables as defined above

EXAMPLE

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

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

= 3,640 gallons

For example, a direct installed faucet in a Elementary School:

Δgallons = ((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.

Source ID	Reference
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-V07-180101

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.[199]

Deemed Measure Cost

The full install cost (including labor) for this measure is $12[200] or program actual.

Loadshape

Loadshape C02 - Commercial Electric DHW

Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%[201].

Algorithm

Calculation of Savings [202]

Electric Energy Savings

Note these savings are per showerhead fixture

[199] 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 , "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

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

[201] Calculated as follows: Assume 11% showers take place during peak hours (based on: http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf). 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

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

ΔkWh =

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

Where:

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

= 1 if electric DHW, 0 if fuel DHW, if unknown assume 16% [203]

GPM_base = Flow rate of the baseline showerhead

= 2.67 for Direct-install programs[204]

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[205]

L_base = Shower length in minutes with baseline showerhead

= 8.20 min[206]

L_low = Shower length in minutes with low-flow showerhead

= 8.20 min[207]

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 [208]

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

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

[205] 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.

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

[207] Set equal to L_base.

[208] Shower temperature cited from SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm

SupplyTemp = Assumed temperature of water entering house

= 54.1°F [209]

RE_electric = Recovery efficiency of electric water heater

= 98% [210]

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[211]
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

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) *NSPD * 365.25) * 0.773[212] / 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[213]

[209] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

[210] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[211] 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.

[212] 77.3% is the proportion of hot 120F water mixed with 54.1°F supply water to give 105°F shower water

[213] Calculated as follows: Assume 11% showers take place during peak hours (based on: http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf). 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

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%[214]

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

= 67% [215]

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

Other variables as defined above.

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

[214] 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

[215] 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.

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

Δgallons = ((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:

Δgallons = ((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.

MEASURE CODE: CI-HWE-LFSH-V04-180101

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 [216]

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. [217].

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

[216] 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

[217] Pool Cover Costs: Lincoln Commercial Pool Equipment website. Accessed 8/26/11. http://www.lincolnaquatics.com/shop/catalog/Pool+and+Spa+Covers+and+Accessories/product.html?ProductID=84-010

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

NET TO GROSS RATIO

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

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. [218]

ΔTherms = SavingFactor x Size of Pool

Where

Savings factor = dependant on pool location and listed in table below[219]

Location	Therm / sq-ft
Indoor	2.61
Outdoor	1.01

Size of Pool = custom input

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔTherms = WaterSavingFactor x Size of Pool

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below.[220].

Location	Annual Savings Gal / sq-ft
Indoor	15.28
Outdoor	8.94

[218] 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.
[219] Business Pool Covers.xlsx
[220] Ibid.

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-V01-130601

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.

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, 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, Table C404.2

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Electric	Gas
The expected measure life is assumed to be 5 years[221].	The expected measure life is assumed to be 20 years[222]

DEEMED MEASURE COST

The incremental capital cost for an electric tankless heater this measure is assumed to be[223]

Output (gpm) at delta T 70	Incremental Cost
5	$1050
10	$1050
15	$1950

The incremental capital cost for a gas fired tankless heater is as follows:

[221] Ohio Technical Reference Manual 8/2/2010 referencing CenterPoint Energy-Triennial CIP/DSM Plan 2010-2012 Report; Additional reference stating >20 years is at Energy Savers.Gov online at http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12820

[222] Ibid.

[223] Act on Energy Technical Reference Manual, Table 9.6.2-3

Program	Capital Cost, $ per unit
Retrofit	$3,255[224]
Time of Sale or New Construction	$2,526[225]

DEEMED O&M COST ADJUSTMENTS

$100[226]

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 [227]

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[228]

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

[224] Based on AOE historical average installation data of 42 tankless gas hot water heaters
[225] http://www.mncee.org/getattachment/7b8982e9-4d95-4bc9-8e64-f89033617f37/, Low contractor estimate used to reflect less labor required in new construction of venting.
[226] 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.
[227] Act on Energy Technical Reference Manual, Table 9.6.2-3
[228] 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 [229]

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[230]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[231]

Eff base = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et); see table below[232]

Input Btu/hr of existing, tanked water heater	Eff base	Units
Size: ≤ 75,000 Btu/hr	0.67 -0.0019*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)

= custom input, if unknown assume 0.84[233]

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[229] 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.

[230] 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.

[231] 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.

[232] International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[233] 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.

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[234]

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))

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[235]

[234] Stand-by loss is provided in 2012/2015 IECC, Table C404.2, Minimum Performance of Water-Heating Equipment

[235] 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 - 0.00 132 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 - 0.00 132 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 19 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 - 0.0019V, 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 $(Q/800 + 110\sqrt{V})$ 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 $(h \cdot ft^2 \cdot {}^\circ F)/Btu$	(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.

MEASURE CODE: CI-HWE-TKWH-V03-160601

REVIEW DEADLINE: 1/1/2019

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.[236]

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[237].

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[238].

$$\Delta kWh_{PUMP} = HP * HP_{CONVERSION} * Hours * \%water\_savings$$

Where:

ΔkWh_{PUMP} = Electric savings from reduced pumping load

HP = Brake horsepower of boiler feed water pump;

= Actual or use 5 HP if unknown[239]

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[236] Aligned with other national energy efficiency programs and confirmed with national vendors

[237] 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)

[238] 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.

[239] Assumed average horsepower for boilers connected to applicable washer

$HP_{CONVERSION}$ = Conversion from Horsepower to Kilowatt

= 0.746

Hours = Actual associated boiler feed water pump hours

= 800 hours if unknown[240]

%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%[241]

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[242]

ΔkWh_{PUMP} / lb capacity = 746/254.38

= 2.93 kWh/lb-capacity

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 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

$\Delta Therm$ = $Therm_{Baseline}$ * %hot_water_savings

Where:

$\Delta Therm$ = Gas savings resulting from a reduction in hot water use, in therm.

$Therm_{Baseline}$ = Annual Baseline Gas Consumption

---

[240] 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.

[241] 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

[242] 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

= WHE * WUtiliz * WUsage_hot

Where:

WHE = water heating energy: energy required to heat the hot water used

= 0.00885 therm/gallon[243]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[244], 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[245]

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%[246]

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

[243] 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

[244] 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

[245] 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:

[246] 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 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

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:

Δgallons = WUsage * WUtiliz * %water_savings

Where:

Δgallons = 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[247]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[248], 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%[249]

Savings using defaults above:

ΔGallons = WUsage * WUtiliz * %water_savings

= 2.03 * 916,150 * 0.25

= 464,946 gallons

Default per lb capacity:

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:[250]

- 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

[247] 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

[248] 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

[249] 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

[250] Confirmed through communications with national vendors and available references E.g. http://ozonelaundry.wordpress.com/2010/11/17/the-importance-of-maintenance/

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 found at :http://www.deeresources.com/index.php?option=com_content&view=article&id=68&Itemid=60 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-VO1-140601

REVIEW DEADLINE: 1/1/2020

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.

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%.[251]

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.[252]

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[253]
<300kBtuh	$65 per kBTUh
300 – 2500 kBtuh	$38 per kBTUh
>2500 kBtuh	$32 per kBTUh

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

[251] International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[252] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.

[253] Baseline install costs are based on data from the W017 Itron California Measure Cost Study, accessed via http://www.energydataweb.com/cpuc/search.aspx. The data is provided in a file named "MCS Results Matrix – Volume I".

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 * ყWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

Early Replacment[254]:

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

= [(MFHH * #Units * GPD * Days/yr * ყWater * (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 * ყWater * (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[255]

#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[256]

Days/yr = 365.25

ყWater = Specific Weight of Water

= 8.33 gal/lb

Tout = tank temperature of hot water

= 125°F or custom

Tin = Incoming water temperature from well or municiple system

[254] 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).

[255]Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

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

= 54°F[257]

Eff_base = thermal efficiency of base unit

= 80%[258]

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%[259]

SL = Standby Loss[260]

= (Input rating / 800) + (110 * √Tank Volume)

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

[257] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

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

[259] 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".

[260] 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 * ɣWater * (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-V02-160601

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[261].

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.[262]

Loadshape

Loadshape C02 - Non-Residential Electric DHW

Coincidence Factor

N/A

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Deemed at 656 kWh[263].

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[261] 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.

[262] 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.

[263] 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[264].

$$\Delta Therms = Boiler\ Input\ Capacity * (t_{normal\ occ} * R_{normal\ occ} + t_{low\ occ} * R_{low\ occ}) / 100{,}000$$

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%[265] of total boiler input capacity for Multi-Family Buildings and 16.48%[266] of total boiler input capacity for Dormitories, as domestic hot water load.

= If unknown capcity use 4,938 BTU/hr per room for Dormitories[267] and 12,493 BTU/hr per apartment for Multi-Family Buildings[268]

$t_{normal\ occ}$ = Total operating hours of domestic hot water burner, when the facility has normal occupancy. If unknown, assume 1,688 hours for Dormitories[269] and 2,089 hours for Multi-Family buildings[270].

$t_{low\ occ}$ = Total operating hours of domestic hot water burner, when the facility has low occupancy[271]. If unknown, assume 520 hours for Dormitories and 0 hours for Multi-Family buildings.

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savings from electric units but electrical savings from gas-fired units. See 'CDHW Controls Summary Calculations.xlsx' for more information.

264 See 'CDHW Controls Summary Calculations.xlsx' for more information.

265 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.

266 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.

267 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 $R_{low\ occ}$,

268 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 $R_{low\ occ}$,

269 Based on results of studies performed in multiple university dormitory buildings in the California region, for Southern California Gas' PREPS Program, 2012.

270 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.

271 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[272] and no heat recovery.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

THE EXPECTED MEASURE LIFE IS ASSUMED TO BE 15 YEARS.[273]

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[274]:

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

Algorithm

[272] Savings methodology factors are for a constant speed fan.
[273] Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment.
[274]Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls, http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech

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[275]

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[276]

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[277]	Assumed days/Year	Number of Filters[278]
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.

= 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

275 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.

276 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.

277 Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

278 Each filter is 20 X 20 inches.

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[279]
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[280]:

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

Water and Other Non-Energy Impact Descriptions and Calculation

N/A

[279] Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

[280]Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls, http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech

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[281] 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.

[281] 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.[282]

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr per tune-up.[283]

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[284]

$HotWaterUse_{Gallon}$ = 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[285]:

1. Consumption per usable storage tank capacity

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[282] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

[283] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

[284] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

[285] 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%.

= 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:

Building Type[286]	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

286 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	Consumption/1,000 sq.ft.
Nursing	30,503
Multi-Family	15,434

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.

$$\Delta Therms = ((T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{water} * 1 * (1/Eff_{before} – 1/Eff_{after}))/100{,}000$$

$$= ((125 - 54) * (100 * 672) * 8.33 * 1 * (1/0.8 – 1/0.822))/100{,}000$$

$$= 13.3 \text{ therms}$$

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[287], applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant[288], 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				
	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
Convenience Store	1,481	1,368	1,214	871	973
Elementary School	1,781	1,736	1,531	1,057	1,283
Garage	985	969	852	680	752
Grocery	1,608	1,602	1,404	876	1,047
Healthcare Clinic	1,579	1,620	1,414	963	1,019
High School	1,845	1,857	1,666	1,187	1,388
Hospital - CAV no econ[289]	1,764	1,818	1,549	1,332	1,512
Hospital - CAV econ[290]	1,788	1,853	1,580	1,369	1,555
Hospital - VAV econ[291]	731	695	522	314	340
Hospital - FCU	1,325	1,512	1,232	1,448	1,946
Hotel/Motel	1,761	1,712	1,544	1,056	1,290
Hotel/Motel - Common	1,601	1,626	1,548	1,260	1,323
Hotel/Motel - Guest	1,758	1,702	1,521	1,018	1,252
Manufacturing Facility	1,048	1,013	939	567	634
MF - High Rise	1,526	1,506	1,373	1,169	1,172
MF - High Rise - Common	1,815	1,762	1,580	1,089	1,406
MF - High Rise - Residential	1,475	1,464	1,330	1,152	1,123
MF - Mid Rise	1,666	1,685	1,450	1,067	1,216
Movie Theater	1,916	1,905	1,718	1,288	1,538

[287] A full description of the ComEd model development is found in "ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010"

[288] http://www.icc.illinois.gov/downloads/public/edocket/397867.pdf

[289] Based on model with single duct reheat system with a fixed outdoor air volume.

[290] Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors.

[291] Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors.

Building Type	Heating EFLH				
	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
Office - High Rise - CAV econ	2,089	2,132	1,960	1,351	1,487
Office - High Rise - VAV econ	1,528	1,558	1,284	759	846
Office - High Rise - FCU	1,118	1,102	952	505	530
Office - Low Rise	1,428	1,425	1,132	692	793
Office - Mid Rise	1,585	1,587	1,342	855	950
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	1,392	1,278	1,200	781	891
Retail - Strip Mall	1,332	1,233	1,090	751	810
Warehouse	1,456	1,357	1,400	875	1,078
Unknown	1,553	1,539	1,369	982	1,139

Equivalent Full Load Hours for Cooling ($EFLH_{cooling}$) :

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
Convenience Store	1,088	1,067	1,368	1,541	1,371
Elementary School	725	764	905	1,142	956
Garage	934	974	1,226	1,582	1,383
Grocery	1,033	1,000	1,236	1,499	1,286
Healthcare Clinic	1,282	1,305	1,519	1,767	1,571
High School	675	721	840	1,060	920
Hospital - CAV no econ	4,166	4,275	4,319	4,692	4,445
Hospital - CAV econ	1,751	1,814	2,120	2,411	2,112
Hospital - VAV econ	1,531	1,592	1,853	2,163	1,876
Hospital - FCU	3,245	3,291	3,451	4,128	3,806
Hotel/Motel	1,233	1,186	1,436	1,274	1,616
Hotel/Motel - Common	2,186	2,103	2,344	1,391	2,651
Hotel/Motel - Guest	1,042	1,019	1,269	1,216	1,418
Manufacturing Facility	1,010	1,055	1,209	1,453	1,273
MF - High Rise	921	845	1,048	1,779	1,099
MF - High Rise - Common	914	839	1,055	2,893	1,132
MF - High Rise - Residential	899	831	1,011	1,569	1,055
MF - Mid Rise	809	767	992	1,119	993
Movie Theater	876	745	1,036	1,178	1,010
Office - High Rise - CAV no econ	1,688	1,708	1,811	1,865	1,725
Office - High Rise - CAV econ	1,454	1,452	1,551	1,568	1,416
Office - High Rise - VAV econ	875	919	1,057	1,275	1,077
Office - High Rise - FCU	1,117	1,170	1,277	1,642	1,412
Office - Low Rise	949	1,010	1,182	1,452	1,281
Office - Mid Rise	883	938	1,072	1,286	1,083
Religious Building	861	817	967	1,159	1,067

Building Type	Cooling EFLH				
	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
Retail - Department Store	949	889	1,124	1,367	1,157
Retail - Strip Mall	950	919	1,149	1,351	1,215
Warehouse	357	338	422	647	533
Unknown	1,215	1,221	1,408	1,670	1,480

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.[292]

Deemed Measure Cost

The incremental capital cost for this measure is $35[293] 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% [294]

[292] 3 years is given for "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils". DEER2014 EUL Table. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

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

[294] 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.

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [295]

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[296] 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 * (1 - %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)[297]

Tune-Up Component	% savings
Condenser Cleaning	6.10%
Evaporator Cleaning	0.22%
Refrig. Charge Off. <=20%	0.68%

[295] 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

[296] 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".

[297] 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
Refrig. Charge Off. >20%	8.44%
Combined (Refrig. Charge Off. <=20%)	7.00%
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% [298]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [299]

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-V04-180101

REVIEW DEADLINE: 1/1/2021

[298] 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.

[299] 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[300] 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[301]

Deemed Measure Cost

The cost of this measure is \$0.83/MBtu/hr[302] per tune-up

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[300] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[301] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[302] 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[303] 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[304]

Deemed Measure Cost

The cost of this measure is $0.83/MBtu/hr[305] per tune-up

[303] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[304] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[305] 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%[306] 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

[306] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

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

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[307]

DEEMED MEASURE COST

The cost of this measure is $612[308]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[307]CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[308] 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%[309] 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

[309] 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[310]

DEEMED MEASURE COST

The incremental capital cost for a unit heater is $676[311]

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.

[310] DEER 2008

[311] 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-V01-120601

REVIEW DEADLINE: 1/1/2019

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).

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years [312].

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[313]
Water cooled, electrically operated, positive displacement (reciprocating)	All capacities	$22/ton[314]
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	< 150 tons	$351/ton[315]
	>= 150 tons and < 300 tons	$127/ton
	>= 300 tons	$87/ton

Loadshape

Loadshape C03 - Commercial Cooling

[312] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008 (http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

[313] 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

[314] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”

[315] Incremental costs for water-cooled, electrically operated, positive displacement (rotary screw and scroll) from the W017 Itron California Measure Cost Study, accessed via http://www.energydataweb.com/cpuc/search.aspx. 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% [316]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [317]

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[318] = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[319]

= 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

[316] 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.

[317] 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

[318] 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.

[319] Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetI.org. http://www.ahrinet.org/

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW_{SSP} = TONS * ((PEbase) – (PEee)) * CF_{SSP}

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		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 ≥ 12.500 IPLV	NA[c]	≥ 10.100 FL ≥ 13.700 IPLV	≥ 9.700 FL ≥ 15,800 IPLV	AHRI 550/ 590
	≥ 150 Tons		≥ 9.562 FL ≥ 12.500 IPLV	NA[c]	≥ 10.100 FL ≥ 14.000 IPLV	≥ 9.700 FL ≥ 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 ≤ 0.630 IPLV	≤ 0.800 FL ≤ 0.600 IPLV	≤ 0.750 FL ≤ 0.600 IPLV	≤ 0.780 FL ≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL ≤ 0.615 IPLV	≤ 0.790 FL ≤ 0.586 IPLV	≤ 0.720 FL ≤ 0.560 IPLV	≤ 0.750 FL ≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.680 FL ≤ 0.580 IPLV	≤ 0.718 FL ≤ 0.540 IPLV	≤ 0.660 FL ≤ 0.540 IPLV	≤ 0.680 FL ≤ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL ≤ 0.540 IPLV	≤ 0.639 FL ≤ 0.490 IPLV	≤ 0.610 FL ≤ 0.520 IPLV	≤ 0.625 FL ≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL ≤ 0.540 IPLV	≤ 0.639 FL ≤ 0.490 IPLV	≤ 0.560 FL ≤ 0.500 IPLV	≤ 0.585 FL ≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL ≤ 0.596 IPLV	≤ 0.639 FL ≤ 0.450 IPLV	≤ 0.610 FL ≤ 0.550 IPLV	≤ 0.695 FL ≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL ≤ 0.596 IPLV	≤ 0.639 FL ≤ 0.450 IPLV	≤ 0.610 FL ≤ 0.550 IPLV	≤ 0.635 FL ≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL ≤ 0.549 IPLV	≤ 0.600 FL ≤ 0.400 IPLV	≤ 0.560 FL ≤ 0.520 IPLV	≤ 0.595 FL ≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL ≤ 0.549 IPLV	≤ 0.600 FL ≤ 0.400 IPLV	≤ 0.560 FL ≤ 0.500 IPLV	≤ 0.585 FL ≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL ≤ 0.539 IPLV	≤ 0.590 FL ≤ 0.400 IPLV	≤ 0.560 FL ≤ 0.500 IPLV	≤ 0.585 FL ≤ 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 ≥ 1.050 IPLV	NA[c]	≥ 1.000 FL ≥ 1.050 IPLV	NA[c]	
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL ≥ 1.000 IPLV	NA[c]	≥ 1.000 FL ≥ 1.050 IPLV	NA[c]	

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.

MEASURE CODE: CI-HVC-CHIL-V05-180101

REVIEW DEADLINE: 1/1/2022

4.4.7 ENERGY STAR and CEE Tier 1 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 TIER 1 minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:[320]

Product Class (Btu/H)	Federal Standard EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, with louvered sides	ENERGY STAR EER, without louvered sides	CEE TIER 1 EER
< 8,000	9.7	9	10.7	9.9	11.2
8,000 to 13,999	9.8	8.5	10.8	9.4	11.3
14,000 to 19,999	9.7	8.5	10.7	9.4	11.2
>= 20,000	8.5	8.5	9.4	9.4	9.8

Casement	Federal Standard (EER)	ENERGY STAR (EER)
Casement-only	8.7	9.6
Casement-slider	9.5	10.5

Reverse Cycle - Product Class (Btu/H)	Federal Standard EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, with louvered sides	ENERGY STAR EER, without louvered sides
< 14,000	N/A	8.5	N/A	9.4
>= 14,000	N/A	8	N/A	8.8
< 20,000	9	N/A	9.9	N/A
>= 20,000	8.5	N/A	9.4	N/A

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

DEFINITION OF EFFICIENT EQUIPMENT

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

[320] http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac and http://www.cee1.org/resid/seha/rm-ac/rm-ac_specs.pdf
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.
http://www.energystar.gov/ia/partners/product_specs/program_reqs/room_air_conditioners_prog_req.pdf

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.[321]

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE TIER 1 unit.[322]

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% [323]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [324]

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

$$\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/EERbase - 1/EERee))/1000$$

Where:

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

= dependent on location:[325]

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[321] Energy Star Room Air Conditioner Savings Calculator, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

[322] Based on field study conducted by Efficiency Vermont

[323] 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.

[324] 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

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

Zone	FLH_{RoomAC}
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 [326]

EERbase = Efficiency of baseline unit

= As provided in tables above

EERee = Efficiency of ENERGY STAR or CEE Tier 1 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 * (1/9.8 – 1/10.8)) / 1000
>
> = 20.3 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Btu/H * ((1/EERbase - 1/EERee))/1000) * CF

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [327]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[328]

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 * (1/9.8 – 1/10.8)) / 1000 * 0.913

= 0.073 kW

FOSSIL FUEL SAVINGS

N/A

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This ratio has been applied to the FLH from the unitary and split system air conditioning measure.

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

[327] 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.

[328] 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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ESRA-V01-120601

REVIEW DEADLINE: 1/1/2019

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[329].

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[330].

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.

[329] DEER 2008 value for energy management systems
[330] This value was extracted from Smart Ideas projects in PY1 and PY2.

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 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[331]. 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

[331] 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'.

Motel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
		No Housekeeping Setback	274
	PTHP	Housekeeping Setback	174
		No Housekeeping Setback	682

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

Hotel Electric Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Electric Savings (kWh/Ton)
	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
		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

Motel Coincident Peak Demand Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Coincident Peak Demand Savings (kW/Ton)
	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

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/ 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
	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
		Housekeeping Setback	2.6

Hotel Natural Gas Energy Savings			
Climate Zone (City based upon)	Heating Source	Baseline	Gas Savings (Therms/Ton)
	Central Hot Water Fan Coil w/ Gas Heating	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
		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 Heat Pump Systems

DESCRIPTION

This measure applies to the installation of high-efficiency air cooled, water source, ground water source, and ground source heat pump systems. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air cooled, water source, ground water source, or ground source heat pump system that exceeds the energy efficiency requirements of the 2012 or 2015 (applicable from 01/01/2016) International Energy Conservation Code (IECC), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, water source, ground water source, or ground source heat pump system that meets the energy efficiency requirements of the 2012 or 2015 IECC, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015). Note the Time of Sale baseline is assumed to be IECC 2015. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[332] except for geothermal heat pump systems which have an expected measures life of 25 years[333].

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.[334] 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% [335]

[332]Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[333] System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.
[334] Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.
[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.

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [336]

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 IECC on the date of the building permit (if unknown assume IECC 2015).

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 IECC on the date of the building permit (if unknown assume IECC 2015).

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

[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

= EER from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).. For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[337]

$$EER = (-0.02 * SEER^2) + (1.12 * SEER)$$

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 IECC on the date of the building permit (if unknown assume IECC 2015). If rating is HSPF, COP = HSPF / 3.413

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed

[337] 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.

Minimum Efficiency Requirements: 2012 IECC

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

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]
				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	
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.

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

$$\Delta kW = ((kBtu/hr_{cool}) * (1/EERbase - 1/EERee)) * CF$$

Where CF value is chosen between:

CF_{SSP} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [338]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [339]

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:

ΔkW = (60 * (1/11 – 1/12.5)) *0.913

= 0.598 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-V05-180101

REVIEW DEADLINE: 1/1/2019

[338] 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.

[339] 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

4.4.10 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.

Hot water boiler baseline:

Year	Efficiency
Hot Water <300,000 Btu/hr < June 1, 2013[340]	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[341]	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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years[342]

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[340] 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.

[341] Ibid.

[342] The Technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf 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

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below[343]

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

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. Baseline efficiency values by boiler type and capacity are found in the Definition of Baseline Equipment Section

EfficiencyRating(actual) = Efficent Boiler Efficiency Rating use actual value

Measure Type	Actual AFUE
ENERGY STAR® Minimum	85%

[343] 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.

Measure Type	Actual AFUE
AFUE 90%	90%
AFUE 95%	95%
AFUE ≥ 96%	≥ 96%
Custom	Value to one significant digit i.e. 95.7%

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-V05-150601

REVIEW DEADLINE: 1/1/2019

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)[344].
- 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%

[344] 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[345]

Remaining life of existing equipment is assumed to be 5.5 years[346].

Deemed Measure Cost

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below[347]:

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[348]. 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[349]

[345] Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010.
[346] Assumed to be one third of effective useful life
[347] Based on data from Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.
[348] $2641 inflated using 1.91% rate.
[349] 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.

Cooling Savings = Brushless DC motor or electronically commutated motor (ECM) savings during cooling season

If air conditioning = 263 kWh

If no air conditioning = 175 kWh

If unknown (weighted average)= 241 kWh[350]

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[351].

Building Type	HOURSyear
Assembly	2150
Assisted Living	4373
College	1605
Convenience Store	2084
Elementary School	3276
Garage	2102
Grocery	2096
Healthcare Clinic	1987
High School	3141
Hospital - VAV econ	2788
Hospital - CAV econ	2881
Hospital - CAV no econ	8760
Hospital - FCU	8729
Manufacturing Facility	2805

[350] The weighted average value is based on assumption that 75% of buildings installing BPM furnace blower motors have Central AC.

[351] 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
MF - High Rise	4237
MF - Mid Rise	2899
Hotel/Motel – Guest	4479
Hotel/Motel - Common	8712
Movie Theater	2120
Office - High Rise - VAV econ	2038
Office - High Rise - CAV econ	4849
Office - High Rise - CAV no econ	5682
Office - High Rise - FCU	3069
Office - Low Rise	2481
Office - Mid Rise	1881
Religious Building	2830
Restaurant	3350
Retail - Department Store	2528
Retail - Strip Mall	2266
Warehouse	770
Unknown	2718

CF =Summer Peak Coincidence Factor for measure is provided below for different building types[352]:

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%

[352] Coincidence Factors are estimated using the eQuest models..

HVAC Pumps	CF
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%

EXAMPLE

For example, a blower motor in an 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[353]:

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% [354].

AFUE(base) = Baseline Furnace Annual Fuel Utilization Efficiency Rating, dependant on year as listed below:

[353] 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).

[354] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

Dependent on program type as listed below[355]:

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%[356]

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-V07-180101

REVIEW DEADLINE: 1/1/2019

[355] 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.

[356] Minimum ENERGY STAR efficiency after 2.1.2012.

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[357]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1716[358]

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[359]

[357]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

[358]Ibid.

[359]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-V01-120601

REVIEW DEADLINE: 1/1/2019

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 conditions is provided in the Federal Baseline reference table provided below.

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years. [360]

Remaining life of existing equipment is assumed to be 5 years[361]

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[362]

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[363].

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton[364]. This cost should be discounted to present value using the nominal discount rate.

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[360] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007
[361] Standard assumption of one third of effective useful life.
[362] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation
[363] Based on DCEO – IL PHA Efficient Living Program data.
[364] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

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% [365]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [366]

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[367] = 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)] * $EFLH_{cool}$

Annual kWh $Savings_{heat}$ = $(kBtu/hr_{heat})$/3.412 * [(1/COPbase) – (1/COPee)] * $EFLH_{heat}$

Where:

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365 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.

366 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

367 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.

$kBtu/hr_{cool}$ = 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[368]

EERbase = Energy Efficiency Ratio of the baseline equipment; see the table below for values.

= Based on applicable IECC code on date of building permit (if unknown assume IECC 2015).

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

Equipment Type	IECC 2012 Minimum Efficiency	IECC 2015 Minimum Efficiency
PTAC (Cooling mode) New Construction	13.8 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER
PTAC (Cooling mode) Replacements	10.9 – (0.213 x Cap/1000) EER	10.9 – (0.213 x Cap/1000) EER
PTHP (Cooling mode) New Construction	14.0 – (0.300 x Cap/1000) EER	14.0 – (0.300 x Cap/1000) EER
PTHP (Cooling mode) Replacements	10.8 – (0.213 x Cap/1000) EER	10.8 – (0.213 x Cap/1000) EER
PTHP (Heating mode) New Construction	3.2 – (0.026 x Cap/1000) COP	3.2 – (0.026 x Cap/1000) COP
PTHP (Heating mode) Replacements	2.9 – (0.026 x Cap/1000) COP	2.9 – (0.026 x Cap/1000) COP

"Cap" = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS 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[369]: $EER = (-0.02 * SEER^2) + (1.12 * SEER)$

= Actual installed

$kBtu/hr_{heat}$ = capacity of the heating equipment in kBtu per hour.

= Actual installed

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

[369] 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.

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[370] 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) * [(1/10.2) – (1/12)] * 1,042

= 184 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 (1st 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:

$\Delta kW = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * CF$

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)

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

= 91.3% [371]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [372]

EXAMPLE

Time of Sale:

For example a 1 ton replacement cooling unit with no heating with an efficient EER of 12 saves:

ΔkW_{SSP} = (12 * (1/10.2 – 1/12) *0.913

= 0.16 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):

ΔkW_{SSP} = 12 * (1/8.1 – 1/12) * 0.913

= 0.44 kW

ΔkW for remaining measure life (next 10 years):

ΔkW_{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-V08-180101

Review Deadline: 1/1/2020

371 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.

372 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.[373]

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.[374]

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

[374] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means[375] pricing reference materials may be used.[376] 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[377] = [((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:

[375] RS Means 2008. Mechanical Cost Data, pages 106 to 119

[376] RS Means 2010: "for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting"

[377] 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 [378]

= 80.7% for steam boilers, except multifamily low-pressure [379]

= 64.8% for multifamily low-pressure steam boilers [380]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [381]

= 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.[382]

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

[378] Average efficiencies of units from the California Energy Commission (CEC).

[379] Ibid.

[380] Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.

[381] 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.

[382] 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.[383] 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

383 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)[384]	75	75	75	75	48.6	48.6	48.6
Wind speed (mph)[385]	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

384 DOE Weather Data. http://apps1.eere.energy.gov/buildings/energyplus/weatherdata/4_north_and_central_america_wmo_region_4/1_usa/USA_IL_Aurora.Muni.AP.744655_TMY3.stat Ibid.

385 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

			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)
		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

			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)
		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

			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)**
		Hotel/Motel - Guest	7.46	7.22	6.45	4.32	5.31
		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

			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)**
		Office - Mid Rise	8.51	8.52	7.21	4.59	5.10
		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

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)
		Warehouse	12.23	11.40	11.77	7.35	9.05
		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[386]	Straight Tee[387]
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)	ft²	ft²	ft²	ft²
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

Flanges				
Class (psi)	150	300	600	900
NPS (in)	ft²	ft²	ft²	ft²
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

[386] Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19
[387] 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
6	7.03	9.71	13.03	15.8
8	10.3	13.5	18.4	23.8
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
6	2.04	2.72	3.6	4.37
8	2.92	3.74	4.89	6.4
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	3.56	1.05	3.56	1.14
300	4.73	1.05	4.73	1.35
600	4.73	1.16	4.73	1.42
900	8.37	3.57	8.37	2.48

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PINS-V04-160601

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 of the current International Energy Conservation Code (IECC).

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively-cooled air conditioner that meets the energy efficiency requirements of the IECC in effect on the date of the building permit (if date is unknown, assume current IECC 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[388].

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[389]

For early replacement, the remaining life of existing equipment is assumed to be 5 years[390].

Deemed Measure Cost

The incremental capital cost for this measure is based upon capacity and efficiency level (defined be CEE specifications[391]), as outlined in the following table:[392]

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

388 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.

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

390 Assumed to be one third of effective useful life

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

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

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:

	Full Install Cost ($/ton)		
Capacity	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% [393]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [394]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of Sale:

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

$$\Delta kWH = (kBtu/hr) * [(1/SEERbase) – (1/SEERee)] * EFLH$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWH = (kBtu/hr) * [(1/IEERbase) – (1/IEERee)] * EFLH$$

Early replacement[395]:

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

[393] 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.

[394] 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

[395] 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).

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

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 IECC on date of building permit (if unknown assume IECC 2015).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed)

SEERexist = Seasonal Energy Efficiency Ratio of the existing equipment

= Actual, or assume IECC 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 IECC on date of building permit (if unknown assume IECC 2015).

IEERee = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed)

IEERexist = Integrated Energy Efficiency Ratio of the existing equipment

= Actual, or assume IECC 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.

2012 IECC Minimum Efficiency Requirements

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

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)

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 1/1/2016	As of 1/1/2016	
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	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 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	12.0 EER 12.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	11.8 EER 12.0 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	11.9 EER 12.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	11.7 EER 11.9 IEER	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	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	11.5 EER 11.7 IEER	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 11.8 IEER	10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	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.
c. Minimum efficiency as of January 1, 2015.

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):

ΔkWH = (kBtu/hr) * [(1/EERbase) – (1/EERee)] * CF

Where:

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER values from tables below, based on applicable IECC on date of the building permit (if unknown assume IECC 2015). (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[396] 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 IECC 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% [397]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [398]

For example, a 5 ton air cooled split system with a SEER of 15 in Rockford would save:

ΔkW_{SSP} = (60) * [(1/13) – (1/15)] * .913

= 0.562 kW

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: CI-HVC-SPUA-V05-180101

REVIEW DEADLINE: 1/1/2019

[396] 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.

[397] 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.

[398] 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

4.4.16 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[399]

DEEMED MEASURE COST

Steam System	Cost per trap[400] ($)
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

[399]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.
[400] 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%,[401] 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.

[401] 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.

Steam System	Average Steam Trap Inlet Pressure psig[402]	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
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[403] (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 [404]

= 64.8% for multifamily low-pressure steam boilers [405]

Hours = Annual operating hours of steam plant

[402] 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.

[403] 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.

[404] Ibid.

[405] Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.

= custom, if unknown:

Steam System	Zone (where applicable)	Hours/Yr[406]
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[407]	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 (%)[408]
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%

[406] 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.

[407] Since commercial LPS reflect heating systems, Hours/yr are equivalent to HDD55 zone table

[408] Dry cleaners survey data as referenced in CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012.

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

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years;[409] measure life for process is 10 years.[410]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs[411] 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
20 HP	$ 3,059

[409] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
[410] DEER 2008
[411] 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.

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

$$\Delta kWh = BHP / EFFi * Hours * ESF$$

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[412]. 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.[413]

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type[414]. When available, actual hours should be used.

Building Type	Heating Run Hours	Cooling Run Hours
Assembly	4888	2150
Assisted Living	4711	4373
College	3990	1605
Convenience Store	4136	2084
Elementary School	5105	3276
Garage	4849	2102
Grocery	4200	2096
Healthcare Clinic	5481	1987
High School	5480	3141

[412] 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.

[413] Ohio TRM 8/6/2010 pp207-209, Com Ed TRM June 1, 2010.

[414] 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
Hospital - VAV econ	3718	2788
Hospital - CAV econ	7170	2881
Hospital - CAV no econ	7139	8760
Hospital - FCU	5844	8729
Manufacturing Facility	3821	2805
MF - High Rise	4522	4237
MF - Mid Rise	5749	2899
Hotel/Motel - Guest	4480	4479
Hotel/Motel - Common	3292	8712
Movie Theater	5063	2120
Office - High Rise - VAV econ	4094	2038
Office - High Rise - CAV econ	5361	4849
Office - High Rise - CAV no econ	5331	5682
Office - High Rise - FCU	3758	3069
Office - Low Rise	3834	2481
Office - Mid Rise	3977	1881
Religious Building	5199	2830
Restaurant	4579	3350
Retail - Department Store	4249	2528
Retail - Strip Mall	4475	2266
Warehouse	4606	770
Unknown	4649	2718

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[415]
Chilled Water Pump	0.411[416]
Cooling Tower Fan	0.126[417]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW =BHP/EFFi * DSF

Where:

DSF = Demand Savings Factor varies by VFD application.[418] Units are kW/HP. Values listed below are based on typical peak load for the listed application.

[415] 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.
[416] Ibid
[417] Based on eQuest model for VSD v one-speed fan, see “CT Savings Factors.xlsx”.
[418] DSF assumptions are based upon the same source as the ESFs.

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-V04-180101

Review Deadline: 1/1/2021

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[419] based upon equipment life only[420]. For the purposes of claiming savings for a new programmable thermostat, this is reduced by a 50% persistence factor to give a final measure life of 4 years.

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown the capital and labor cost for this measure is assumed to be $181 per thermostat[421]. 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

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

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

421 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[422]

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

[422] 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.

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)

Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)[423]					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	

[423] 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

= ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****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

= ***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 = [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	***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***

Building Type	Fan Mode During Occupied Period (*Fo*)	Equation
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 –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

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
	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-V02-150601

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.

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) which is the value assumed in this measure.

Deemed Lifetime of Efficient Equipment

The deemed measure life is 10 years and based on CO2 sensor estimated life. [424]

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[425].

Loadshape

Commercial ventilation C23

Coincidence Factor

N/A

[424] 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.

[425] Discussion with vendors

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas,

ΔkWh = Condition Space/1000 * $SF_{cooling}$

For facilities heated by heat pumps,

ΔkWh = Condition Space/1000 * $SF_{cooling}$+ Condition Space/1000 * $SF_{Heat\ HP}$

For facilities heated by electric resistance,

ΔkWh = 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[426]

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	454	456	460	456	462
Office - Mid-rise	430	431	432	428	433
Office - High-rise	448	450	452	449	454
Religious Building	493	509	573	584	605
Restaurant	505	515	553	569	581
Retail - Department Store	620	625	630	638	642
Retail - Strip Mall	380	376	356	406	407
Convenience Store	602	603	610	612	614
Elementary School	317	327	352	352	363
High School	305	316	340	340	352
College/University	392	410	434	449	462
Healthcare Clinic	353	358	379	383	389
Lodging	576	578	586	588	591

[426] 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 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)
Manufacturing	481	482	482	477	482
Special Assembly Auditorium	410	427	479	494	514
Default	451	458	475	482	490

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	203	180	172	148
Office - Mid-rise	156	133	117	117	102
Office - High-rise	209	183	164	153	133
Religious Building	1,495	1,322	1,172	1,116	1,000
Restaurant	1,058	954	828	810	711
Retail - Department Store	365	326	289	283	250
Retail - Strip Mall	244	214	195	185	164
Convenience Store	179	161	141	137	117
Elementary School	652	567	500	470	414
High School	636	553	492	457	406
College/University	1,257	1,105	969	937	789
Healthcare Clinic	443	393	344	331	297
Lodging	204	182	156	153	156
Manufacturing	166	145	125	120	109
Special Assembly Auditorium	1,759	1,551	1,399	1,366	1,202
Default	604	533	472	454	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	610	539	516	445
Office - Mid-rise	467	399	352	352	305
Office - High-rise	627	549	492	458	399
Religious Building	4,486	3,966	3,517	3,348	3,001
Restaurant	3,175	2,862	2,485	2,429	2,134
Retail - Department Store	1,094	979	868	848	750
Retail - Strip Mall	732	641	586	554	492
Convenience Store	537	484	422	410	352
Elementary School	1,956	1,701	1,501	1,409	1,243
High School	1,908	1,659	1,477	1,372	1,219
College/University	3,770	3,314	2,907	2,810	2,368
Healthcare Clinic	1,330	1,179	1,032	992	891
Lodging	611	546	469	458	469
Manufacturing	499	436	375	359	328
Special Assembly Auditorium	5,276	4,652	4,197	4,099	3,606
Default	1,811	1,598	1,415	1,361	1,200

For example: 7,500 SqFt of low-rise office space in Chicago with gas heat.

ΔkWh = 7,500 /1000 *456

= 3,420 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

NATURAL GAS SAVINGS

$$\Delta therms = Condition\ Space/1000 * SF_{Heat\ Gas}$$

Where:

$SF_{Heat\ Gas}$ = value in table below based on building type and weather zone[427]

Building Type	$SF_{Heat\ Gas}$ (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	17	15	15	13
Office- High-rise	27	23	21	20	17
Religious Building	191	169	150	143	128
Restaurant	135	122	106	104	91
Retail - Department Store	47	42	37	36	32
Retail - Strip Mall	31	27	25	24	21
Convenience Store	23	21	18	17	15
Elementary School	83	73	64	60	53
High School	81	71	63	59	52
College/ University	161	141	124	120	101
Healthcare Clinic	57	50	44	42	38
Lodging	26	23	20	20	20
Manufacturing	21	19	16	15	14
Special Assembly Auditorium	225	198	179	175	154
De-fault	77	68	60	58	51

For example: 7500 SqFt of low-rise office space in Chicago.

ΔTherms = 7,500 * 26

= 195 Therms

427 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-DCV-V04-180101

REVIEW DEADLINE: 1/1/2022

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.[428] 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%[429] of the full fire input MBH for greater than 60%[430] 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.[431]

Deemed Measure Cost

The deemed installed measure cost including labor is approximately $2.53/MBtu/hr.[432]

Deemed O&M Cost Adjustments

N/A

Loadshape

N/A

Coincidence Factor

N/A

[428] The standard turndown ratio for boilers is 6:1. Understanding Fuel Savings in the Boiler Room, ASHRAE Journal, David Eoff, December, 2008 p 38

[429] Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

[430] FES Analysis of bin hours based upon a 30% oversizing factor.

[431] “Burner,” Obtained from a nation-wide survey conducted by ASHRAE TC 1.8 (Akalin 1978). Data changed by TC 1.8 in 1986.

[432] 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 * $(\text{Cycles\_base})^2$ – 0.001 * Cycles_base [433]

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[434] or custom

TDR_base = Turndown ratio = 0.33[435] or custom

EL_eff = Efficient Boiler Percentage of energy loss due to cycling at % of Efficient Boiler Load

= 0.003 * $(\text{Cycles\_eff})^2$ – 0.001 * Cycles_eff

Where:

Cycles_eff = Number of Cycles/hour

---

433 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.

434 PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010, Page 4-12.

435 Ibid.

= TDR_eff / BL

Where:

TDR_eff = Turndown ratio = 0.10[436] 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

436 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.[437]

Deemed Measure Cost

The deemed measure cost is estimated at $2.50/MBtu/hr burner input.[438]

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.

[437] 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.[439] 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.[440] 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

[439] 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

[440] 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.[441]

DEEMED MEASURE COST

The deemed measure cost is approximately $23,250.[442]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

[441] 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.

[442] 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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

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.[443] O2 trim controls have an excess air rate of 15%.[444] The average difference is 13%. A 15% reduction in excess air is approximately a 1% increase in efficiency.[445] 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.[446]

MEASURE CODE: CI-HVC-O2TC-V01-140601

REVIEW DEADLINE: 1/1/2022

[443] 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.
[444] Ibid

[446] 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.[447]

DEEMED MEASURE COST

The deemed measure cost for this approximately $1,500.[448]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

[447] 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.
[448] 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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

ΔTherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%[449]

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.[450]

MEASURE CODE: CI-HVC-SODP-V01-140601

REVIEW DEADLINE: 1/1/2020

[449] Based on internet review of savings potential;
"Up to 4%": Use of Automatic Vent Dampers for New and Existing Boilers and Furnaces, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency, Canada, 2002
"Up to 1%": Page 9, The Carbon Trust, "Steam and high temperature hot water boilers" http://www.carbontrust.com/media/13332/ctv052_steam_and_high_temperature_hot_water_boilers.pdf,
"1 - 2%": Page 2, Sustainable Energy Authority of Ireland "Steam Systems Technical Guide", http://www.seai.ie/Your_Business/Technology/Buildings/Steam_Systems_Technical_Guide.pdf.

[450] 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.[451]

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.[452]

Insulation Thickness	¾" pipe	½" pipe
1"	$4.45	$4.15

Loadshape

N/A

Coincidence Factor

N/A

[451] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
[452] 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[453] = [((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 [454]

= 80.7% for steam boilers, except multifamily low-pressure [455]

[453] 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"
[454] Average efficiencies of units from the California Energy Commission (CEC).
[455] Ibid.

= 64.8% for multifamily low-pressure steam boilers [456]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [457]

= 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.458

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.

[456] Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.

[457] 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.

[458] 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)
Space Heating Non-recirculating	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
	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

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 - 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[459] based upon equipment life only[460]. 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[461] per thermostat, as summarized in the table below.

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

[460] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption.

[461] 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[462]

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***

[462] 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
	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.)

= 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	
	Continuous	1510.201	1496.47	1706.105	1716.128	1688.464	93

Building Type	Fan Mode During Occupied Period (*Fo*)	Climate Zone Coefficient (*CZ*)					Minimum *Ws*
		1	2	3	4	5	
Retail – Department Store	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	

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 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PRGA-V01-150601

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years;[463] measure life for process is 10 years.[464]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs[465] 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
20 HP	$ 3,059

LOADSHAPE

Loadshape C39 - VFD - Supply fans <10 HP

Loadshape C40 - VFD - Return fans <10 HP

Loadshape C41 - VFD - Exhaust fans <10 HP

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[463] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors

[464] DEER 2008

[465] 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.

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[466]

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

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

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

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

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%)[467]

η_{motor} = Installed nominal/nameplate motor efficiency

Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

[466] 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.

[467] 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.

NEMA Premium Efficiency Motors Default Efficiencies[468]

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
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[469]. When available, actual hours should be used.

Building Type	Total Fan Run Hours
Assembly	7235
Assisted Living	8760
College	6103
Convenience Store	7004
Elementary School	7522

[468] Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA. Retrieved October 17, 2013, from http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf

[469] 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
Garage	7357
Grocery	7403
Healthcare Clinic	6345
High School	7879
Hospital - VAV econ	8760
Hospital - CAV econ	8760
Hospital - CAV no econ	8760
Hospital - FCU	8760
Manufacturing Facility	8706
MF - High Rise	8760
MF - Mid Rise	8760
Hotel/Motel - Guest	8760
Hotel/Motel - Common	8760
Movie Theater	7505
Office - High Rise - VAV econ	6064
Office - High Rise - CAV econ	5697
Office - High Rise - CAV no econ	5682
Office - High Rise - FCU	6163
Office - Low Rise	6288
Office - Mid Rise	6125
Religious Building	7380
Restaurant	7809
Retail - Department Store	6890
Retail - Strip Mall	6846
Warehouse	6786
Unknown	7100

$\%FF$ = 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
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-V02-160601

REVIEW DEADLINE: 1/1/2021

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. This measure analyzes the heating savings potential from recovering energy from exhaust or relief building air. This measure assumes 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.

Definition of Baseline Equipment

The baseline is unitary equipment not required by IECC 2012/2015 to incorporate energy recovery.

Deemed Lifetime of Efficient Equipment

The measure life for the domestic energy recovery equipment is 15 years.[470]

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 1 to 1 ratio of fresh and exhausted air.

Energy Recovery Equipment Type	Incremental Cost $/CFM[471]
Fixed Plate	$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

[470] Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy
[471]"Map to HVAC Solutions", by Michigan Air, Issue 3, 2006

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no anticipated electrical savings from this measure as it is assumed that the additional fan energy due to the increased static pressure drop offsets cooling energy savings. Where this is not expected to be the case, a custom calculation should be used to determine the savings.

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

T_DD = Temperature on design day of outside air[472]

= (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[473]

= (see Table below) or custom

Heat Recovery Equipment Type	TE_ERV (%)
Fixed Plate	0.65
Rotary Equipment	0.68
Heat Pipe	0.55

[472]Weather Station Data, 99.6% Heating DB - 2013 Fundamentals, ASHRAE Handbook
[473]Energy Recovery Fact Sheet - Center Point Energy, MN

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
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-V02-160601

REVIEW DEADLINE: 1/1/2022

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.[474]

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

$$\Delta therms = SF * MBH\_In * EFLH / 100$$

[474] 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

Where:

T_existing = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 425F[475] (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)[476] or custom

= 365°F (conventional economizer – Steam Boiler)[477] or custom

= 280°F (condensing economizer – Water Boiler)[478] or custom

= 308°F (condensing economizer – Steam Boiler)[479] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[480] or custom

Based on defaults provided above:

Boiler Type	SF[481]	
	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

[475] Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

[476] 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.

[477] 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.

[478] 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.

[479] 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.

[480] 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.

[481] 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.

EFLH = Equivalent Full Load Hours for heating are provided in Section 4.4 HVAC End Use

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.[482]

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

[482] PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

NATURAL GAS SAVINGS

Δtherms = SF * MBH_In * 8766 * UF / 100

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[483] (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)[484] or custom

= 365°F (conventional economizer – Steam Boiler)[485] or custom

= 280°F (condensing economizer – Water Boiler)[486] or custom

= 308°F (condensing economizer – Water Boiler)[487] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[488] or custom

Based on defaults provided above:

Boiler Type	SF[489]	
	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

483 Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.
484 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.
485 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.
486 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.
487 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.
488 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.
489 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.

= Actual

8766 = Hours a year

UF = Utilization Factor

= 41.9%[490] 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

[490] 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[491] [492] [493] 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[494] 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.

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[491] "Gates Corporation Announces New EPDM Molded Notch V-Belts," The Gates Rubber Co., June 2010 (Assumed 3% efficiency improvement) https://ww2.gates.com/news/index.cfm?id=11296&show=newsitem&location_id=753&view=Gates

[492] "Synchronous Belt Drives Offer Low Cost Energy Savings," Baldor., February 2009. (attached in Reference Documents)

[493] "Energy Savings from Synchronous Belts," The Gates Rubber Co., February 2014. (Assumed 5% efficiency improvement) http://www.gates.com/~/media/Files/Gates/Industrial/Power%20Transmission/White%20Papers/Energy%20Savings%20from%20Synchronous%20Belt%20Drives.pdf

[494] "Motor System Tip Sheet #5, Replace V-Belts with Cogged or Synchronous Belt Drives," USDOE-EERE, September 2005. (Assumed 2% efficiency improvement) http://www1.eere.energy.gov/industry/bestpractices/pdfs/replace_vbelts_motor_systemts5.pdf

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).

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[495] 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[496]

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)
Assembly	7235	3.3
Assisted Living	8760	2.7
College	6103	3.9
Convenience Store	7004	3.4
Elementary School	7522	3.2
Garage	7357	3.3
Grocery	7403	3.2
Healthcare Clinic	6345	3.8
High School	7879	3.0
Hospital - VAV econ	8760	2.7
Hospital - CAV econ	8760	2.7
Hospital - CAV no econ	8760	2.7
Hospital - FCU	8760	2.7
Manufacturing Facility	8706	2.8
MF - High Rise	8760	2.7
MF - Mid Rise	8760	2.7
Hotel/Motel - Guest	8760	2.7
Hotel/Motel - Common	8760	2.7
Movie Theater	7505	3.2
Office - High Rise - VAV econ	6064	4.0

[495] 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.

[496] "DEER2014-EUL-table-update_2014-02-05.xlsx," Database for Energy Efficiency Resources (DEER), Deer 2014. www.deerresources.com (attached in Reference Documents)

Building Type	Total Fan Run Hours	EUL (Years)
Office - High Rise - CAV econ	5697	4.2
Office - High Rise - CAV no econ	5682	4.2
Office - High Rise - FCU	6163	3.9
Office - Low Rise	6288	3.8
Office - Mid Rise	6125	3.9
Religious Building	7380	3.3
Restaurant	7809	3.1
Retail - Department Store	6890	3.5
Retail - Strip Mall	6846	3.5
Warehouse	6786	3.5
Unknown	7100	3.4

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[497] 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	$113.00	$67.10

[497] Grainger catalog on-line web-site for Dayton v-belt pricing http://www.grainger.com/Grainger/ecatalog/N-1z0r596/Ntt-v-belts

Smooth V-Belt Industry Number	Smooth belt system Price*	Synchronous Belt Industry Number	Synchronous System Price*	Price Difference
		GTR-36G-8M-12 (Item # 2UWH6)		
* 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.

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor[498] 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[499].

= (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[500]. 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[501]. Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

498 Assumed to be $150 based on mechanical contractor estimate.
499 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.
500 Com Ed TRM June 1, 2010
501 Efficiency values for motors less than one HP taken from Baldor Electric Catalog 501: http://www.baldor.com/pdf/501_Catalog/CA501.pdf

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[502] are provided in table below for HVAC fan operation which varies by building type:

Building Type	Total Fan Run Hours
Assembly	7235
Assisted Living	8760
College	6103
Convenience Store	7004
Elementary School	7522
Garage	7357
Grocery	7403
Healthcare Clinic	6345
High School	7879
Hospital - VAV econ	8760
Hospital - CAV econ	8760
Hospital - CAV no econ	8760
Hospital - FCU	8760
Manufacturing Facility	8706
MF - High Rise	8760
MF - Mid Rise	8760
Hotel/Motel - Guest	8760
Hotel/Motel - Common	8760
Movie Theater	7505
Office - High Rise - VAV econ	6064
Office - High Rise - CAV econ	5697
Office - High Rise - CAV no econ	5682
Office - High Rise - FCU	6163
Office - Low Rise	6288
Office - Mid Rise	6125
Religious Building	7380
Restaurant	7809
Retail - Department Store	6890
Retail - Strip Mall	6846
Warehouse	6786
Unknown	7100

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%[503]

[502] 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.

[503] 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-V03-180101

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[504] 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.[505]

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

504 American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html
505 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%[506]

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

[506] 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)[507] 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.

[507] 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. [508]

[508] For complex systems this value may be obtained from a CHP System design/financial analysis study.

= ($CHP_{capacity}$ * Hours) - $E_{Parasitic}$

$CHP_{capacity}$ = CHP nameplate capacity

= Custom input

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)[509]. 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. [510]

= $CHP_{thermal}$ / $Boiler_{eff}$ (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

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[509] 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 2014 are:

- Non-Baseload RFC West: 9,346 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,157 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,931 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 10,209 Btu/kWh * (1 + Line Losses)

[510] For complex systems this value may be obtained from a CHP System design/financial analysis study.

= Custom input

Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))

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 thermal output that can be claimed also differ slightly depending on whether the project was included in both electric[511] and gas[512] Energy Efficiency Portfolio Standard (EEPS)[513] 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).

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[511] 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B

[512] 220 ILCS 5/8-104

[513] 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).

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%.

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[514] 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[515].

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:

$$\Delta kWh = E_{CHP}$$

[514] 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.

[515] 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.

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = CF * CHP_{capacity}$$

Where:

CF = Summer Coincidence factor. This factor should also consider any displaced chiller capacity[516]

= 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[517].

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[518].

516 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.

517 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.

518 "EPA Combined Heat and Power Partnership Resources" Oct 07, 2014, http://www.epa.gov/chp/resources.html in the document "Catalog of CHP technologies" http://www.epa.gov/chp/documents/catalog_chptech_full.pdf pages 2-16, 3-14, 4-14, 5-14, and 6-16.

COST-EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING

For the purposes of forecasting load reductions due to CHP projects per Section 16-111.5B, 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:

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-V02-180101

REVIEW DEADLINE: 1/1/2020

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.[519]

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.

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[519] 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.[520]

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.[521]

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%[522]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[523]

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.[524] The calculation

[520] 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.

[521] Based on manufacturer interviews and air curtain specification sheets.

[522] 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.

[523] 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

[524] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): Ch 16.1 - 16.37

assumes that the air curtain is appropriately sized and commissioned to be effective in mitigating infiltration of winds 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).[525] 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.[526] 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.[527]

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

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

[525] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

[526] 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

[527] 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[528]

.	CD (Balance Point Temperature)				
Climate Zone - Weather Station/City	45 °F	50 °F	55 °F	60 °F	65 °F
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

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[529]:

	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

Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

[528] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
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, Error! eference source not found.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 °F 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.

[529] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

Q_{tbc} = 4.5 * CFM_{tot} *(h_{oc} – h_{ic}) / (1,000 Btu/kBtu)

Where:

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.[530]

	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:

530 Average enthalpies were estimated following ASHRAE guidelines for perfect gas relationships for dry air associated with hourly TMY3 data.Error! Reference source not found. Enthalpies were then averaged for all values associated with a dry-bulb outdoor air emperature 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.

v_{wc} = average wind speed during the cooling season based on entryway orientation (mph)

= use the below table to for the wind speed effects based on climate zone and entryway orientation[531]:

	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 sec/min) * sqrt[2 * g * H/2 * (T_{oc} - T_{ic}) / (459.7 + T_{oc})]

Where:

C_{dc} = the discharge coefficient during the cooling season[532]

= 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.

531 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

532 ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): p 16.13

g = acceleration due to gravity

= 32.2 ft/sec^2

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 (^oF)

= 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[533]:

	T_{oc}				
Climate Zone - Weather Station/City	62 ^oF	67 ^oF	72 ^oF	77 ^oF	82 ^oF
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 ^oF to ^oR

= 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[534]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ($\Delta kWh_{cooling}$ / (CD *24)) * CF

Where:

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)

[533] Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed.
[534] 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): http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1972&context=iracc
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8
[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.

= 47.8% [536]

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[537]:

Climate Zone - Weather Station/City	HD				
	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)

$Q_{bc} = (1.08 \text{ Btu/(hr*}^{o}\text{F*cfm)}) * CFM_{tot} * (T_{ih} - T_{oh}) / (100{,}000 \text{ Btu/therm})$

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

[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] 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
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
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:

$CFM_t = A_d * C_{dh} * (60 \text{ sec/min}) * \text{sqrt}[2 * g * H/2 * (T_{ih} – T_{oh}) / (459.7 + T_{ih})]$

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[538]

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[539].

MEASURE CODE: CI-MSC-AIRC-V01-160601

REVIEW DEADLINE: 1/1/2022

[538] 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): http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1972&context=iracc
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[539] 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[540]. 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[541].

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.

[540] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 16
[541] 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[542]

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[543]:

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:

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542 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.

543 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)
Heat Pump	Before 2006	6.8	2.0
	2006 - 2014	7.7	2.3
	2015 on	8.2	2.40
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:

ΔkWh = - (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

ΔTherms = [(ΔQ_r + ΔQ_w) * t_{eff}] / (100,000 * η)

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[544]:

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)

[544] 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.

η = thermal efficiency of heating equipment

= 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 * ^{o}F / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

Thermal Resistance Factor (R-Factor) for Roof	Retrofit[545]	New Construction[546] (2010 or newer)
R_r	10.0 (hr * ft^2 * ^{o}F / Btu)	20.0 (hr * ft^2 * ^{o}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 (^{o}F)

= Actual. If unknown, use the following equation

[545] 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.

[546] 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

$= m_s * h_r + T_{f,s}$

h_r = ceiling height/roof deck (ft)

m_s = estimated heat gain per foot elevation, stratified case (°F/ft)

= 0.8 °F/ft

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[547,548]. Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 °F/ft heat gain.

$T_{f,s}$ = estimated floor temperature, stratified case (°F)

$= T_{tstat} - m_s * h_{tstat}$

$= T_{tstat} - 4$ °F

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:[549,550]

$= T_{tstat} + 1$ °F

EXAMPLE:

For a 50,000 ft² warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 °F. No further measured values available.

$\Delta Q_r = (1/R_r) * A_r * (T_{r,s} - T_{r,d}) = (1/R_r) * A_r * [(m_s * h_r + T_{tstat} - 4\,°F) - (T_{tstat} + 1\,°F)]$

$= (1/R_r) * A_r * [(0.8°F/ft * h_r) - 5\,°F]$

$= 1/(10\ hr * ft^2 * °F / Btu) * (50{,}000\ ft^2) * [(0.8°F/ft * 30\ ft) - 5\,°F]$

= 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%.[551]

$\Delta Q\_w = Q_{w,s} - Q_{w,d}$

$= (1/R_w) * A_w * (T_{w,s} - T_{w,d})$

Where:

[547] 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.

[548] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain.

[549] 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.

[550] 13. Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48.

[551] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 51

R_w = overall thermal resistance through the exterior walls (hr * ft^2* ^{o}F / Btu)

= Actual or estimated based on construction type[552]. If unknown, assume the following

Thermal Resistance Factor (R-Factor) for Wall	Retrofit[553]	New Construction[554] (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[555]

= $[(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r$

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

= $T_{tstat} + 0.5$

[552] 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.

[553]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.

[554]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

[555] Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48

= 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 ^oF and a measured temperature at the ceiling of 85 ^oF and unit heaters located 10 feet from the roof:

ΔQ_w = $(1/R_w) * A_w * (T_{w,s} – T_{w,d})$

= $(1/R_w) * A_w * [([(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r) – (T_{tstat} + 0.5\ ^oF)]$

= $1/(6.5\ hr*ft^2*^oF/Btu) * (1200 * 30) * [([(85^oF * 10ft) + (65\ ^oF * 20ft)] / 30ft) – (65 + 0.5\ ^oF)]$

= $1/(6.5\ hr*ft^2*^oF/Btu) * (36{,}000ft^2) * (71.7\ ^oF – 65.5\ ^oF)$

= 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 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[556]. 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-V02-180101

REVIEW DEADLINE: 1/1/2021

556 Enbridge Gas Distribution, Inc., "Big Fans Deliver Big Bonus," (Aug 2007) https://www.enbridgegas.com/businesses/assets/docs/hunter_douglas_case_study.pdf. 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)[557].

[557] ASHRAE, Standard 90.1-2013 - https://www.ashrae.org/resources--publications/bookstore/standard-90-1

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.

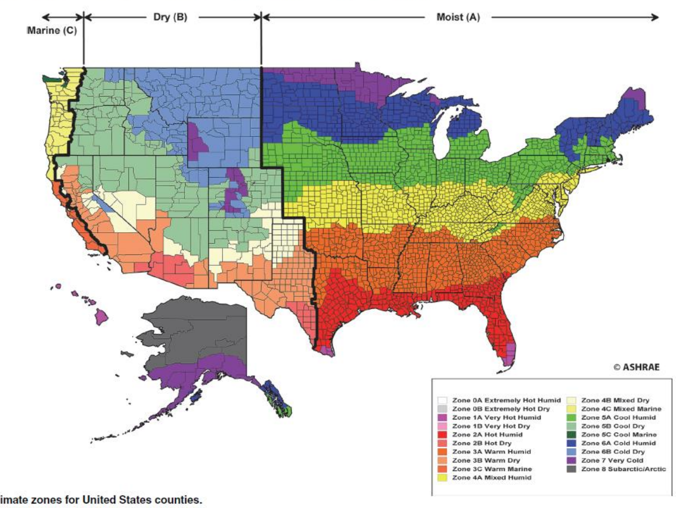

FIGURE B-1 Climate zones for United States counties.

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[558].

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.

[558] California Public Utilities Commission, DEER 2014 EUL Table D08 v2.05

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[559]. 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[560].

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
Religious Facility	DB	cz+CSP*-1.131+OAn*3.542+OAx*-1.01
	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

559 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.

560 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
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
	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

Building Type	Changeover Type	Electric Climate Zone Coefficients CZ1 (Rockford)	CZ2 (Chicago)	CZ3 (Springfield)	CZ4 (Belleville)	CZ5 (Marion)
	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)

= 0 for Economizer w/ Integrated Operation (Two Stage Cooling)

= 1 for Economizer w/ out Integrated Operation (One Stage Cooling)

Oan = Minimum Outside Air (% OSA)[561]

= 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)[562])

Oax = Maximum Outside Air (%)[i]

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 70%
Non functional Economizer (Damper failed closed) – 15%

561 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)

562 Technician rule of thumb taken from CPUC 'HVAC Impact Evaluation Final Report', WO32, 28Jan 2015, p18.

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

Building Type	Changeover Type	Equation
Convenience Store	DB	cz+OAn*0.26
	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

		Natural Gas Climate Zone Coefficients				
Building Type	**Changeover Type**	**CZ1 (Rockford)**	**CZ2 (Chicago)**	**CZ3 (Springfield)**	**CZ4 (Belleville)**	**CZ5 (Marion)**
	Enth	2.96	0.50	-1.49	-2.98	-5.59
	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-V02-160601

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 5 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.[563]

DEEMED MEASURE COST

AS A RETROFIT MEASURE, THE ACTUAL INSTALLED COST SHOULD BE USED FOR SCREENING PURPOSES.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[563] The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

Natural Gas Energy Savings

$$\Delta Therms = Capacity \times EFLH \times SF / 100,000$$

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

= 5%[564] 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 0.05 / 100,000
>
> = 843 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: **CI-HVC-SBAC-V01-160601**

Review Deadline: **1/1/2022**

[564] A conservative estimate considering only setback savings, with DOE estimates as much as 1% per degree per 8 hours of setback. http://energy.gov/energysaver/thermostats

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)[565].

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[566]. 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[567]. In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[568] 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.

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[565] Illinois Statewide Technical Reference Manual (TRM), Version 4.0 (effective June 1, 2015), 2015. http://www.ilsag.info/technical-reference-manual.html (Accessed September 25, 2015).

[566] American National Standards Institute (ANSI), ANSI Z21.47 Standard for Central Gas-Fired Central Furnaces, 2012. http://www.techstreet.com/products/1837013#product (Accessed September 25, 2015).

[567] Department of Energy (DOE), Commercial Warm Air Furnace Standard DOE 10 CFR, Part 431, Subpart D – Commercial Warm Air Furnaces, 2004. https://www.law.cornell.edu/cfr/text/10/part-431/subpart-D (Accessed September 25, 2015).

[568] American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, 2013. https://www.ashrae.org/resources-- publications/bookstore /standard-90-1 (Accessed September 25, 2015).

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[569]. 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[570]. 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)[571] weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 ^{o}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 ^{o}F and 65 ^{o}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)[572] 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 ^{o}F), and likewise for the annual heating loads for HDD45 (HDD at

[569] Department of Energy (DOE), Rulemaking for Commercial Warm Air Furnace Standard, Technical Support Document 2015. https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/70 (Accessed September 25, 2015).
[570] Department of Energy (DOE) National Renewable Energy Laboratory, Commercial Reference Building Models of the National Building Stock, 2011. http://www.nrel.gov/docs/fy11osti/46861.pdf (Accessed September 25, 2015).
[571] Department of Energy (DOE) National Renewable Energy Laboratory, Users Manual for TMY3 Data Sets, 2008. http://www.nrel.gov/docs/fy08osti/43156.pdf (Accessed September 25, 2015).
[572] National Climatic Data Center, 1981-2010 Climate Normals, 2015. https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data (Accessed November 4, 2015).

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.

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:

$\Delta kWh = -(t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$

$= -(8760 * 5000 * 0.15) / (0.6 * 8520)$

$= -1285$ 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 ^oF (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 ^{o}F:

ΔTherms = [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^{o}F	85^{o}F	95^{o}F	105^{o}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
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

<u>3911 Hour Annual Operation Scenario</u>

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-V01-160601

REVIEW DEADLINE: 1/1/2019

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[573].

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[574] 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

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[573] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs V4, April 2016 (New York TRM).

[574] 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[575]

= $ELA * 0.000645 * (f_s^2 * (T_{OA} - T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

Where:

ELA = Effective Leakage Area (sq. in.)

= Can be collected on site; if unknown, assume 6 sq. in.[576]

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/s²)

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[577]. Use values from table below, based on facility location[578]. 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

[575] 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).

[576] 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.

[577] "Heating Period" is defined as hours when the TMY3 dry bulb temperature is less than 55°F (balance point)

[578] 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[579].

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[580].

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

579 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.
580 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[581]

3,412 = Converts Btus to kWh

COP = Coefficient of Performance of the heating unit

= Collected on site. If unknown assume 2.6 for PTHP[582]

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

581 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.

582 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:

$ΔTherms = (Q_{infiltration} * 1.08\ Btu/hr.CFM.°F * (T_{OA} – T_{SA}) * EFLH_{heat}) / (100,000\ Btu/therm * η)$

Where,

η = Efficiency of heating equipment.

= Collected on site. If unknown, assume 80%[583].

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

583 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
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
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,

$f_s = 1/3 * (9.81\ m/s^2 * 80\ ft * 0.3048\ m/ft / 274.26\ K)^{0.5} = 0.3\ m/K^{½}.s$

$f_w = 0.24 * 0.85 * (80\ ft * 0.3048\ m/ft / 10\ m)^{0.2} = 0.24$

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

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[584].

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)[585].

The incremental measure cost, assuming a baseline of standard efficiency unit heaters, is $7.43/MBtu/hr (material cost)[586].

[584] Based on "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014.
[585] Average costs from CLEAResult's evaluation of 9 different projects in the Chicagoland area.
[586] 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.

$$\Delta kWh = - kWh/HDD * HDD$$

Where:

kWh/HDD = increase in electric energy consumption due to HTHV fan motor

= 1.04[587]

HDD = heating degree days

Zone	City	HDD55[588]	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:

[587] 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.

[588] 30-year normals from the National Climactic Data Center (NCDC), assuming base temperature 55.

FLH_{base} = LF_{base} * Hours

FLH_{eff} = LF_{eff} * Hours

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[589]

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[590] (°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[591]	
Heat Loads		
Infiltration Load[592]:	$Q_{inf,base} = 0.04CFM/ft^2$ * (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 * $(T_{r,eff} - T_{OA})$

[589] 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.

[590] 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.

[591] Use Typical Meteorological Year (TMY3) data from NREL available here: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

[592] Typical infiltration rate assumed from Infiltration Modeling Guidelines for Commercial Building Energy Analysis, prepared for US. DOE by Pacific Northwestern National Laboratory, 2009

Parameter	Existing Unit	Proposed (Efficient) Unit
Wall Conduction Load[593]:	$Q_{w,base}$ = 1/R-value$_{wall}$ * (Wall Surface Area * 1.08 * ($T_{r,base}$ - T_{OA}) Where R-value$_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15.	$Q_{w,eff}$ = 1/R-value$_{wall}$ * (Wall Surface Area * 1.08 * ($T_{r,eff}$ - T_{OA}) Where R-value$_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15.
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[594] = 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

[593] Roof and Wall Insulation R-values are based on ASHRAE 90.1- 2010. (Jim Young 2014) (K. Gowri 2009)
[594] Based on DOE's Commercial Prototype Modeled Warehouse building (in Chicago), found here: https://www.energycodes.gov/commercial-prototype-building-models

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)
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
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

4.5 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 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[595]	Screw based bulb Annual Operating hours[596]	Waste Heat Cooling Energy WHFe [597]	Waste Heat Cooling Demand WHFd	Coincid-ence Factor CF[598]	Waste Heat Gas Heating IFTherms [599]	Waste Heat Electric Resistance Heating IFkWh[600]	Waste Heat Electric Heat Pump Heating IFkWh
Assisted Living	7,862	5,950	1.14	1.30	0.66	0.035	0.823	0.358
Childcare/Pre-School	2,860	2,860	1.17	1.29	0.72	0.018	0.420	0.183
College	3,395	2,588	1.06	1.39	0.63	0.020	0.462	0.201
Convenience Store	4,672	3,650	1.09	1.26	0.76	0.035	0.828	0.360
Elementary School	3,038	2,118	1.17	1.29	0.72	0.018	0.420	0.183
Garage	3,401	3,540	1.00	1.00	0.92	0.000	0.000	0.000
Garage, 24/7 lighting	8,766	8,766	1.00	1.00	1.00	0.000	0.000	0.000
Grocery	4,650	3,650	1.05	1.22	0.73	0.022	0.511	0.222
Healthcare Clinic	3,890	4,207	1.40	1.85	0.65	0.006	0.144	0.063
High School	3,038	2,327	1.18	1.39	0.72	0.028	0.656	0.285
Hospital - CAV no econ	7,616	4,207	1.11	1.29	0.76	0.022	0.527	0.229
Hospital - CAV econ	7,616	4,207	1.06	1.27	0.75	0.023	0.533	0.232
Hospital - VAV econ	7,616	4,207	1.37	1.79	0.70	0.010	0.241	0.105
Hospital - FCU	7,616	4,207	1.38	1.29	0.73	0.001	0.033	0.015

[595]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).

[596] 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.

[597] 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.

[598]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) or based upon schedules defined in the eQuest models described (all others).

[599] IF Therms value is developed using EQuest models consistent with methodology for Waste Heat Factor for Energy.

[600] 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[595]	Screw based bulb Annual Operating hours[596]	Waste Heat Cooling Energy WHFe [597]	Waste Heat Cooling Demand WHFd	Coincid-ence Factor CF[598]	Waste Heat Gas Heating IFTherms [599]	Waste Heat Electric Resistance Heating IFkWh[600]	Waste Heat Electric Heat Pump Heating IFkWh
Manufacturing Facility	4,618	2,629	1.02	1.04	0.81	0.012	0.270	0.117
MF - High Rise - Common	6,138	5,950	1.14	1.32	0.64	0.025	0.596	0.259
MF - Mid Rise - Common	6,138	5,950	1.14	1.32	0.64	0.025	0.596	0.259
Hotel/Motel - Guest	2,390	777	1.18	1.36	0.28	0.020	0.463	0.201
Hotel/Motel - Common	6,138	4,542	1.20	1.24	0.73	0.032	0.748	0.325
Movie Theater	3,506	5,475	1.11	1.38	0.53	0.029	0.673	0.293
Office - High Rise - CAV no econ	2,886	3,088	1.00	1.07	0.57	0.037	0.874	0.380
Office - High Rise - CAV econ	2,886	3,088	1.00	1.07	0.57	0.039	0.905	0.394
Office - High Rise - VAV econ	2,886	3,088	1.27	1.65	0.53	0.022	0.510	0.222
Office - High Rise - FCU	2,886	3,088	1.35	1.56	0.59	0.015	0.346	0.150
Office - Low Rise	2,698	3,088	1.11	1.31	0.52	0.016	0.371	0.161
Office - Mid Rise	3,068	3,088	1.26	1.61	0.52	0.024	0.557	0.242
Religious Building	2,085	1,664	1.12	1.37	0.48	0.015	0.356	0.155
Restaurant	5,571	4,784	1.17	1.31	0.68	0.021	0.491	0.213
Retail - Department Store	5,478	2,935	1.12	1.31	0.95	0.022	0.514	0.223
Retail - Strip Mall	4,093	2,935	1.12	1.29	0.71	0.019	0.450	0.196
Warehouse	5,242	4,293	1.00	1.22	0.68	0.011	0.257	0.112
Unknown	3,379	3,612	1.09	1.36	0.58	0.022	0.522	0.227
Exterior – dusk to dawn	4,903	4,903	1.00	1.00	0.00	0.000	0.000	0.000
Exterior – dusk to business close	See calculation below		1.00	1.00	0.00	0.000	0.000	0.000
Low-Use Small Business	2,954	2,954	1.31	1.53	0.66	0.023	0.524	0.262
Uncooled Building	Varies	varies	1.00	1.00	0.66	0.014	0.320	0.160
Refrigerated Cases	5,802	n/a	1.29	1.29	0.69	0.000	0.000	0.000
Freezer Cases	5,802	n/a	1.50	1.5	0.69	0.000	0.000	0.000

Exterior Lighting Hours – dusk to business close

Hours = (6.19 * Days) + (%Adj * Days)

Where:

6.19 = Average hours per day between dusk and midnight[601]

Days = Days of business operation

= Actual

%Adj = Percent adjustment dependent on hour closing[602]

[601] 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).

[602] See "IL TRM Ext Lighting.xlsx" for calculation.

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

4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

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[603], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[604].

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[605]) 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.

---

[603] 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'.

[604] Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.

[605] 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[606].

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

$$\Delta kWh = ((WattsBase - WattsEE)/1000) * ISR * Hours * WHFe$$

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

606 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)
2601	2999	150
1490	2600	72
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%[607] 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%[608]	14.5%	12.3%	98.0%[609]

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[610]. 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

607 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.

608 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.

609The 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

610 Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{611} = (((WattsBase - WattsEE)/1000) * ISR * Hours * -IFkWh$$

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

$$\Delta kW = ((WattsBase - WattsEE)/1000) * ISR * WHFd * CF$$

Where:

[611] 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 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, 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[612] = (((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)[613]	Replacement Cost[614]
= 1000 / Hours	$1.25

[612] Negative value because this is an increase in heating consumption due to the efficient lighting.
[613] 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).
[614] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

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-CCFL-V07-180101

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[615].

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[616]
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

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615 Based on ComEd's estimate of lamp type saturation.

616 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

$$\Delta kWh = ((WattsBase - WattsEE)/1000) * ISR * Hours * WHFe$$

Where:

WattsBase = Assume wattage reduction of lamp removed

	Wattage of lamp removed[617]		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.

[617] 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 (http://www.sce.com/NR/rdonlyres/7A3455F0-A337-439B-9607-10A016D32D4B/0/spc_B_Std_Fixture_Watts.pdf). An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor. See 'Delamping calculation.xls' for details.

=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.

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:

$$\Delta kWh = ((19.4 - 0)/1000) * 1.0 * 4439 * 1.25$$
$$= 107.6\ kWh$$

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{618} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

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

$$\Delta kW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF$$

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:

$$\Delta kW = ((19.4 - 0)/1000) * 1.0 * 1.3 * 0.66$$
$$= 0.017\ kW$$

[618] Negative value because this is an increase in heating consumption due to the efficient lighting.

NATURAL GAS ENERGY SAVINGS

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

ΔTherms[619] = (((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, 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

619 Negative value because this is an increase in heating consumption due to the efficient lighting.

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 99% Commercial and 1% Residential should be used[620].

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.

[620] 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 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[621] and qualifying RWT8 products[622].

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 v6.0 until 1/1/2019 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2019. See table C-1.

Deemed Lifetime of Efficient Equipment

The deemed lifetime of efficient equipment varies based on the program and is defined below:

621 http://library.cee1.org/content/cee-high-performance-t8-specification
622 http://library.cee1.org/content/reduced-wattage-t8-specification

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
Fixture lifetime is 15 years[623]. 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 15 years.624	Fixture lifetime 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 15 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

[623] 15 years from GDS Measure Life Report, June 2007
[624] 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%[625] 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:

[625] 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
98%[626]	0%	0%	98.0%[627]

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[628] = (((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

ΔkW =(($Watts_{base}$-$Watts_{EE}$)/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[629] = (((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.

626 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

627 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

628 Negative value because this is an increase in heating consumption due to the efficient lighting.

629 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[630]

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

[630] 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[631]

EE Measure Description	Nominal Watts	Ballast Factor	WattsEE	Baseline Description	Nominal Watts	WattsBASE	WattsSAVE	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

[631] 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.

A– 3: RWT8 New and Baseline Assumptions

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

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

B-1: Time of Sale T8 Component Costs and Lifetime[632]

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

632 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

B-2: T8 Retrofit Component Costs and Lifetime[633]

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

[633] 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

B-3: Reduced Wattage T8 Component Costs and Lifetime[634]

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

[634] 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 1/1/2019, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2019. 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 2018 will claim full savings for one year. Savings adjustment factors will be applied to the full savings for savings starting in 1/1/2019 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'.[635]

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-V06-160601

REVIEW DEADLINE: 1/1/2019

[635] See "HPRWT8_reference.xlsx" for more information.
EPE Program Downloads. Web accessed http://www.epelectricefficiency.com/downloads.asp?section=ci download 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 available at http://www.focusonenergy.com/files/Document_Management_System/Evaluation/bpdeemedsavingsmanuav10_evaluationreport.pdf Based on ComEd's BILD program data from PY4 and PY5. 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.

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 95% Residential and 5% Commercial assumptions should be used[636], and for Commercial targeted programs a deemed split of 96% Commercial and 4% Residential should be used[637].

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 v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd).

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 between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014.

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

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[636] 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'.

[637] Based on final ComEd's BILD program data from PY4,PY5 and PY6. 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.

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:

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[638] (WattsEE)	Baseline 2014-2019 (WattsBase)	Delta Watts 2014-2019 (WattsEE)	Baseline Post EISA 2020 requirement[639] (WattsBase)	Delta Watts Post 2020 (WattsEE)
5280	6209	5745	72.9	300.0	227.1	300.0	227.1
3000	5279	4140	52.5	200.0	147.5	200.0	147.5
2601	2999	2800	35.5	150.0	114.5	150.0	114.5

[638] 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.
[639] Calculated as 45lm/W for all EISA non-exempt bulbs.

Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage[638] (WattsEE)	Baseline 2014-2019 (WattsBase)	Delta Watts 2014-2019 (WattsEE)	Baseline Post EISA 2020 requirement[639] (WattsBase)	Delta Watts Post 2020 (WattsEE)
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

Nominal wattage of lamp to be replaced ($Watts_{base}$)	Minimum initial light output of LED lamp (lumens)	LED Wattage ($Watts_{EE}$)	Delta Watts
10	70	1.08	8.92
15	90	1.38	13.6
25	150	2.31	22.7
40	300	4.62	35.4
60	500	7.69	52.3

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	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Delta Watts
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	446	6.6	33.4
	473	524	45	499	7.3	37.7
	525	714	50	620	9.1	40.9
	715	937	65	826	12.1	52.9
	938	1259	75	1099	16.2	58.8
	1260	1399	90	1330	19.6	70.4
	1400	1739	100	1570	23.1	76.9
	1740	2174	120	1957	28.8	91.2
	2175	2624	150	2400	35.3	114.7
	2625	2999	175	2812	41.3	133.7
	3000	4500	200	3750	55.1	144.9
***R, BR, and ER with medium screw bases w/**	400	449	40	425	6.2	33.8
	450	499	45	475	7.0	38.0
	500	649	50	575	8.5	41.5
	650	1199	65	925	13.6	51.4

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	Lumens used to calculate LED Wattage (midpoint)	LED Wattage ($Watts_{EE}$)	Delta Watts
diameter <=2.25"						
***ER30, BR30, BR40, or ER40**	400	449	40	425	6.2	33.8
	450	499	45	475	7.0	38.0
	500	649	50	575	8.5	41.5
***BR30, BR40, or ER40**	650	1419	65	1035	15.2	49.8
***R20**	400	449	40	425	6.2	33.8
	450	719	45	585	8.6	36.4
***All reflector lamps below lumen ranges specified above**	200	299	20	250	3.7	16.3
	300	399	30	350	5.1	24.9

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.[640] 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.[641]

$$\text{Wattsbase} = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

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

[640] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[641] 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.

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%[642] 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
95.7%[643]	1.2%	1.1%	98.0%[644]

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{645} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

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:

$$\Delta kWh_{heatpenalty} = ((29-6.7)/1000)*1.0*3088* -0.151$$

$$= - 10.4 \text{ kWh}$$

[642] 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.

[643] Based on ComEd's BILD program data from PY5 and PY6, see "IL Commercial Lighting ISR_2014.xls".

[644] 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:
'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

[645]Negative value because this is an increase in heating consumption due to the efficient lighting.

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:

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 Referecne 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:

$$\Delta kW = ((29-6.7)/1000) * 1.0*1.3*0.66$$

$$= 0.019 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

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

$$\Delta Therms = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms$$

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:

$$\Delta Therms = ((29-6.7)/1000)*1.0*3088* -0.016$$

$$= - 1.10 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For all measures except Standard Omnidirectional lamps (which have an EISA baseline shift) the individual component lifetimes and costs are provided in the reference table section below[646].

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 15,000/3612 =4.2 years) is calculated[647]. The key assumptions used in this calculation are documented below[648]:

	Std Inc.	EISA Compliant Halogen	CFL
2017	$0.43	$1.25	N/A
2018	$0.43	$1.25	N/A
2019	$0.43	$1.25	N/A
2020 & after	$0.43	N/A	$2.45

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:

Location	Lumen Level	NPV of replacement costs for period			Levelized annual replacement cost savings		
		2018	2019	2020	2018	2019	2020
Commercial	Lumens <310 or >2600 (EISA exempt)	$6.02	$6.02	$6.02	$1.47	$1.47	$1.47
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$13.22	$9.64	$6.04	$3.22	$2.35	$1.47
Multi Family Common Areas	Lumens <310 or >2600 (non-EISA compliant)	$5.92	$5.92	$5.92	$2.37	$2.37	$2.37
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$17.20	$14.25	$8.32	$6.88	$5.70	$3.33

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[649] 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[650]:

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[646] See “LED Lighting Systems TRM Reference Tables” for breakdown of component cost assumptions.

[647] See C&I OmniDirectional LED O&M Calc_012017.xls” for more information. The values assume the non-residential average hours assumption of 3612.

[648] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

[649] 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.

[650] 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.

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

Directional and Decorative O&M; apply incandescent cost assumption provided above with a frequency calculated by dividing the assumed rated life of the baseline bulb (1000 hours) by the building specific hours of use assumption

LED Fixture Wattage and Incremental Cost Assumptions[651]

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
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, Horizontal or Vertical (per foot)	15.2 per ft	$11/ft	N/A
	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	LED 4' Linear Replacement Lamp	18.7	80:20 T12:T8; Lamp Only 32w T8:34w T12	33.6	$24	89%
	LED 2' Linear Replacement Lamp	9.7	80:20 T12:T8; Lamp Only 17w T8:20w T12	19.4	$13	75%
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	34.1	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$48	85%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	42.8	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$91	69%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	37.9	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$62	83%

[651] 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.xlsx" for more information and specific product links.

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	54.3	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$99	62%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	72.7	80:20 T12:Standard T8 4-Lamp 32w T8, 4-Lamp 34w T12	137.7	$150	61%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	18.1	80:20 T12:Standard T8 1-Lamp 32w T8 , 1-Lamp 34w T12	30.6	$36	88%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	39.6	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$76	81%
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	53.1	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$130	62%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	19.7	80:20 T12:Standard T8 1-Lamp 32w T8, 1-Lamp 34w T12	30.6	$54	86%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	37.8	80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12	61.0	$104	83%
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	55.9	80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12	103.3	$158	60%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	62.6	T5HO 2L-F54T5HO - 4'	120.0	$215	N/A
	LED Surface & Suspended Linear Fixture, > 7500 lumens	95.4	T5HO 3L-F54T5HO - 4'	180.0	$374	N/A
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	90.3	3-Lamp T8HO Low-Bay	157.0	$191	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	127.5	4-Lamp T8HO High-Bay	196.0	$331	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	191.0	6-Lamp T8HO High-Bay	294.0	$482	N/A
	LED High-Bay Fixtures, > 20,000 lumens	249.7	8-Lamp T8HO High-Bay	392.0	$818	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	17.0	25% 73 Watt EISA Inc, 75% 1L T8	42.0	$33	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	27.8	25% 146 Watt EISA Inc, 75% 2L T8	81.0	$54	N/A
	LED Ag Interior Fixtures, 4,001-6,000 lumens	51.2	25% 217 Watt EISA Inc, 75% 3L T8	121.0	$125	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	71.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	$190	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	103.5	200W Pulse Start Metal Halide	227.3	$298	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	143.8	320W Pulse Start Metal Halide	363.6	$450	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	183.3	350W Pulse Start Metal Halide	397.7	$595	N/A

LED Category	EE Measure Description	$Watts_{EE}$	Baseline Description	$Watts_{BASE}$	Incremental Cost	Mid Life Savings Adjustment (2018)
	LED Ag Interior Fixtures, > 20,000 lumens	305.0	(2) 320W Pulse Start Metal Halide	727.3	$998	N/A
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	42.6	100W Metal Halide	113.6	$190	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	68.2	175W Pulse Start Metal Halide	198.9	$287	N/A
	LED Exterior Fixtures, 10,001-15,000 lumens	122.5	250W Pulse Start Metal Halide	284.1	$391	N/A
	LED Exterior Fixtures, > 15,000 lumens	215.0	400W Pulse Start Metal Halide	454.5	$793	N/A

LED Fixture Component Costs & Lifetime[652]

		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	LED 4' Linear Replacement Lamp	50,000	$8.57	70,000	$13.67	24,000	$6.17	40,000	$11.96
	LED 2' Linear Replacement Lamp	50,000	$5.76	70,000	$13.67	24,000	$6.17	40,000	$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$46.68	70,000	$40.00	24,000	$26.33	40,000	$35.00

[652] Note some measures have blended baselines (T12:T8 80:20). 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 Tables" 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 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$56.31	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$49.58	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$57.76	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$68.89	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$43.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$52.31	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$63.86	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	50,000	$45.01	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$58.73	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$73.50	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$88.69	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	50,000	$123.91	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	50,000	$90.03	70,000	$62.50	18,000	$64.50	40,000	$92.50
	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

		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, 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	$37.00	70,000	$40.00	18,250	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$44.96	70,000	$40.00	18,250	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$63.02	70,000	$40.00	18,250	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$79.78	70,000	$40.00	18,250	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$119.91	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$151.89	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$184.62	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$285.75	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	50,000	$86.92	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$111.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	$138.32	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Exterior Fixtures, > 15,000 lumens	50,000	$223.67	70,000	$62.50	15,000	$73.00	40,000	$132.50

MEASURE CODE: CI-LTG-LEDB-V06-180101

REVIEW DEADLINE: 1/1/2019

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 a fluorescent or incandescent model.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 16 years[653].

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $30[654].

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100%[655].

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	WattsBase
Incandescent	35W[656]

[653] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
[654] NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.
[655] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
[656] Based on review of available product.

Baseline Type	WattsBase
Fluorescent	11W[657]
Unknown (e.g. time of sale)	23W[658]

WattsEE = Actual wattage if known, if unknown assume 2W[659]

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 fluorescent fixture in a hospital

ΔkWH = (11 – 2)/1000 * 8766 * 1.35

= 106.5 kWh

HEATING PENALTY

If electrically heated building:

$\Delta kWh_{heatpenalty}$[660] = (((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 fluorescent fixture in a heat pump heated hospital

$\Delta kWh_{heatpenalty}$ = (11 – 2)/1000 * 8766 * -0.104

= -8.2 kWh

657 Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

658 ComEd has been using a weighted baseline of 70 percent incandescent and 30 percent compact fluorescent, reflecting program experience and a limited sample of evaluation verification findings that we consider to be reasonable (Navigant, through comment period February 2013)

659 Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

660 Negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF$$

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 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 fluorescent fixture in a hospital
>
> ΔkW = (11 – 2)/1000 * 1.69 * 1.0
>
> = 0.015 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 fluorescent fixture in a hospital
>
> ΔTherms = (11 – 2)/1000 * 8766 * -0.011
>
> = - 0.87 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)

	Baseline Measures	
Lamp	$7.00[661]	1.37 years[662]

MEASURE CODE: CI-LTG-LEDE-V02-140601

REVIEW DEADLINE: 1/1/2021

661 Consistent with assumption for a Standard CFL bulb with an estimated labor cost of $4.50 (assuming $18/hour and a task time of 15 minutes).

662 Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

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.[663] 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[664]

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

[663] ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals, http://www.cee1.org/gov/led/led-ace3/ace3led.pdf
[664] Ibid

Lamp Type	CF
Red Arrows	0.90
Green Arrows	0.10
Yellow Arrows	0.03
Green Round, always changing or flashing	0.43
Flashing Yellow	0.50
Yellow Round, always changing	0.02
“Hand” Don’t Walk Signal	0.75
“Man” Walk Signal	0.21

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:

$$\Delta kW = ((69 - 7) \times 0.55) / 1000$$

$$= 0.0341 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

REFERENCE TABLES

Traffic Signals Technology Equivalencies[665]

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[666]	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

[665] 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
[666] Technical Reference Manual for Ohio, August 6, 2010

MEASURE CODE: CI-LTG-LEDT-V01-120601

REVIEW DEADLINE: 1/1/2019

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 or 2015, 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[667]. 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)..

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[668]

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
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting

[667] 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 (ASHRAE 90.1).
[668] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

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.[669]

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:

$$\Delta kWh_{heatpenalty}[670] = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * -IFkWh$$

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

669 See IECC 2012 and 2015 - Reference Code documentation for additional information.

670 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 [671]	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

[671] 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 [671]	IECC 2012 Lighting Power Density (w/ft²)	IECC 2015 Lighting Power Density (w/ft²)
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[672]	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

[672] 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 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

COMMERCIAL ENERGY EFFICIENCY

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)

C-62 2012 INTERNATIONAL ENERGY CONSERVATION CODE®

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.

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).

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/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	0.075 W/ft² of gross above-grade wall area	0.113 W/ft² of gross above-grade wall area	0.15 W/ft² 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/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.
W = watts.

MEASURE CODE: CI-LTG-LPDE-V03-160601

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 deemed lifetime of the efficient equipment fixture, regardless of program type is 15 years[673].

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

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.

[673] 15 years from GDS Measure Life Report, June 2007

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%[674] 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%[675]	12.1%	10.3%	98.0%[676]

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{677} = (((WattsBase - WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

[674] 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.

[675] 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.

[676] 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.

[677] Negative value because this is an increase in heating consumption due to the efficient lighting.

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[678] = (((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.

[678]Negative value because this is an increase in heating consumption due to the efficient lighting.

MEASURE CODE: CI-LTG-MSCI-V02-140601

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).

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[679].

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[680].

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

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[679] Consistent with Occupancy Sensor control measure.

[680] 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[681]:

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:

$$\Delta kWh_{heatpenalty}{}^{682} = KW_{Controlled} * Hours * ESF * -IFkWh$$

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

[681] 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. http://lightingcontrolsassociation.org/bi-level-switching-study-demonstrates-energy-savings/

[682]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

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

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[683].

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-V03-160601

REVIEW DEADLINE: 1/1/2021

[683] 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 Occupancy Sensor Lighting Controls

DESCRIPTION

This measure relates to the installation of new occupancy sensors on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling or fixture mounted occupancy sensors. 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[684].

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

Lighting control type	Cost[685]
Full cost of wall mounted occupancy sensor	$51
Full cost of ceiling or remote mounted occupancy sensor	$102
Full cost of fixture-mounted occupancy sensor	$91.83
Full cost of fixture embedded occupancy sensor[686]	$54

[684] DEER 2008

[685] Taken from NEEP Commercial Lighting Controls, Incremental Cost Data Analysis, 2011 “NEEP Commercial Lighting Controls 2011_08_29.xlsx”

[686] Fixture embedded Occupancy Sensors are included with the fixture and therefore no additional installation costs are incurred for these sensors. Therefore, it is assumed that the costs associated with Fixture-embedded Occupancy Sensors should not surpass those of the wall mounted due to the similarity in installation.

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	Default kw controlled[687]
Wall mounted occupancy sensor (per control)	0.305
Remote mounted occupancy sensor (per control)	0.517
Fixture mounted sensor (per fixture)	0.180

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.

[687] Based on EVT control data for Occupancy Sensor Costs 2009-2014.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system).

Lighting Control Type	Energy Savings Factor[688]
Wall, Ceiling or Fixture-Mounted Occupancy Sensors	24%
Wall-Mounted Occupancy Sensors Configured as "Vacancy Sensors"	31%[689]

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:

$$\Delta kWh_{heatpenalty}{}^{690} = KW_{Controlled} * Hours * ESF * -IFkWh$$

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.[691]

NATURAL GAS ENERGY SAVINGS

$$\Delta therms = KW_{Controlled} * Hours * ESF * - IFTherms$$

Where:

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688 Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Page & Associates Inc. 2011

689 Papamichael, Konstantions, Bi-Level Switching in Office Spaces, California Lighting Technology Center, February 1,2010. Note: See Figure 8 on page 10 for relevant study results. The study shows a 30% extra savings above a typical occupancy sensor; 24% * 1.3 = 31%.

690 Negative value because this is an increase in heating consumption due to the efficient lighting.

691 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.

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-V04-160601

REVIEW DEADLINE: 1/1/2021

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[692].

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)[693]

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

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692 Equal to the manufacturers standard warranty

693 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)[694]	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 [695]

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:

$\Delta kWh_{heatpenalty}$[696] = 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

ΔkW = ΔkW_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

ΔTherms[697] = ΔkW_f * HOURS *- IFTherms

Where:

[694] Solatube Test Report (2005). http://www.mainegreenbuilding.com/files/file/solatube/stb_lumens_datasheet.pdf
[695] Ibid. The lumen values presented in the kW table represent the average of the lightest 2400 hours.
[696]Negative value because this is an increase in heating consumption due to the efficient lighting.
[697]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[698].

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.

[698] 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 v6.0 until 1/1/2019 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2019 in years remaining in the measure life. See table C-1.

Deemed Lifetime of Efficient Equipment

The deemed lifetime of the efficient equipment fixture, regardless of program type is Fixture lifetime is 15 years[699].

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

[699] 15 years from GDS Measure Life Report, June 2007

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%[700] 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%[701]	0%	0%	98.0%[702]

[700]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.

[701] 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

[702] 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.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{703} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

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

$$\Delta Therms^{704} = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms$$

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.

[703] Negative value because this is an increase in heating consumption due to the efficient lighting.
[704] 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[705]

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

[705] 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[706]

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

[706]Ibid.

B-1: Time of Sale T5 Component Costs and Lifetime[707]

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

[707] 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[708]

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

[708] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011
EPE Program Downloads. Web accessed http://www.epelectricefficiency.com/downloads.asp?section=ci download 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 available at http://www.focusonenergy.com/files/Document_Management_System/Evaluation/bpdeemedsavingsmanuav10_evaluationreport.pdf

C-1: T12 Baseline Adjustment:

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%	

Measures installed in 2018 will claim full savings for one year. Savings adjustment factors based on a T8 baseline will be applied to the full savings for savings starting in 2019 and for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table above and is based on equivalent lumens.

MEASURE CODE: CI-LTG-T5FX-V05-180101

REVIEW DEADLINE: 1/1/2019

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).

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[709].

Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the assumed measure cost is $274[710].

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

[709] DEER 2008.
[710] 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%[711]	50%	39.3%
		33%	52.6%
		10%	70.7%
		5%	74.6%
Corridors		50%	25.0%

[711] Average found from the four buildings in the State of California Energy Commission Lighting Research Program Bi-Level Stairwell Fixture Performance Final Report: http://www.archenergy.com/lrp/lightingperf_standards/project_5_1_reports.htm

Application	% Standby Mode	% Full Light at Standby Mode	Energy Savings Factor (ESF)
	50.0%[712]	33%	33.5%
		10%	45.0%
		5%	47.5%
Other 24/7 Space Type	50.0%[713]	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:

$$\Delta kWh_{heatpenalty}{}^{714} = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * -IFkWh$$

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.[715]

712 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. http://www.energy.ca.gov/title24/2005standards/archive/documents/2002-07-18_workshop/2002-07-18_BILEVEL_LIGHTING.PDF
713 Conservative estimate.
714 Negative value because this is an increase in heating consumption due to the efficient lighting.
715 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.

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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OCBL-V02-160601

REVIEW DEADLINE: 1/1/2021

4.5.14 Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

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 (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.

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[716], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[717].

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[718]) 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[719].

For the Retrofit measures, the full cost of $8.50 should be used plus $5 labor[720] for a total of $13.50. However actual program delivery costs should be utilized if available.

[716] 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'.
[717] Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.
[718] 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.
[719] NEEP Residential Lighting Survey, 2011
[720] Based on 15 minutes at $20 per hour.

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[721]; use 60W if unknown[722]

EISA exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals >=2601	2601	2999	150
	3000	5279	200
	5280	6209	300

[721] Based upon the draft ENERGY STAR specification for lamps (http://energystar.gov/products/specs/sites/products/files/ENERGY_STAR_Lamps_V1_0_Draft%203.pdf) and the Energy Policy and Conservation Act of 2012.
[722] 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
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[723].

For Directional R, BR, and ER lamp types[724]:

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.[725] If CBCP and beam angle information are not

[723] From pg 10 of the Energy Star Specification for lamps v1.1

[724] From pg 11 of the Energy Star Specification for lamps v1.1

[725] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[726]

$$Wattsbase = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

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[727]

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[728] if application form completed with sign off that equipment is not placed into storage

[726] 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.

[727] An evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting http://ilsag.org/yahoo_site_admin/assets/docs/ComEd_Res_Lighting_PY2_Evaluation_Report_2010-12-21_Final.12113928.pdf) 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).

[728] 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.

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
71.2%[729]	14.5%	12.3%	98.0%[730]

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[731]. 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.

$$\Delta kWh = (((45 - 14)/1000) * 1.0 * 3088 * 1.25$$

$$= 119.7 \text{ kWh}$$

HEATING PENALTY

If electrically heated building:

729 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.

730 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

731 Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

$\Delta kWh_{heatpenalty}$[732] = (((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.

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[733] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

[732]Negative value because this is an increase in heating consumption due to the efficient lighting.

[733] Negative value because this is an increase in heating consumption due to the efficient lighting.

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

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[734]. 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-V03-180101

REVIEW DEADLINE: 1/1/2020

[734] 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. [735]

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

[735] 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[736]

$Watts_{ee}$ = Wattage of LED sign with low voltage transformer

= Actual; if unknown use 14.9W[737]

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:

$$\Delta kWh_{heatpenalty}{}^{738} = ((WattsBase-WattsEE)/1000) * Hours * -IFkWh$$

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.

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[736] Measured average demand data. Southern California Edison, "Replace Neon Open Sign with LED Open Sign", Workpaper SCE13LG070, Revision 2, October 2015. Pg. 10

[737] Ibid.

[738]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 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[739]	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[740] = ((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

[739] Savings can be calculated for additional building types using the default values provided in the Reference Table in Section 4.5.
[740] Negative value because this is an increase in heating consumption due to the efficient lighting.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OPEN-V01-180101

REVIEW DEADLINE: 1/1/2022

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.[741]

DEEMED MEASURE COST

The deemed measure cost is $156.82 for a walk-in cooler or freezer.[742]

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[743].

Annual Savings	kWh
Walk in Cooler	943
Walk in Freezer	2307

[741] Source: DEER 2008
[742] Ibid.
[743] Measure savings from ComEd TRM developed by KEMA. June 1, 2010

Summer Coincident Peak Demand Savings

Annual Savings	kW
Walk in Cooler	0.137
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-V01-120601

Review Deadline: 1/1/2019

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 [744].

Deemed Measure Cost

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes[745]:

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[746].

[744] Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005.
[745] ComEd workpapers, 8—15-11.pdf
[746] 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[747]
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)[748]
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

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747 USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. <http:// http://www.usatech.com/energy_management/energy_productsheets.php>

748 Ibid.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-BEVM-V02-150601

REVIEW DEADLINE: 1/1/2019

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 12 years [749].

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[750].

Loadshape

Loadshape C51 - Door Heater Control

Coincidence Factor[751]

The summer peak coincidence factor for this measure is assumed to be 0%[752].

[749] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
[750] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
[751] Source partial list from DEER 2008
[752] 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWH = kWbase * NUMdoors * ESF * BF * 8766

Where:

kWbase[753] = 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[754] = 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[755] = 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[756]	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

753 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.

754 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.

755 Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

756 Energy Efficiency Supermarket Refrigeration, Wisconsin Electric Power Company, July 23, 1993

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-DHCT-V01-120601

REVIEW DEADLINE: 1/1/2019

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[757]

DEEMED MEASURE COST

The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer. [758]

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The peak kW coincidence factor is 100%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \text{Savings per motor} * \text{motors}$$

Where:

[757] DEER

[758] 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)

Savings per motor = based on the motor rating of the ECM motor:

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[759]

Deemed Measure Cost

The incremental cost of this measure is $500[760]

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[761]

Vending Machine Capacity (cans)	kWh Savings Per Machine w/o software	kWh Savings Per Machine w/ software
<500	1,099	1,659

[759] ENERGY STAR
[760] ENERGY STAR
[761] Savings from Vending Machine Calculator:
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC

Vending Machine Capacity (cans)	kWh Savings Per Machine w/o software	kWh Savings Per Machine w/ software
500 - 599	1,754	2,231
600 - 699	1,242	1,751
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-V02-150601

REVIEW DEADLINE: 1/1/2019

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 16 years[762]

Deemed Measure Cost

The measure cost is assumed to be $291[763]

Loadshape

Loadshape C46 - Evaporator Fan Control

Coincidence Factor

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

[762] Source: DEER
[763] Source: DEER

Algorithm

Calculation of Savings

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association[764] and supported by a PGE workpaper. Note that climate differences across all California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to 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

[764] See 'EC_motor_with_controller_182014.xlsx'.

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: CI-RFG-EVPF-V03-180101

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.[765]

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[766] 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[767].

Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening [768]

Loadshape

Loadshape C22 - Commercial Refrigeration

Coincidence Factor

The summer peak coincidence factor for this measure is 100%[769].

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765 The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's 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. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.

766 Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

767 DEER 2014 Effective Useful Life.

768 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.

769 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[770]

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[771]

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[772]

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

[770] 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].

[771]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.

[772] 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

ΔkW = ΔkWh / 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[773].

DEEMED MEASURE COST

The installation cost for an economizer is $2,558.[774]

LOADSHAPE

Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 0%[775].

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated based on whether evaporator fans run all

With Fan Control Installed

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans) – kWCirc) * Hours * DCComp * BF] – [kWEcon * DCEcon * Hours]

[773] Estimated life from Efficiency Vermont TRM

[774] Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems.

[775] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings.

Without Fan Control Installed

ΔkWh = [HP * kWhCond] – [kWEcon * DCEcon * Hours]

Where:

HP = Horsepower of Compressor

= actual installed

kWhCond = Condensing unit savings, per hp. (value from savings table) [776]

	Hermetic / Semi-Hermetic	Scroll	Discus
kWh/HP	1,256	1,108	1,051

Hours = Number of annual hours that economizer operates [777].

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% [778]

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW[779]

kWCirc = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW[780]

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%[781]

[776] 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

[777] 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).

[778] 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)

[779] Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

[780] 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

[781] Average of two manufacturer estimates of 50% and 75%.

BF = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)[782]

kWEcon = Connected load kW of the economizer fan

= If known, actual installed. Otherwise assume 0.227 kW.[783]

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

[782] 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

[783] 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.[784]

DEEMED MEASURE COST

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.[785]

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:

[784] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

[785] 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[786]	ES ΔkWh/ft reduction (= 9% reduction of electricity use[787,788])
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

[786] 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.

[787] 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.

[788] 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 12 years.[789]

Deemed Measure Cost

The incremental measure cost is $150/sq.ft.[790]

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:

---

789 DEER 2008, Consulted from similar refrigerated warehouse measures.

790 Rite Hite – Industrial High Speed Doors

0.00008333 = conversion from Btu/h to tons

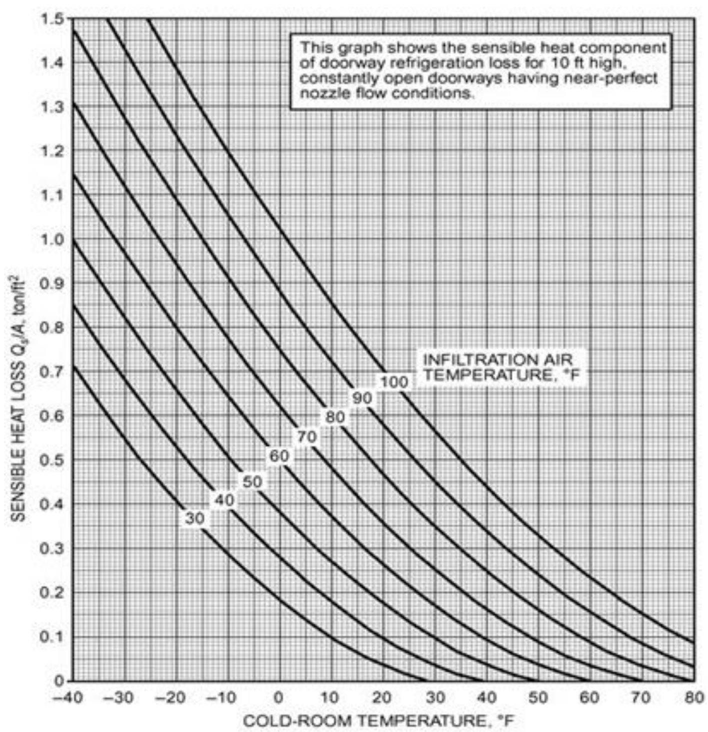
q = sensible and latent refrigeration load for fully established flow, Btu/h

$$= 3790 * W * H^{1.5} * \left(\frac{Q_s}{A}\right) * \left(\frac{1}{R_s}\right)$$

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[791], cooler temperature 35^{o}F and freezer temperature -10^{o}F[792], 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%[793], resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.

[791] 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).

[792] Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011

[793] 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[794].

η = Efficiency of refrigeration system (kW/ton). Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton[795] 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.

794 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7

795 Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD).

$$D_{tE} = \frac{(P\ \theta_{pE}\ +\ 60\ \theta_{oE})}{3600\ \theta_d}$$

P = Number of passages through doorway per hour. Custom input, assume 5.9[796] if unknown.

Θ_{pE} = Door open to close time in seconds. Custom input, assume 7.5 seconds[797] if unknown.

Θ_{oE} = Time door remains open in minutes. Custom input, assume 3 minutes[798] 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[799].

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[800] if unknown.

t = hours per year when primary doors to the cooled space are open.

= Custom input, assume 2,959 hrs/yr[801] 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

796 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.11
797 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.6
798 Professional judgement
799 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7
800 Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives.
801 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[802].

Measure Code: CI-RFG-HSRD-V01-180101

Review Deadline: 1/1/2022

[802] Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets.

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. The baseline compressors defined 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

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 a modulating compressor with blow down ≤ 40 hp

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

10 years.

DEEMED MEASURE COST

$$IncrementalCost (\$) = (127 \times hp_{compressor}) + 1446$$

Where:

127 and 1446[803] = 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 coincidence factor equals 0.95

[803] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Several Vermont vendors were surveyed to determine the cost of equipment. See "Compressed Air Analysis.xls" and "Compiled Data ReQuest Results.xls" for incremental cost details.

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[804] = 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[805]

=0.890

CF_e = efficient compressor [806]

=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

804 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. See "BHP Weighted Compressed Air Load Profiles v2.xls".

805 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. "See "BHP Weighted Compressed Air Load Profiles.xls" for source data and calculations (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).

806 Ibid.

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / HOURS * CF

EXAMPLE

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

ΔkW = 3290/1976*.95

= 1.58 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-MSC-VSDA-V01-120601

Review Deadline: 1/1/2019

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

5 years

DEEMED MEASURE COST

The incremental cost for this measure is estimated to be $1000 Incremental cost per filter[807]

LOADSHAPE

Loadshape C35 - Industrial Process

COINCIDENCE FACTOR

The coincidence factor equals 0.95

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:

[807] Incremental cost research found in LPDF Costs. xlsx

Compressor $kW_{typical}$

Control Type	$kW_{typical}$ [808]
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 %	$kW_{typical}$ [809]
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[810]

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[811]

Hours = depending on shifts

Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 2476 hrs

2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 4452 hrs

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 6428 hrs

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[812]

[808] See "Industrial System Standard Deemed Saving Analysis.xls"
[809] See "Industrial System Standard Deemed Saving Analysis.xls"
[810] 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
[811] "Optimizing pneumatic systems for extra savings," 10, 2010, http://www.compressedairchallenge.org/library/articles/2010-10-CABP.pdf

[812] Industrial System Standard Deemed Saving Analysis.xls

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / HOURS * CF$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-CALPDF-V01-140601

REVIEW DEADLINE: 1/1/2020

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 [813]

Loadshape

Loadshape C35 - Industrial Process

Coincidence Factor

The coincidence factor equals 0.95

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[814]

kW_{CFM} = System power reduction per reduced air demand (kw/CFM) depending on the type of compressor control:

[813] Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls

[814] Reduced CFM consumption is based on an a timer drain opening for 10 seconds every 300 seconds as the baseline. See "Industrial System Standard Deemed Saving Analysis.xls"

System Power Reduction per Reduced Air Demand[815]

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[816]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / HOURS * 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-MSC-CANCLD-V01-140601

REVIEW DEADLINE: 1/1/2020

[815] 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"
[816] 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[817]

Deemed Measure Cost

The estimated incremental measure costs are presented in the following table[818]

Nozzle Diameter	1/8”	1/4"	5/16”	1/2"
Average IMC	$42	$57	$87	$121

Loadshape

Loadshape C35 - Industrial Process

Coincidence Factor

The coincidence factor equals 0.95

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[817] PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission.

[818] 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. www.exair.com. Accessed March 20, 2014

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (SCFM * SCFM\%Reduced) * kW/CFM * \%USE * HOURS$$

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[819, 820].

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%[821]

kW/CFM = System power reduction per air demand (kW/CFM) depending on the type of air compressor found in table below[822]

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%[823]

Hours = Compressed air system pressurized hours.

= Use actual hours if known, otherwise assume values in table below:

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819 Review of manufacturer’s information

820 Technical Reference Manual (TRM) for Ohio Senate Bill 221”Energy Efficiency and Conservation Program” and 09-512-GE-UNC, October 15,
2009. Pgs 170-171

821 Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th
Edition, and manufacturers’ catalog.

822 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”

823 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.

Shift	Hours
Single Shift	1976
Two Shifts	3952
Three Shifts	5928
Four Shifts or Continual Operation	8320
Unknown / Weighted average[824]	5702

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / HOURS * CF$$

Where:

ΔkWh = As calculated above

CF = 0.95

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE CI-MSC-CNOZ-V01-150601

REVIEW DEADLINE: 1/1/2022

[824] 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

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 10 years[825].

Deemed Measure Cost

The incremental capital cost for this measure is $6 per CFM.[826]

Loadshape

Loadshape C35 – Industrial Process

Coincidence Factor

The coincidence factor equals 0.95

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = P_s \times (EC50_{baseline} - EC50_{efficient}) \times HOURS \times CFM$$

[825] State of Wisconsin Public Service Commission, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

[826] Analysis of material cost between cycling and non-cycling dryers according to prices from Grainger. Cost provided is the average incremental cost when comparing non-cycling and cycling dryers of the same CFM capacity. http://www.grainger.com/category/refrigerated-compressed-air-dryers/compressed-air-treatment/pneumatics/ecatalog/N-kk5?bc=y

Where:

P_s = Full flow specific power of the dryer

= 0.007 kW/CFM[827] (for both baseline and efficient equipment)

$EC50_{baseline}$ = Energy consumption ratio of baseline dryer at 50%[828] inlet load capacity as compared to fully loaded operating conditions.[829]

= 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[830]:

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[831]	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, rate of airflow through the dryer.

[827] Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron. http://www.compressedairchallenge.org/library/articles/2011-11-CABP.pdf
[828] Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50% capacity.
[829] Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron. http://www.compressedairchallenge.org/library/articles/2011-11-CABP.pdf
[830] Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron. http://www.compressedairchallenge.org/library/articles/2011-11-CABP.pdf
[831] DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.

= Assume 50% of actual rated capacity.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / HOURS * CF$$

Where:

CF = 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-CADR-V01-160601

REVIEW DEADLINE: 1/1/2023

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 10 years[832]

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%[833]

[832] Martin, N. et al., Emerging Energy-Efficient Industrial Technologies: New York State Edition, American Council for an Energy Efficient Economy (ACEEE), March 2001 (as stated in the OH State TRM, page 269)

[833] 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)

Algorithm

Calculation of Savings

Electric Energy Savings

$\Delta kWh = (HP_{motor} * 0.746 * LF / \eta_{motor}) * HOURS * ESF$

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 [834]

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%[835].

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

[834] "Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings," ACEEE 1994 Summer Study Conference, Asilomar, CA.

[835] 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, https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

MEASURE CODE: CI-MSC-PMPO-V01-150601

REVIEW DEADLINE: 1/1/2022

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)..

<u>R-Values: ASHRAE – 90.1 – 2010</u>

	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 – 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	0.032	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[836], 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% [837]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [838]

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-^{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.

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{o}F] during cooling season between outdoor air temperature and assumed 75^{o}F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][839]	$\Delta T_{AVG,cooling}$ [°F]
1 (Rockford)	81	6

[836] Measure costs are from the W017 Itron California Measure Cost Study, accessed via http://www.energydataweb.com/cpuc/search.aspx. The data is provided in a file named "MCS Results Matrix – Volume I".
[837] 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.
[838] 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
[839] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][839]	$\Delta T_{AVG,cooling}$ [°F]
2 (Chicago)	81	6
3 (Springfield)	81	6
4 (Belleville)	82	7
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^oF heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][840]	$\Delta T_{AVG,heating}$ [°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.

[840] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3
http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

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

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%

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% [841]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [842]

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.

$EFLH_{heating}$ = Equvalent 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

[841] 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.

[842] 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

MEASURE CODE: CI-MSC-RINS-V02-160601

REVIEW DEADLINE: 1/1/2021

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.[843]

DEEMED MEASURE COST

The deemed measure cost is $29 per networked computer, including labor.[844]

LOADSHAPE

Loadshape C21: Commercial Office Equipment.

COINCIDENCE FACTOR

N/A

Algorithm

[843] 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;).

[844] Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Wsavings * W$$

Where:

Wsavings = annual energy savings per workstation

= 200 kWh[845] for desktops, 50 kWh for laptops[846]

= If unknown assume 161 kWh (based on 74% desktop and 26% laptop[847])

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 [848]

MEASURE CODE: CI-MSC-CPMS-V01-150601

REVIEW DEADLINE: 1/1/2020

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845 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 http://rtf.nwcouncil.org/measures/measure.asp?id=95 (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)
http://www.energystar.gov/ia/products/power_mgt/LowCarbonITSavingsCalc.xlsx?78c1-120e&78c1-120e
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)

846 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

847 Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.

848 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[849].

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)[850].

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

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[849] Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013.

[850] 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[851]	1,483
Multi-family Dryers[852]	1,074
On-Premise Laundromats[853]	3,607

SF = Savings factor

= 0.18 therms/cycle[854]

If using default cycles the savings are as follows:

Application	ΔTherms
Coin- Operated Laundromats[855]	267
Multi-family Dryers[856]	193
On-Premise Laundromats[857]	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

[851] From DOE's Federal Register Notices - found here: http://energy.gov/eere/buildings/recent-federal-register-notices
[852] Ibid.
[853] 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.
[854] 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.
[855] From DOE's Federal Register Notices - found here: http://energy.gov/eere/buildings/recent-federal-register-notices
[856] Ibid.
[857] 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[858] 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[859].

For early replacement measures it is assumed the existing unit would last another 2.3 years[860]

Deemed Measure Cost[861]

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

[858] "The Real Size of a Front Load Washer" http://laundromat123.com/Laundromat_Washer_Comparison.html
[859] "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. http://www.coinwash.com/temp/coinwash_Assessment_Water_%20Savings_Commercial_Clothes_Washers.pdf
[860] Third of expected measure life.
[861] Measure costs are based on data from a quote provided by a commercial washer distributor to Franklin Energy Services.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

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[862]
Multi-family	3.4[863]
Hotel/Motel/Hospital	10.4[864]

Days = Days per year of commercial laundromat operation

= Actual, or if unknown, assume 360 days[865]

Capacity = Clothes washer rated capacity (lb/cycle)[866]

= Actual

RMC = Retained Moisture Content (%)[867] reduction from replacing a low extraction speed washer

= Assume 25%[868]

862 "2014-2015 State of the Self-Service Laundry Industry Report." Carlo Calma, April 13, 2015. https://americancoinop.com/articles/2014-2015-state-self-service-laundry-industry-report-conclusion

863 "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. http://www.coinwash.com/temp/coinwash_Assessment_Water_%20Savings_Commercial_Clothes_Washers.pdf

864 "Laundry Planning Guide." EDRO, January 2015. http://www.edrocorp.com/do wnloads/Laundry-Planning-Guide%202015.pdf

865 Based on professional judgement, assuming closed on holidays.

866 Clothes washer capacity is based on weight of dry clothing.

867 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.

868 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.

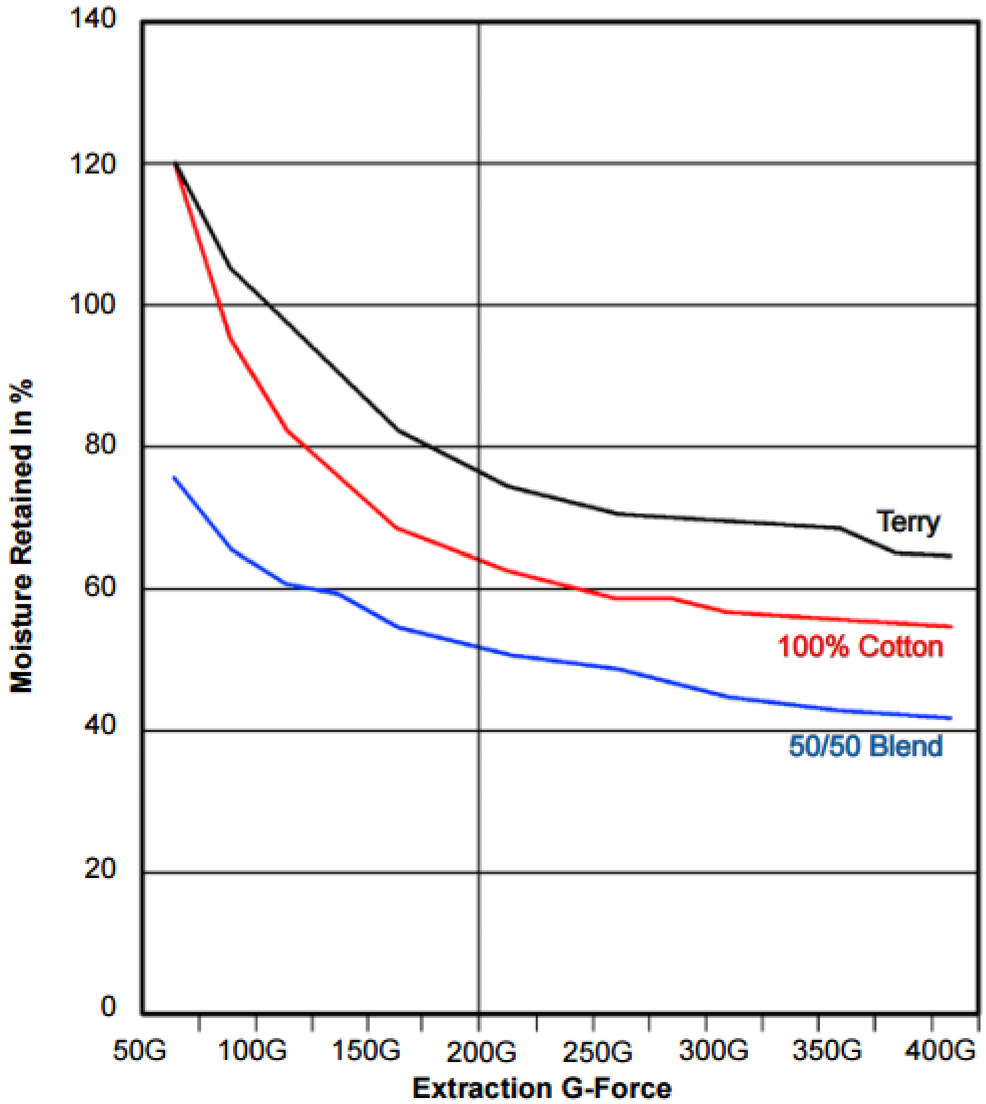

Figure 1

h_e = Heat required by a dryer to evaporate 1 lb of water

= Assume 1,200 Btu/lb[869]

η_{dryer} = Efficiency of the clothes dryer

= Actual, or if unknown, assume 60%[870]

100,000 = Converts Btus to therms

DryerUse = % of washer loads dried in the field

= Assume 91%[871]

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869 "Laundry Planning Guide." EDRO, January 2015.

870 "Are We Missing Energy Savings in Clothes Dryers?" Paul Bendt (Ecos), 2010 http://aceee.org/files/proceedings/2010/data/papers/2206.pdf

871 "Dryer Field Study." Northwest Energy Efficiency Alliance, November 20, 2014. http://www.ecotope.com/wp/wp-content/uploads/2014/04/neea-clothes-dryer-field-study.pdf

LF = Load Factor (%) to account for the pounds per washer load, as a percentage of rated capacity

= Assume 66%[872]

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

[872] "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.[873]

DEEMED MEASURE COST[874]

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*[875]*

$\Delta kWh = 8760/1000 * (((Watts_{Base,Off} * \%Time_{Off}) + (Watts_{Base,Sleep} * \%Time_{Sleep}) + (Watts_{Base,Long} * \%Time_{Long}) + (Watts_{Base,Short} * \%Time_{Short})) - ((Watts_{Eff,Off} * \%Time_{Off}) + (Watts_{Eff,Sleep} * \%Time_{Sleep}) + (Watts_{Eff,Long} * \%Time_{Long}) + (Watts_{Eff,Short} * \%Time_{Short})))$

Where (see assumptions in table below):

8760/1000 = Converts W to kWh

$Watts_{Base,Off}$ = baseline equipment power in off mode

[873] Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013 Page 6. http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/documents/comments_12-AAER-2A/California_IOUs_Standards_Proposal_Addendum_Computers_2014-10-27_TN-73899.pdf
[874] Research Into Action, 80 PLUS Market Progress Evaluation Report #5, November 26, 2013. Page 24.
[875] Algorithm comes from ENERGY STAR Version 6.0 Guide

$\%Time_{Off}$ = 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

$\%Time_{Sleep}$ = 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[876]	45%	5%	15%	35%

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle
Baseline[877]	0.88	2.1	26.5	27.9
ES 6.0 Desktops[878]	0.55	1.23	24.66	26.04
ES 6.0 +20% Desktops[879]	0.52	1.63	21.33	22.58
ES 6.0 Desktops w/ 80 PLUS Gold PSUs[880]	0.50	1.50	23.08	24.38
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs[881]	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"

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876 ECMA 283, Appendix B, Majority Profile Study; ENERGY STAR v6.0 duty cycle. See https://www.energystar.gov/sites/default/files/specs//Version%206%201%20Computers%20Final%20Program%20Requirements.pdf.

877 Computer CASE Report, CA IOUs. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Standards_Proposal_Computers_UPDATED_2013-08-06_TN-71813.pdf

878 Analysis of current DT I2 category desktops in ES v6.0 QPL, available at http://www.energystar.gov/productfinder/product/certified-computers/results.

879 Analysis of current DT I2 category desktops in ES v6.0 QPL, passing with > 20% margin.

880 80 PLUS program savings calculator, additional 6.4% savings over ES v6.0 Bronze PSU levels. Based on program measurements, available at http://www.80plus.org.

881 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels.

SUMMER COINCIDENT PEAK DEMAND SAVINGS[882]

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

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

[882] 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.[883]

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[884]

Coincidence Factor

N/A due to no savings attributable to standby losses between 1 and 5 PM.

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[883] This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

[884] 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[885] = $((kW_{wkday} * (hrs_{wkday} - hrs_{wkday\text{-}open}) + kW_{wkend} * (hrs_{wkend} - hrs_{wkend\text{-}open}) * weeks/year) * ISR$

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[886]

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

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885 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".

886 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-V01-180101

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[887].

(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.***

[887] 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.

Single-phase				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

Single-phase				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 (%)
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[888]

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)

[888] 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.

EFF_{EE} = actual total efficiency rating of the transformer as calculated by the appropriate DOE test method[889]

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.[890]

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.[891]

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

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REVIEW DEADLINE: 1/1/2021

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[889] Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006. https://www.regulations.gov/document?D=EERE-2006-TP-0090-0001

[890] Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013

[891] 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. https://www.regulations.gov/document?D=EERE-2006-TP-0090-0001

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[892]

Deemed Measure Cost

The deemed incremental measure cost is $400[893]

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. [894]

[892] Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 45
[893] Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 42
[894] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.

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[895]

DOD = Depth of Discharge
= Use actual depth of discharge, otherwise use a default value of 80%.[896]

CHG = Number of Charges per year
= Use actual number of annual charges, if unknown use values below based on the type of operations[897]

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[898]

PC_B = Baseline Power Conversion Efficiency
= 0.84[899]

CR_{EE} = Efficient Charge Return Factor
= 1.107[900]

PC_{EE} = Efficient Power Conversion Efficiency
= 0.89[901]

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

[895] 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

[896] 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

[897] 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

[898] 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)

[899] Ibid.

[900] Ibid.

[901] Ibid.

Standard Operations	ΔkWh
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[902]

PF_{EE} = Power factor of high frequency charger
= 0.9370[903]

$Volts_{DC}$ = 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.[904]

$Amps_{DC}$ = 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.[905]

1,000 = watt to kilowatt conversion factor

CF = Summer Coincident Peak Factor for this measure

= 0.0 (for 1 and 2-shift operation)[906]

= 1.0 (for 3 and 4-shift operation)[907]

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

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902 Ibid.
903 Ibid.
904 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.
905 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.
906 Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.
907 Ibid.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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