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**Version 7.0**

**Volume 2: Commercial and Industrial Measures**

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Volume 4: Cross Cutting Measures and Attachments

# Volume 2: Commercial and Industrial Measures

## Agricultural End Use

### 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]](#footnote-1)

###### Deemed Measure Cost

The incremental cost per installed plug-in timer is $10.19[[2]](#footnote-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

ΔkWh*=* ISR \* Use Season \* %Days \* HrSave/Day \* kWheater - ParaLd

Where:

ISR = In Service Rate

= 78.39%[[3]](#footnote-3)

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

= 75 days[[4]](#footnote-4)

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

= 84.23%[[5]](#footnote-5)

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

= 7.765 hours per day[[6]](#footnote-6)

kWheater  = Connected load of the engine block heater

= 1.5 kW[[7]](#footnote-7)

ParaLd = Parasitic load

= 5.46 kWh[[8]](#footnote-8)

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

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

= 571 kWh

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: RS-APL-ESDH-V02-190101

###### Review Deadline: 1/1/2024

### High Volume Low Speed Fans

###### Description

The measure applies to 20-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non HVLS fans that have reached the end of useful life in agricultural applications.

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be classified as HVLS and have a VFD[[9]](#footnote-9).

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[[10]](#footnote-10).

###### Deemed Measure Cost

The incremental capital cost for the fans are as follows[[11]](#footnote-11):

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

###### Loadshape

Loadshape C34 - Industrial Motor

###### Coincidence Factor

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

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings [[12]](#footnote-12)

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

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

###### Summer Coincident Peak Demand Savings[[13]](#footnote-13)

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

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

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-AGE-HVSF-V02-190101

###### Review Deadline: 1/1/2024

### High Speed Fans

###### Description

The measure applies to high speed exhaust, ventilation and circulation fans that are replacing an existing unit that reached the end of its useful life in agricultural applications.

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be diffuser equipped and meet the following minimum efficiency criteria[[14]](#footnote-14).

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

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years[[15]](#footnote-15).

###### Deemed Measure Cost

The incremental capital cost for all fan sizes is $150[[16]](#footnote-16).

###### Loadshape

Loadshape C34 - Industrial Motor

###### Coincidence Factor

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

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings [[17]](#footnote-17)

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

| **Diameter of Fan (inches)** | **kWh** |
| --- | --- |
| 24 through 35 | 372 |
| 36 through 47 | 625 |
| 48 through 71 | 1,122 |

###### Summer Coincident Peak Demand Savings[[18]](#footnote-18)

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

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

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-AGE-HSF\_-V02-190101

###### Review Deadline: 1/1/20124

### Livestock Waterer

###### Description

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

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts[[19]](#footnote-19).

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[[20]](#footnote-20).

###### Deemed Measure Cost

The incremental capital cost for the waters are $787.50:[[21]](#footnote-21)

###### Loadshape

Loadshape C04 - Non-Residential Electric Heating

###### Coincidence Factor

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

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings [[22]](#footnote-22)

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

###### Summer Coincident Peak Demand Savings

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

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-AGE-LSW1-V02-190101

###### Review Deadline: 6/1/2024

## Food Service Equipment End Use

### Combination Oven

###### Description

This measure applies to both natural gas fired and electric high efficiency combination convection and steam ovens installed in a commercial kitchen.

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

###### Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new natural gas or electric combination oven meeting the ENERGY STAR idle rate and cooking efficiency requirements as specified below.[[24]](#footnote-24)

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

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

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

###### Definition of Baseline Equipment

The baseline equipment is a natural gas or electric combination oven that is not ENERGY STAR certified.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[[26]](#footnote-26)

###### Deemed Measure Cost

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

###### Loadshape

Loadshape C01 - Commercial Electric Cooking

###### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[[27]](#footnote-27):

| **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

###### Electric Energy Savings

The algorithm below applies to electric combination ovens only.[[28]](#footnote-28)

∆kWh = (CookingEnergyConvElec + CookingEnergySteamElec + IdleEnergyConvElec + IdleEnergySteamElec) \* Days / 1,000

Where:

CookingEnergyConvElec = Change in total daily cooking energy consumed by electric oven in convection mode

= LBElec \* (EFOODConvElec / ElecEFFConvBase - EFOODConvElec / ElecEFFConvEE) \* %Conv

CookingEnergySteamElec = Change in total daily cooking energy consumed by electric oven in steam mode

= LBElec \* (EFOODSteamElec / ElecEFFSteamBase – EFOODSteamElec / ElecEFFSteamEE) \* %Steam

IdleEnergyConvElec = Change in total daily idle energy consumed by electric oven in convection mode

= [(ElecIDLEConvBase \* ((HOURS – LBElec/ElecPCConvBase) \* %Conv)) - (ElecIDLEConvEE \* ((HOURS - LBElec/ElecPCConvEE) \* %Conv))]

IdleEnergySteamElec = Change in total daily idle energy consumed by electric oven in convection mode

= [(ElecIDLESteamBase \* ((HOURS – LBElec/ElecPCSteamBase) \* %Steam)) - (ElecIDLESteamEE \* ((HOURS - LBElec/ElecPCSteamEE) \* %Steam))]

Where:

LBElec  = 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)

EFOODConvElec = Energy absorbed by food product for electric oven in convection mode

= Custom or if unknown, use 73.2 Wh/lb

ElecEFF = Cooking energy efficiency of electric oven

= Custom or if unknown, use values from table below

|  | **Base** | **EE** |
| --- | --- | --- |
| ElecEFFConv | 72% | 76% |
| ElecEFFSteam | 49% | 55% |

%Conv = Percentage of time in convection mode

= Custom or if unknown, use 50%

EFOODSteamElec = 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

ElecIDLEBase = Idle energy rate (W) of baseline electric oven

= Custom or if unknown, use values from table below

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode**  **(ElecIDLEConvBase)** | **Steam Mode**  **(ElecIDLESteamBase)** |
| < 15 | 1,320 | 5,260 |
| > = 15 | 2,280 | 8,710 |

HOURS = Average daily hours of operation

= Custom or if unknown, use 12 hours

ElecPCBase = Production capacity (lbs/hr) of baseline electric oven

= Custom of if unknown, use values from table below

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (ElecPCConvBase)** | **Steam Mode (ElecPCSteamBase)** |
| < 15 | 79 | 126 |
| > = 15 | 166 | 295 |

ElecIDLEConvEE = Idle energy rate of ENERGY STAR electric oven in convection mode

= (0.08\*P +0.4989)\*1000

ElecPCEE = Production capacity (lbs/hr) of ENERGY STAR electric oven

= Custom of if unknown, use values from table below

| **Pan Capacity** | **Convection Mode (ElecPCConvEE)** | **Steam Mode (ElecPCSteamEE)** |
| --- | --- | --- |
| < 15 | 119 | 177 |
| > = 15 | 201 | 349 |

ElecIDLESteamEE = 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:

∆kWh = (CookingEnergyConvElec + CookingEnergySteamElec + IdleEnergyConvElec + IdleEnergySteamElec) \* Days / 1,000

CookingEnergyConvElec = 200 \* (73.2 / 0.72 – 73.2 / 0.76) \* 0.50

= 535 Wh

CookingEnergySteamElec = 200 \* (30.8 / 0.49 – 30.8 / 0.55) \* (1 – 0.50)

= 686 Wh

IdleEnergyConvElec = [(1,320 \* ((12 – 200/79) \* 0.50)) - (1,299 \*((12 - 200/119) \* 0.50))]

= -453 Wh

IdleEnergySteamElec = [(5,260 \* ((12 – 200/126) \* (1 – 0.50))) - (1,970 \* ((12 - 200/177) \* (1 – 0.50)))]

= 16,678 Wh

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

= 6,368 kWh

###### Summer Coincident Peak Demand Savings

∆kW = ∆kWh / (HOURS \* DAYS) \*CF

Where:

CF = Summer peak coincidence factor is dependent on building type[[29]](#footnote-29):

| **Location** | **CF** |
| --- | --- |
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.36 |

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:

∆kW = ∆kWh / (HOURS \* DAYS) \*CF

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

= 0.74 kW

###### Natural Gas Energy Savings

The algorithm below applies to natural gas combination ovens only.[[30]](#footnote-30)

∆Therms = (CookingEnergyConvGas + CookingEnergySteamGas + IdleEnergyConvGas + IdleEnergySteamGas) \* Days / 100,000

Where:

CookingEnergyConvGas = Change in total daily cooking energy consumed by gas oven in convection mode

= LBGas \* (EFOODConvGas / GasEFFConvBase - EFOODConvGas / GasEFFConvEE) \* %Conv

CookingEnergySteamGas = Change in total daily cooking energy consumed by gas oven in steam mode

= LBGas \* (EFOODSteamGas / GasEFFSteamBase – EFOODSteamGas / GasEFFSteamEE) \* %Steam

IdleEnergyConvGas = Change in total daily idle energy consumed by gas oven in convection mode

= [(GasIDLEConvBase \* ((HOURS – LBGas/GasPCConvBase) \* %Conv)) - (GasIDLEConvEE \* ((HOURS - LBGas/GasPCConvEE) \* %Conv))]

IdleEnergySteamGas = Change in total daily idle energy consumed by gas oven in convection mode

= [(GasIDLESteamBase \* ((HOURS – LBGas/GasPCSteamBase) \* %Steam)) - (GasIDLESteamEE \* ((HOURS - LBGas/GasPCSteamEE) \* %Steam))]

Where:

LBGas = 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)

EFOODConvGas = 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** |
| GasEFFConv | 52% | 56% |
| GasEFFSteam | 39% | 41% |

EFOODSteamGas = Energy absorbed by food product for gas oven in steam mode

= Custom or if unknown, use 105 Btu/lb

GasIDLEBase = Idle energy rate (Btu/hr) of baseline gas oven

= Custom or if unknown, use values from table below

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (GasIDLEConvBase)** | **Steam Mode (GasIDLESteamBase)** |
| < 15 | 8,747 | 18,656 |
| 15-30 | 10,788 | 24,562 |
| >30 | 13,000 | 43,300 |

GasPCBase = Production capacity (lbs/hr) of baseline gas oven

= Custom of if unknown, use values from table below

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (GasPCConvBase)** | **Steam Mode (GasPCSteamBase)** |
| < 15 | 125 | 195 |
| 15-30 | 176 | 211 |
| >30 | 392 | 579 |

GasIDLEConvEE = Idle energy rate of ENERGY STAR gas oven in convection mode

= 150\*P + 5,425

GasPCEE = Production capacity (lbs/hr) of ENERGY STAR gas oven

= Custom of if unknown, use values from table below

|  |  |  |
| --- | --- | --- |
| **Pan Capacity** | **Convection Mode (GasPCConvEE)** | **Steam Mode (GasPCSteamEE)** |
| < 15 | 124 | 172 |
| 15-30 | 210 | 277 |
| >30 | 394 | 640 |

GasIDLESteamEE = 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:

∆Therms = (CookingEnergyConvGas + CookingEnergySteamGas + IdleEnergyConvGas + IdleEnergySteamGas) \* Days / 100,000

CookingEnergyConvGas = 200 \* (250 / 0.52 – 250 / 0.56) \* 0.50

=3,434 therms

CookingEnergySteamGas = 200 \* (105 / 0.39 – 105 / 0.41) \* (1 – 0.50)

= 1,313 therms

IdleEnergyConvGas = [(8,747 \* ((12 – 200/125) \* 0.50)) - (6,925 \*((12 - 200/124) \* 0.50))]

= 9,519 therms

IdleEnergySteamGas = [(18,658 \* ((12 – 200/195) \* (1 – 0.50))) - (8,511 \* ((12 - 200/172) \* (1 – 0.50)))]

= 56,251 therms

∆Therms = (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

### Commercial Solid and Glass Door Refrigerators & Freezers

###### Description

This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. ENERGY STAR labeled commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a new ENERGY STAR certified vertical closed solid or glass door refrigerator or freezer meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V).

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

| Volume (ft3) | Maximum Daily Energy Consumption (kWh/day) | |
| --- | --- | --- |
| Refrigerator | Freezer |
| **Vertical Closed** | | |
| Solid Door | | |
| 0 < V < 15 | ≤ 0.022V + 0.97 | ≤ 0.21V + 0.9 |
| 15 ≤ V < 30 | ≤ 0.066V + 0.31 | ≤ 0.12V + 2.248 |
| 30 ≤ V < 50 | ≤ 0.04V + 1.09 | ≤ 0.285V -2.703 |
| V ≥ 50 | ≤ 0.024V + 1.89 | ≤ 0.142V + 4.445 |
| Glass Door | | |
| 0 < V < 15 | ≤ 0.095V + 0.445 | ≤ 0.232V + 2.36 |
| 15 ≤ V < 30 | ≤ 0.05V + 1.12 |
| 30 ≤ V < 50 | ≤ 0.076V + 0.34 |
| V ≥ 50 | ≤ 0.105V – 1.111 |

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years [[31]](#footnote-31).

###### Deemed Measure Cost

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

| Equipment Type | Incremental Cost per Cubic Foot (ft3) |
| --- | --- |
| Solid Door | |
| Refrigerator | $24.21 |
| Freezer | $30.41 |
| Glass Door | |
| Refrigerator | $24.77 |
| Freezer | $33.01 |



###### Loadshape

Loadshape C23 - Commercial Refrigeration

###### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0.937.[[33]](#footnote-33)

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = (kWhbase – kWhee) \* 365.25

Where:

kWhbase= baseline maximum daily energy consumption in kWh

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

|  |  |
| --- | --- |
| Type | kWhbase[[34]](#footnote-34) |
| Solid Door Refrigerator | 0.05 \* V + 1.36 |
| Glass Door Refrigerator | 0.1 \* V + 0.86 |
| Solid Door Freezer | 0.22 \* V + 1.38 |
| Glass Door Freezer | 0.29 \* V + 2.95 |

kWhee[[35]](#footnote-35) = efficient maximum daily energy consumption in kWh

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

| Volume (ft3) | kWhee | |
| --- | --- | --- |
| Refrigerator | Freezer |
| **Vertical Closed** | | |
| Solid Door | | |
| 0 < V < 15 | ≤ 0.022V + 0.97 | ≤ 0.21V + 0.9 |
| 15 ≤ V < 30 | ≤ 0.066V + 0.31 | ≤ 0.12V + 2.248 |
| 30 ≤ V < 50 | ≤ 0.04V + 1.09 | ≤ 0.285V -2.703 |
| V ≥ 50 | ≤ 0.024V + 1.89 | ≤ 0.142V + 4.445 |
| Glass Door | | |
| 0 < V < 15 | ≤ 0.095V + 0.445 | ≤ 0.232V + 2.36 |
| 15 ≤ V < 30 | ≤ 0.05V + 1.12 |
| 30 ≤ V < 50 | ≤ 0.076V + 0.34 |
| V ≥ 50 | ≤ 0.105V – 1.111 |

V = the chilled or frozen compartment volume (ft3) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979)

= Actual installed

365.25 = days per year

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

ΔkWh = (2.11 – 1.30) \* 365.25

= 296 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / HOURS \* CF

Where:

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

= 8766

CF = Summer Peak Coincidence Factor for measure

= 0.937

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

ΔkW = 296/ 8766 \* .937

=0.0316 kW

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code: CI-FSE-CSDO-V02-190101**

###### Review Deadline: 1/1/2024

### Commercial Steam Cooker

###### Description

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

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

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be as follows:

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

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[[36]](#footnote-36)

###### Deemed Measure Cost

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

###### Loadshape

Loadshape C01 - Commercial Electric Cooking

###### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[[39]](#footnote-39):

| **Location** | **CF**  **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**

###### 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)\* IDLEBASE + CSM%Baseline \* PCBASE \* EFOOD / EFFBASE) \* (HOURSday - (F / PCBase) - ( PREnumber \*0.25))) - (((1- CSM%ENERGYSTAR) \* IDLEENERGYSTAR + CSM%ENERGYSTAR \* PCENERGY \* EFOOD / EFFENERGYSTAR) \* (HOURSDay - (F l/ PCENERGY ) - (PREnumber \* 0.25 ))))

Where:

CSM%Baseline = Baseline Steamer Time in Manual Steam Mode (% of time)

= 90%[[40]](#footnote-40)

IDLEBase = Idle Energy Rate of Base Steamer[[41]](#footnote-41)

| **Number of Pans** | **IDLEBASE - Gas, Btu/hr** | **IDLEBASE - Electric, kw** |
| --- | --- | --- |
| 3 | 11,000 | 1.0 |
| 4 | 14,667 | 1.33 |
| 5 | 18,333 | 1.67 |
| 6 | 22,000 | 2.0 |

PCBase = Production Capacity of Base Steamer[[42]](#footnote-42)

| **Number of Pans** | **PCBASE, gas (lbs/hr)** | **PCBASE, electric (lbs/hr)** |
| --- | --- | --- |
| 3 | 65 | 70 |
| 4 | 87 | 93 |
| 5 | 108 | 117 |
| 6 | 130 | 140 |

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

=105 Btu/lb[[43]](#footnote-43) (gas steamers) or 0.03088 (electric steamers)

EFFBASE =Heavy Load Cooking Efficiency for Base Steamer

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

HOURSday  = Average Daily Operation (hours)

| **Type of Food Service** | **Hoursday[[45]](#footnote-45)** |
| --- | --- |
| Fast Food, limited menu | 4 |
| Fast Food, expanded menu | 5 |
| Pizza | 8 |
| Full Service, limited menu | 8 |
| Full Service, expanded menu | 7 |
| Cafeteria | 6 |
| Unknown | 6[[46]](#footnote-46) |
| Custom | Varies |

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[[47]](#footnote-47)

CSM%ENERGYSTAR = ENERGY *STAR Steamer's Time in Manual Steam Mode (% of time)[[48]](#footnote-48)*

*= 0%*

*IDLEENERGYSTAR = Idle E*nergy Rate of ENERGY STAR®[[49]](#footnote-49)

| **Number of Pans** | **IDLEENERGY STAR – gas, (Btu/hr)** | **IDLEENERGY STAR – electric, (kW)** |
| --- | --- | --- |
| 3 | 6,250 | 0.40 |
| 4 | 8,333 | 0.53 |
| 5 | 10,417 | 0.67 |
| 6 | 12,500 | 0.80 |

PCENERGY = Production Capacity of ENERGY STAR® Steamer[[50]](#footnote-50)

|  |  |  |
| --- | --- | --- |
| **Number of Pans** | **PCENERGY - gas(lbs/hr)** | **PCENERGY – electric (lbs/hr)** |
| 3 | 55 | 50 |
| 4 | 73 | 67 |
| 5 | 92 | 83 |
| 6 | 110 | 100 |

EFFENERGYSTAR = Heavy Load Cooking Efficiency for ENERGY STAR® Steamer(%)

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

PREnumber = Number of preheats per day

=1[[52]](#footnote-52) (if unknown, use 1)

ΔPreheat Energy = ( PREnumber \* Δ Preheat)

Where:

PREnumber = Number of Preheats per Day

=1[[53]](#footnote-53)(if unknown, use 1)

PREheat = Preheat energy savings per preheat

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

ΔCooking Energy = ((1/ EFFBASE) - (1/ EFFENERGY STAR®)) \* F \* EFOOD

Where:

EFFBASE =Heavy Load Cooking Efficiency for Base Steamer

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

EFFENERGYSTAR =Heavy Load Cooking Efficiency for ENERGY STAR® Steamer

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

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[[58]](#footnote-58)

EFOOD = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food[[59]](#footnote-59)

|  |  |
| --- | --- |
| **EFOOD - gas(Btu/lb)** | **EFOOD (kWh/lb)** |
| 105[[60]](#footnote-60) | 0.0308[[61]](#footnote-61) |

EXAMPLE

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

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

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

= 188,321

ΔPreheat Energy = (1 \*11,000)

= 11,000

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

= 42368

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

= 883 therms

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

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

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

= 31.18

ΔPreheat Energy = (1 \*0.5))

= 0.5

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

= 5.69

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

= 13,649 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Supply Energy Factor (kWh/Million Gallons)

=2,571[[62]](#footnote-62)

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

ΔkWhwater = 76,703/1,000,000\*2,571

= 197 kWh

**Summer Coincident Peak Demand Savings**

This is only applicable to the electric steam cooker.

ΔkW = (ΔkWh/(HOURSDay \*DaysYear)) \* CF

Where:

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

CF =Summer Peak Coincidence Factor for measure is provided below for different locations[[63]](#footnote-63):

|  |  |
| --- | --- |
| **Location** | **CF**  **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 |

DaysYear =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:

ΔkW = (ΔkWh/(HOURSDay \*DaysYear)) \* 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.

ΔWater = (WBASE -WENERGYSTAR®)\*HOURSDay \*DaysYear

Where

WBASE = Water Consumption Rate of Base Steamer (gal/hr)

= 40[[64]](#footnote-64)

WENERGYSTAR = Water Consumption Rate of ENERGY STAR® Steamer look up[[65]](#footnote-65)

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

DaysYear =Annual Days of Operation

=custom or 365.25 days a year[[66]](#footnote-66)

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-V05-190101

###### Review Deadline: 1/1/2023

### Conveyor Oven

###### Description

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

Conveyor ovens are available using four different heating processes: infrared, natural convection with a ceramic baking hearth, forced convection or air impingement, or a combination of infrared and forced convection. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates. They are highly flexible and can be used to bake or roast a wide variety of products including pizza, casseroles, meats, breads, and pastries.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

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

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a natural gas conveyor oven with a tested baking energy efficiency > 42% and an idle energy consumption rate < 57,000 Btu/hr utilizing ASTM standard F1817.

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 17 years.[[67]](#footnote-67)

###### Deemed Measure Cost

The incremental capital cost for this measure is $1800[[68]](#footnote-68).

###### 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 884 Therms[[69]](#footnote-69).

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

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

###### Review Deadline: 1/1/2024

### ENERGY STAR Convection Oven

###### Description

This measure applies to natural gas fired ENERGY STAR convection ovens installed in a commercial kitchen.

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

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a natural gas convection oven with a cooking efficiency ≥ 46% utilizing ASTM standard 1496 and an idle energy consumption rate < 12,000 Btu/hr[[70]](#footnote-70)

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[[71]](#footnote-71)

###### Deemed Measure Cost

The incremental capital cost for this measure is $50[[72]](#footnote-72)

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Energy Savings

ustom calculation below, otherwise use deemed value of 306 therms. [[73]](#footnote-73)

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

### ENERGY STAR Dishwasher

###### Description

This measure applies to ENERGY STAR high and low temp under counter, stationary single tank door type, single tank conveyor, and multiple tank conveyor dishwashers, as well as high temp pot, pan, and utensil dishwashers installed in a commercial kitchen.

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

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an ENERGY STAR certified dishwasher meeting idle energy rate (kW) and water consumption (gallons/rack) limits, as determined by both machine type and sanitation approach (chemical/low temp versus high temp).

**ENERGY STAR Requirements (Effective February 1, 2013)**

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

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be[[74]](#footnote-74)

|  |  |  |
| --- | --- | --- |
| Dishwasher Type | | Equipment Life |
| Low Temp | Under Counter | 10 |
| Stationary Single Tank Door | 15 |
| Single Tank Conveyor | 20 |
| Multi Tank Conveyor | 20 |
| High Temp | Under Counter | 10 |
| Stationary Single Tank Door | 15 |
| Single Tank Conveyor | 20 |
| Multi Tank Conveyor | 20 |
| Pot, Pan, and Utensil | 10 |

###### Deemed Measure Cost

The incremental capital cost for this measure is provided below:[[75]](#footnote-75)

| 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[[76]](#footnote-76):

|  |  |
| --- | --- |
| Location | CF  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.

Where:

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

= [(WaterUseBase \* RacksWashed \* Days) \* (∆Tin \*1.0 \* 8.2 ÷ EffHeater ÷ 3,413)] - [(WaterUseESTAR \* RacksWashed \* Days) \* (∆Tin \*1.0 \* 8.2 ÷ EffHeater ÷ 3,413)]

ΔBoosterEnergy= Annual electric energy consumption of booster water heater

= [(WaterUseBase \* RacksWashed \* Days) \* (∆Tin \*1.0 \* 8.2 ÷ EffHeater ÷ 3,413)] - [(WaterUseESTAR \* RacksWashed \* Days) \* (∆Tin \*1.0 \* 8.2 ÷ EffHeater ÷ 3,413)]

ΔIdleEnergy= Annual idle electric energy consumption of dishwasher

= [IdleDrawBase\* (Hours \*Days – Days \* RacksWashed \* WashTime ÷ 60)] –

[IdleDrawESTAR\* (Hours \*Days – Days \* RacksWashed \* WashTime ÷ 60)]

Where:

WaterUseBase = 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

WaterUseESTAR = 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

Tin = 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)

EffHeater = Efficiency of water heater

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

3,413 = kWh to Btu conversion factor

IdleDrawBase = Idle power draw (kW) of baseline dishwasher

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

IdleDrawESTAR = 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, kWIdle, and WashTime are presented in the table below.

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

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

Electric building and electric booster water heating

| **Dishwasher type** | | **kWhBase** | **kWhESTAR** | **ΔkWh** |
| --- | --- | --- | --- | --- |
| **Low Temp** | Under Counter | 10,972 | 8,431 | 2,541 |
| Stationary Single Tank Door | 39,306 | 23,142 | 16,164 |
| Single Tank Conveyor | 42,230 | 28,594 | 13,636 |
| Multi Tank Conveyor | 50,112 | 31,288 | 18,824 |
| **High Temp** | Under Counter | 12,363 | 9,191 | 3,173 |
| Stationary Single Tank Door | 39,852 | 27,981 | 11,871 |
| Single Tank Conveyor | 45,593 | 36,375 | 9,218 |
| Multi Tank Conveyor | 72,523 | 45,096 | 27,426 |
| Pot, Pan, and Utensil | 21,079 | 17,766 | 3,313 |

Electric building and natural gas booster water heating

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

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[[77]](#footnote-79)

EXAMPLE

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

∆Water = (WaterUseBase \* RacksWashed \* Days) - (WaterUseESTAR \* RacksWashed \* Days)

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

= 14,793 gallons

ΔkWhwater = 14,793/1,000,000\*5,010

= 74 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/ AnnualHours \* CF

Where:

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

AnnualHours = Hours \* Days

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

CF = Summer Peak Coincidence Factor

= dependent on restaurant type[[78]](#footnote-80):

| Location | CF  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

Where:

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

= [(WaterUseBase \* RacksWashed \* Days)\*(∆Tin \* 1.0 \* 8.2 ÷ EffHeater ÷ 100,000)] - [(WaterUseESTAR\* RacksWashed \* Days)\*(∆Tin \* 1.0\*8.2 ÷ EffHeater ÷ 100,000)]

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

= [(WaterUseBase \* RacksWashed \* Days)\*(∆Tin \* 1.0 \* 8.2 ÷ EffHeater ÷ 100,000)] - [(WaterUseESTAR\* RacksWashed \* Days)\*(∆Tin \* 1.0\*8.2 ÷ EffHeater ÷ 100,000)]

Where:

WaterUseBase = 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

WaterUseESTAR = 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

Tin = 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)

EffHeater = 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** | | **ThermsBase** | **ThermsESTAR** | **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** | | **ThermsBase** | **ThermsESTAR** | **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** | | **ThermsBase** | **ThermsESTAR** | **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



Where:

WaterUseBase = 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

WaterUseESTAR = 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:

∆Water = (WaterUseBase \* RacksWashed \* Days) - (WaterUseESTAR \* RacksWashed \* Days)

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

= 14,793 gallons

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

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

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-FSE-ESDW-V04-190101

###### Review Deadline: 1/1/2023

### ENERGY STAR Fryer

###### Description

This measure applies to electric or natural gas fired ENERGY STAR certified fryers installed in a commercial kitchen.

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

###### Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be an ENERGY STAR certified fryer meeting idle energy rate (W or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and fryer capacity (standard versus large vat).

**ENERGY STAR Requirements (Version 3.0, Effective October 1, 2016)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fryer Capacity** | **Electric Efficiency Requirements** | | **Natural Gas Efficiency Requirements** | |
|  | **Idle Energy Rate** | **Cooking Efficiency**  **Consumption** | **Idle Energy Rate** | **Cooking Efficiency**  **Consumption** |
| Standard Open Deep-Fat Fryer | ≤ 800 W | ≥ 83% | ≤ 9,000 Btu/hr | ≥ 50% |
| Large Vat Open Deep-Fat Fryer | ≤ 1,100 W | ≥ 80% | ≤ 12,000 Btu/hr |

###### Definition of Baseline Equipment

The baseline equipment is a new electric or natural gas fryer that is not ENERGY STAR certified.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[[79]](#footnote-82)

###### Deemed Measure Cost

The incremental capital cost for this measure is $1200.[[80]](#footnote-83)

###### Loadshape

Loadshape C01 - Commercial Electric Cooking

###### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[[81]](#footnote-84):

|  |  |
| --- | --- |
| Location | CF  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

###### Electric Energy Savings

Custom calculation for an electric fryer below, otherwise use deemed value of 2,378.0 kWh for standard fryers and 2,537.9 kWh for large vat fryers.[[82]](#footnote-85)

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

Where:

ΔDailyIdleEnergy = (ElecIdleBase\* (HOURS – LB/ElecPCBase)) – (ElecIdleESTAR \* (HOURS – LB/ElecPCESTAR))

ΔDailyCookingEnergy = (LB \* EFOODElec/ ElecEffBase) – (LB \* EFOODElec/ElecEffESTAR)

Where:

ΔDailyIdleEnergy = Difference in idle energy between baseline and efficient fryer

ΔDailyCookingEnergy = Difference in cooking energy between baseline and efficient fryer

Cper

1,000 = Wh to kWh conversion factor

ElecIdleBase = Idle energy rate of baseline electric fryer

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

ElecIdleESTAR = Idle energy rate of ENERGY STAR electric fryer

= Custom or if unknown, use 800 W for standard fryers and 1,100 for large vat fryers

HOURS = Average daily hours of operation

= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer

LB = Food cooked per day

= Custom or if unknown, use 150 pounds

ElecPCBase = Production capacity of baseline electric fryer

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

ElecPCESTAR = Production capacity of ENERGY STAR electric fryer

= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers

EFOODElec = ASTM energy to food for electric fryers

= 167 Wh/lb

ElecEffBase = Cooking efficiency of baseline electric fryer

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

ElecEffESTAR = Cooking efficiency of ENERGY STAR electric fryer

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

EXAMPLE

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

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

Where:

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

= 3,291 Wh

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

= 3,219 Wh

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

= 2,378.0 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/(HOURS \* Days) \* CF

Where:

ΔkWh = Electric energy savings, calculated above

Other variables as defined above.

EXAMPLE

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

ΔkW = ΔkWh/(HOURS \* Days) \* CF

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

= 0.1465 kW

###### Natural Gas Energy Savings

Custom calculation for a gas fryer below, otherwise use deemed value of 507.9 therms for standard fryers and 415.1 therms for large vat fryers.[[83]](#footnote-87)

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

Where:

ΔDailyIdleEnergy = (GasIdleBase\* (HOURS – LB/GasPCBase)) – (GasIdleESTAR \* (HOURS – LB/GasPCESTAR))

ΔDailyCookingEnergy = (LB \* EFOODGas/ GasEffBase) – (LB \* EFOODGas/GasEffESTAR)

Where:

100,000 = Btu to therms conversion factor

GasIdleBase = Idle energy rate of baseline gas fryer

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

GasIdleESTAR = Idle energy rate of ENERGY STAR gas fryer

= Custom or if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers

GasPCBase = Production capacity of baseline gas fryer

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

GasPCESTAR = Production capacity of ENERGY STAR gas fryer

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

EFOODGas  = ASTM energy to food

= 570 Btu/lb

GasEffBase = Cooking efficiency of baseline gas fryer

= 35% for both standard and large vat fryers

GasEffESTAR = Cooking efficiency of ENERGY STAR gas fryer

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

Other variables as defined above.

EXAMPLE

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

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

Where:

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

= 65,769 Btu/day

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

=73,286 Btu/day

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

= 507.9 therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-FSE-ESFR-V02-190101

###### Review Deadline: 1/1/2022

### 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[[84]](#footnote-88)

###### Deemed Measure Cost

The incremental capital cost for this measure is $0 for and electric griddle and $60 for a gas griddle.[[85]](#footnote-89)

###### Loadshape

Loadshape C01 - Commercial Electric Cooking

###### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[[86]](#footnote-90):

|  |  |
| --- | --- |
| 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 [[87]](#footnote-91)

###### Electric Energy Savings

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

Where:

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

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

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

Where:

HOURSday = Average Daily Operation

= custom or if unknown, use 12 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

LB = Food cooked per day

= custom or if unknown, use 100 pounds

Width = Griddle Width

= custom or if unknown, use 3 feet

Depth = Griddle Depth

= custom or if unknown, use 2 feet

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 70%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 65%

PCENERGYSTAR = Production Capacity ENERGY STAR

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

PCBase = Production Capacity base

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

PreheatNumberENERGYSTAR = Number of preheats per day

= custom or if unknown, use 1

PreheatNumberBase = Number of preheats per day

= 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

### 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[[88]](#footnote-92)

###### Deemed Measure Cost

The incremental capital cost for this measure is[[89]](#footnote-93)

|  |  |
| --- | --- |
| 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[[90]](#footnote-94):

|  |  |
| --- | --- |
| 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

###### Electric Energy Savings

Custom calculation below, otherwise use deemed values depending on HFHC size[[91]](#footnote-95)

|  |  |
| --- | --- |
| 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

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

### ENERGY STAR Ice Maker

###### Description

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

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a new commercial ice machine meeting the minimum ENERGY STAR efficiency level standards.

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

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

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 9 years[[92]](#footnote-96).

###### Deemed Measure Cost

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is $0 for Batch-Type and $222 for Continuous-Type ice makers.[[93]](#footnote-97)

###### Loadshape

Loadshape C23 - Commercial Refrigeration

###### Coincidence Factor

The Summer Peak Coincidence Factor is assumed to equal 0.937

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWH = [(kWhbase – kWhee) / 100] \* (DC \* H) \* 365.25

Where:

kWhbase  = 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.

kWhee = maximum kWh consumption per 100 pounds of ice for the efficient equipment

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

| **Energy Consumption of Air-Cooled Batch-Type Ice Makers** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Ice Maker Type** | **Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)** | | **kWhBase** | | **kWhESTAR** | |
| **IMH** | H < 300 | | 10-0.01233H | | ≤ 9.20 - 0.01134H | |
| 300 ≤ H < 800 | | 7.05-0.0025H | | ≤ 6.49 - 0.0023H | |
| 800 ≤ H < 1500 | | 5.55-0.00063H | | ≤ 5.11 - 0.00058H | |
| 1500 ≤ H ≤ 4000 | | 4.61 | | ≤ 4.24 | |
| **RCU** | H < 988 | | 7.97-0.00342H | | ≤ 7.17 – 0.00308H | |
| 988 ≤ H ≤ 4000 | | 4.59 | | ≤ 4.13 | |
| **SCU** | H < 110 | | 14.79-0.0469H | | ≤ 12.57 - 0.0399H | |
| 110 ≤ H < 200 | | 12.42-0.02533H | | ≤ 10.56 - 0.0215H | |
| 200 ≤ H ≤ 4000 | | 7.35 | | ≤ 6.25 | |
| **Energy Consumption of Air-Cooled Continuous-Type Ice Makers** | | | | | | |
| **Equipment Type** | **Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)** | | **kWhBase** | | **kWhESTAR** | |
| **IMH** | H < 310 | | 9.19-0.00629H | | ≤ 7.90 – 0.005409H | |
| 310 ≤ H < 820 | | 8.23-0.0032H | | ≤ 7.08 – 0.002752H | |
| 820 ≤ H ≤ 4000 | | 5.61 | | ≤ 4.82 | |
| **RCU** | H < 800 | | 9.7-0.0058H | | ≤ 7.76 – 0.00464H | |
| 800 ≤ H ≤ 4000 | | 5.06 | | ≤ 4.05 | |
| **SCU** | H < 200 | | 14.22-0.03H | | ≤ 12.37 – 0.0261H | |
| 200 ≤ H < 700 | | 9.47-0.00624H | | ≤ 8.24 – 0.005429H | |
| 700 ≤ H ≤ 4000 | | 5.1 | | ≤ 4.44 | |

100 = conversion factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice.

DC = Duty Cycle of the ice machine

= 0.57[[94]](#footnote-101)

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

= Actual installed

365.35 = days per year

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

ΔkWH = [(5.9 – 5.5) / 100] \* (0.57 \* 450) \* 365.25

= 440 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / (HOURS \* DC) \* CF

Where:

HOURS = annual operating hours

= 8766[[95]](#footnote-102)

CF = 0.937

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

ΔkW = 440/(8766 \* 0.57) \* .937

= 0.083 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[[96]](#footnote-103) indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-FSE-ESIM-V02-190101

###### Review Deadline: 1/1/2024

### 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.[[97]](#footnote-104) 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[[98]](#footnote-105)

**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[[99]](#footnote-106) may be assumed.

**Loadshape**

Loadshape C01 - Commercial Electric Cooking

**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[[100]](#footnote-107)

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[[101]](#footnote-108)

EFF\_Elec = Efficiency of electric water heater supplying hot water to pre-rinse spray valve

=custom, otherwise assume 97%[[102]](#footnote-109)

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

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[[103]](#footnote-110)

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

ΔGallons = (1.6 – 1.06) \* 60 \* 3 \* 312

= 30,326 gal/yr

ΔkWhwater = 30,326/1,000,000\*5,010

= 152 kWh

###### Summer Coincident Peak Demand Savings

N/A

###### 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%[[104]](#footnote-111)

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[[105]](#footnote-112)

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[[106]](#footnote-113) | 1.9 gal/min[[107]](#footnote-114) |

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

| **Time of Sale** | **Retrofit, Direct Install** |
| --- | --- |
| 1.06 gal/min[[108]](#footnote-115) | 1.06 gal/min[[109]](#footnote-116) |

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise[[110]](#footnote-117):

|  |  |
| --- | --- |
| **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-V05-190101

###### Review Deadline: 1/1/2023

### 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[[111]](#footnote-118)

###### Deemed Measure Cost

The incremental capital cost for this measure is $2173[[112]](#footnote-119)

###### 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.[[113]](#footnote-120)

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[[114]](#footnote-121)

100,000 = Btu to therms conversion factor

PreheatRateBase = Preheat energy rate of baseline charbroiler

= 64,000 Btu/hr

PreheatRateEE = 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[[115]](#footnote-122)

60 = Minutes to hours conversion factor

InputRateBase = Input energy rate of baseline charbroiler

= 140,000 Btu/hr

InputRateEE = 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%[[116]](#footnote-123)

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

### 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[[117]](#footnote-124)

###### Deemed Measure Cost

The incremental capital cost for this measure is $2665[[118]](#footnote-125)

###### 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.

Where:

InputRateBase = Energy input rate of baseline rotisserie oven (Btu/hr)

= Custom of if unknown, use 90,000 Btu/hr[[119]](#footnote-126)

InputRateEE  = Energy input rate of infrared rotisserie oven (Btu/hr)

= Custom of if unknown, use 50,000 Btu/hr[[120]](#footnote-127)

Duty = Duty cycle of rotisserie oven (%)

= Custom or if unknown, use 60%[[121]](#footnote-128)

Hours = Typical operating hours of rotisserie oven

= Custom or if unknown, use 2,496 hours[[122]](#footnote-129)

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

### 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[[123]](#footnote-130)

###### Deemed Measure Cost

The incremental capital cost for this measure is $1000[[124]](#footnote-131)

###### 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.

Where:

InputRateBase = Rated energy input rate of baseline salamander broiler (Btu/hr)

= 38,500 Btu/hr[[125]](#footnote-132)

InputRateEE  = Rated energy input rate of infrared salamander broiler (Btu/hr)

= Custom or if unknown, use 24,750 Btu/hr[[126]](#footnote-133)

Duty = Duty cycle of salamander broiler (%)

= Custom or if unknown, use 70%[[127]](#footnote-134)

Hours = Typical operating hours of salamander broiler

= Custom or if unknown, use 2,496 hours[[128]](#footnote-135)

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

### 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[[129]](#footnote-136)

###### Deemed Measure Cost

The incremental capital cost for this measure is $4400[[130]](#footnote-137)

###### 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.

Where:

InputRateBase = Rated energy input rate of baseline upright broiler (Btu/hr)

= 144,000 Btu/hr[[131]](#footnote-138)

InputRateEE  = Rated energy input rate of infrared upright broiler (Btu/hr)

= Custom or if unknown, use 90,000 Btu/hr[[132]](#footnote-139)

Duty = Duty cycle of upright broiler (%)

= Custom or if unknown, use 70%[[133]](#footnote-140)

Hours = Typical operating hours of upright broiler

= Custom or if unknown, use 2,496 hours[[134]](#footnote-141)

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

### 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.[[135]](#footnote-142)

###### Deemed Measure Cost

The incremental capital cost for this measure is[[136]](#footnote-143)

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

###### Loadshape

Loadshape C23 - Commercial Ventilation

###### Coincidence Factor

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

**Algorithm**

###### Calculation of Savings

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

###### Electric Energy Savings

kWh savings are assumed to be 4966 kWh per horsepower of the fan[[137]](#footnote-144)

###### Summer Coincident Peak Demand Savings

kW savings are assumed to be 0.68 kW per horsepower of the fan[[138]](#footnote-145)

###### Natural Gas Energy Savings

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

Where:

CFM = the average airflow reduction with ventilation controls per hood

= 430 cfm/HP[[139]](#footnote-146)

HP = actual if known, otherwise assume 7.75 HP[[140]](#footnote-147)

Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air, Btu/cfm dependent on location[[141]](#footnote-148):

| 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%[[142]](#footnote-149)

100,000 = conversion from Btu to Therm

EXAMPLE

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

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

= 6,415 Therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-FSE-VENT-V03-160601

###### Review Deadline: 1/1/2021

### 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[[143]](#footnote-150).

###### Deemed Measure Cost

The incremental capital cost for this measure is $2400[[144]](#footnote-151).

###### 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[[145]](#footnote-152).

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-FSE-PCOK-V02-180101

###### Review Deadline: 1/1/2024

### 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.[[146]](#footnote-153)

###### Deemed Measure Cost

The incremental capital cost for this measure is $3000.[[147]](#footnote-154)

###### 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.[[148]](#footnote-155)

Where:

InputRate = Input energy rate of rack oven – double oven

= Custom or if unknown, 275,000 Btu/hr[[149]](#footnote-156)

BakingEfficiencyEE = Baking efficiency of energy efficiency rack oven – double oven

= Custom or if unknown, use 55%[[150]](#footnote-157)

BakingEfficiencyBase = 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%[[151]](#footnote-158)

Hours = Average daily hours of operation

= Custom or if unknown, use 3,744 hours[[152]](#footnote-159)

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

### 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.[[153]](#footnote-160)

###### Deemed Measure Cost

The incremental cost for this measure is assumed to be $800 for half size units and $1000 for full size[[154]](#footnote-161)

###### Loadshape

Loadshape C01 - Commercial Electric Cooking

###### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[[155]](#footnote-162):

| **Location** | **CF**  **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**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = kWHbase - kWheff

kWh = [(LB \* EFOOD/EFF) + (IDLE \* (HOURSDAY – LB/PC – PRETIME/60)) + PREENERGY] \* DAYS

Where:

kWHbase = the annual energy usage of the baseline equipment calculated using baseline values

kWHeff = the annual energy usage of the efficient equipment calculated using efficient values

HOURSDAY = daily operating hours

= Actual, defaults:

|  |  |
| --- | --- |
| **Type of Food Service** | **HOURSDAY [[156]](#footnote-163)** |
| 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[[157]](#footnote-164) |
| Custom | Varies |

DAYS = Days per year of operation

= Actual, default = 365[[158]](#footnote-165)

PRETIME = Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on

= 15 min/day[[159]](#footnote-166)

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

= 0.0732[[160]](#footnote-167)

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

= Actual, default = 100[[161]](#footnote-168)

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

IDLE = Idle energy rate. See table below.

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

PREENERGY = Preheat energy (kWh/day). See table below.

Performance Metrics: Baseline and Efficient Values

|  |  |  |
| --- | --- | --- |
| **Metric** | **Baseline Model [[162]](#footnote-169)** | **Energy Efficient Model [[163]](#footnote-170)** |
| PREENERGY (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:

kWHbase = [(100 \* 0.0732/0.65) + (2 \* (6 – 100/70 – 15/60)) + 1.5] \* 365

= 7,813 kWh

kWheff  = [(100 \* 0.0732/0.74) + (1 \* (6 – 100/79 – 15/60)) + 1.0] \* 365

= 5,612 kWh

ΔkWh = kWHbase - kWheff

= 7,813 – 5,612

= 2200 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh / (HOURSDAY \* DAYS)) \* CF

Where:

ΔkWh = Annual energy savings (kWh)

CF = Summer Peak Coincidence Factor for measure is provided below for different building type[[164]](#footnote-171):

|  |  |
| --- | --- |
| **Location** | **CF**  **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:

ΔkW = (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

## Hot Water

### 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[[165]](#footnote-172)** |
| 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% Et  Standby Loss: (Q/800 + 110√V) |
| Electric Water Heaters  ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.96 – (0.0003 \* rated volume in gallons) EF |
| >55 gallon tanks [[166]](#footnote-173) | 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/Vm (%/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[[167]](#footnote-174)

###### Deemed Measure Cost

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available[[168]](#footnote-175):

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

For electric water heaters the incremental capital cost for this measure is assumed to be[[169]](#footnote-176)

|  |  |
| --- | --- |
| **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 [[170]](#footnote-177).

**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:

Where:

Tout = Tank temperature

= 125°F

Tin = Incoming water temperature from well or municiple system

= 54°F[[171]](#footnote-178)

HotWaterUseGallon = 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:[[172]](#footnote-179)

| **Building Type[[173]](#footnote-180)** | **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 |

1. 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:[[174]](#footnote-181)

| **Building Type[[175]](#footnote-182)** | **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)

EFelecbase = Rated efficiency of baseline water heater expressed as Energy Factor (EF);

|  |  |  |
| --- | --- | --- |
| **Equipment Type** | **Sub Category** | **Federal Standard Minimum Efficiency[[176]](#footnote-183)** |
| Electric Water Heaters  ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.96 – (0.0003 \* rated volume in gallons) EF |
| >55 gallon tanks [[177]](#footnote-184) | 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) |

EFeff = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et)

= 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:

Tair = Ambient Air Temperature

= 70°F

V = Rated tank volume in gallons

= Actual

SLelecbase = Standby loss of electric baseline unit (%/hr)

= 0.30 + 27/V

SLeff = 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

Where:

Hours = Full load hours of water heater

= 6461 [[178]](#footnote-185)

CF = Summer Peak Coincidence Factor for measure

= 0.925 [[179]](#footnote-186)

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.

Where:

100,000 = Converts Btu to Therms

EFgasbase = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et);

|  |  |  |
| --- | --- | --- |
| **Equipment Type** | **Sub Category** | **Federal Standard Minimum Efficiency[[180]](#footnote-187)** |
| 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% Et |

**Additional Standby Loss Savings**

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

Where:

SLgasbase = Standby loss of gas baseline unit (Btu/h)

Q =Nameplate input rating in Btu/h

V = Rated volume in gallons

SLeff = 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 ft2 restaurant:

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

= 54.8 Therms

ΔThermsStandby = (((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

###### Measure Code: CI-HWE-STWH-V03-190101

###### Review Deadline: 1/1/2022

### 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[[181]](#footnote-188). Note if flow rates are measured, for example through a Direct Install program, then actual baseline flow rates should be used as opposed to the deemed values.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[[182]](#footnote-189)

###### Deemed Measure Cost

The full install cost (including labor) for this measure is $8[[183]](#footnote-190) or program actual. For LFRs, The incremental cost is $14.27[[184]](#footnote-191) 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.

**Algorithm**

###### ‘Calculation of Savings

###### Electric Energy Savings

###### Note these savings are *per* faucet retrofitted[[185]](#footnote-192).

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[[186]](#footnote-193) or custom based on metering studies[[187]](#footnote-194) or if measured during DI:

= Measured full throttle flow \* 0.83 throttling factor[[188]](#footnote-195)

Baseline for LFRs[[189]](#footnote-196): = 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[[190]](#footnote-197) or custom based on metering studies[[191]](#footnote-198) or if measured during DI:

= Rated full throttle flow \* 0.95 throttling factor[[192]](#footnote-199)

For LFRs[[193]](#footnote-200): = 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[[194]](#footnote-201)**  **(A)** | **Unit** | **Estimated % hot water from Faucets [[195]](#footnote-202)**  **(B)** | **Multiplier [[196]](#footnote-203)**  **(C)** | **Unit** | **Days per year**  **(D)** | **Annual gallons mixed water per faucet**  **(A\*B\*C\*D)** |
| Small Office | 1 | person | 100% | 10 | employees per faucet | 250 | 2,500 |
| Large Office | 1 | person | 100% | 45 | employees per faucet | 250 | 11,250 |
| Fast Food Rest | 0.7 | meal/day | 50% | 75 | meals per faucet | 365 | 9,581 |
| Sit-Down Rest | 2.4 | meal/day | 50% | 36 | meals per faucet | 365 | 15,768 |
| Retail | 2 | employee | 100% | 5 | employees per faucet | 365 | 3,650 |
| Grocery | 2 | employee | 100% | 5 | employees per faucet | 365 | 3,650 |
| Warehouse | 2 | employee | 100% | 5 | employees per faucet | 250 | 2,500 |
| Elementary School | 0.6 | person | 50% | 50 | students per faucet | 200 | 3,000 |
| Jr High/High School | 1.8 | person | 50% | 50 | students per faucet | 200 | 9,000 |
| Health | 90 | patient | 25% | 2 | Patients per faucet | 365 | 16,425 |
| Motel | 20 | room | 25% | 1 | faucet per room | 365 | 1,825 |
| Hotel | 14 | room | 25% | 1 | faucet per room | 365 | 1,278 |
| Other | 1 | employee | 100% | 20 | employees per faucet | 250 | 5,000 |

EPG\_electric = Energy per gallon of mixed water used by faucet (electric water heater)

= (8.33 \* 1.0 \* (WaterTemp - SupplyTemp)) / (RE\_electric \* 3412)

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

8.33 = Specific weight of water (lbs/gallon)

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

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[[197]](#footnote-204), 110F for health care facilities[[198]](#footnote-205)

SupplyTemp = Assumed temperature of water entering building

= 54.1°F [[199]](#footnote-206)

RE\_electric = Recovery efficiency of electric water heater

= 98% [[200]](#footnote-207)

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below[[201]](#footnote-208)

|  |  |
| --- | --- |
| **Selection** | **ISR** |
| Direct Install - Deemed | 0.95 |

EXAMPLE

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

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

= 335.3 kWh

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

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

= 73.4 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[[202]](#footnote-209)

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

ΔkWhwater = 3,640/1,000,000\*5,010

= 18 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh / Hours) \* CF

Where:

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

Hours = Annual electric DHW recovery hours for faucet use

= (Usage \* 0.545[[203]](#footnote-210) )/GPH

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

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

Where:

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

= 56

CF = Coincidence Factor for electric load reduction

= Dependent on building type[[204]](#footnote-211)

| **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 |

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% [[205]](#footnote-212)

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

Other variables as defined above.

EXAMPLE

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

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

= 16.7 Therms

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

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

= 3.66 Therms

###### Water Impact Descriptions and Calculation

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. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

###### Measure Code: CI-HWE-LFFA-V08-190101

###### Review Deadline: 1/1/2023

### 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.[[206]](#footnote-213)

###### Deemed Measure Cost

The full install cost (including labor) for this measure is $12[[207]](#footnote-214) or program actual.

###### Loadshape

Loadshape C02 - Commercial Electric DHW

###### Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%[[208]](#footnote-215).

**Algorithm**

###### Calculation of Savings [[209]](#footnote-216)

###### Electric Energy Savings

Note these savings are per showerhead fixture

ΔkWh =

%ElectricDHW \* ((GPM\_base \* L\_base - GPM\_low \* L\_low) \* NSPD \* 365.25) \* EPG\_electric \* ISR

Where:

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

= 1 if electric DHW, 0 if fuel DHW, if unknown assume 16% [[210]](#footnote-217)

GPM\_base = Flow rate of the baseline showerhead

= 2.67 for Direct-install programs[[211]](#footnote-218)

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[[212]](#footnote-219) |

L\_base = Shower length in minutes with baseline showerhead

= 8.20 min[[213]](#footnote-220)

L\_low = Shower length in minutes with low-flow showerhead

= 8.20 min[[214]](#footnote-221)

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 [[215]](#footnote-222)

SupplyTemp = Assumed temperature of water entering house

= 54.1°F [[216]](#footnote-223)

RE\_electric = Recovery efficiency of electric water heater

= 98% [[217]](#footnote-224)

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[[218]](#footnote-225)** |
| 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

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[[219]](#footnote-226)

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

ΔkWhwater = 10,302/1,000,000\*5,010

= 52 kWh

**Summer Coincident Peak Demand Savings**

ΔkW = ΔkWh/Hours \* CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM\_base \* L\_base) \*NSPD \* 365.25 ) \* 0.773[[220]](#footnote-227) / 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[[221]](#footnote-228)

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%[[222]](#footnote-229) |

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% [[223]](#footnote-230)

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

Other variables as defined above.

EXAMPLE

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

ΔTherms = 1.0 \* (( 2.67 \*8.2) – (1.5 \* 8.2)) \* 3 \* 365.25 \* 0.0063 \* 0.98

= 64.9 therms

###### Water Impact Descriptions and Calculation

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. |
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| 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-V05-190101

###### Review Deadline: 1/1/2020

### 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 [[224]](#footnote-231)

###### 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. [[225]](#footnote-232).

|  |  |  |
| --- | --- | --- |
| **Cover Size** | **Edge Style** | |
| **Hemmed (indoor)** | **Weighted (outdoor)** |
| 1000-1,999 sq. ft. | $2.19 | $2.24 |
| 2,000-2,999 sq. ft. | $2.01 | $2.06 |
| 3,000+ sq. ft. | $1.80 | $1.83 |
| Average | $2.00 | $2.04 |

###### Loadshape

N/A

###### Coincidence Factor

N/A

###### Net To Gross Ratio

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = Water Supply Energy Factor (kWh/Million Gallons)

= 2,571[[226]](#footnote-233)

###### 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. [[227]](#footnote-234)

ΔTherms = SavingFactor x Size of Pool

Where

Savings factor = dependant on pool location and listed in table below[[228]](#footnote-235)

|  |  |
| --- | --- |
| **Location** | **Therm / sq-ft** |
| Indoor | 2.61 |
| Outdoor | 1.01 |

Size of Pool = custom input

###### Water Impact Descriptions and Calculation

ΔWater = WaterSavingFactor x Size of Pool

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below.[[229]](#footnote-236).

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

Size of Pool = Custom input

###### Deemed O&M Cost Adjustment Calculation

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

###### Measure code: CI-HWE-PLCV-V02-190101

###### Review Deadline: 1/1/2020

### 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. The Federal Standard applies to units with input ≤75,000 Btu/hr, consistent with the baseline definitions of 4.3.1 Storage Water Heater. |

###### Deemed Lifetime of Efficient Equipment

|  |  |
| --- | --- |
| **Electric** | **Gas** |
| The expected measure life is assumed to be 5 years[[230]](#footnote-237). | The expected measure life is assumed to be 20 years[[231]](#footnote-238) |

###### Deemed Measure Cost

The incremental capital cost for an electric tankless heater this measure is assumed to be[[232]](#footnote-239)

| **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:

| **Program** | **Capital Cost, $ per unit** |
| --- | --- |
| Retrofit | $3,255[[233]](#footnote-240) |
| Time of Sale or New Construction | $2,526[[234]](#footnote-241) |

###### Deemed O&M Cost Adjustments

$100[[235]](#footnote-242)

###### 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 [[236]](#footnote-243)

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[[237]](#footnote-244)

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 |

**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 [[238]](#footnote-245)

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[[239]](#footnote-246)

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[[240]](#footnote-247)

Eff base = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et); see table below[[241]](#footnote-248)

|  |  |  |
| --- | --- | --- |
| **Input Btu/hr of existing, tanked water heater** | **Eff base** | **Units** |
| Size: ≤ 75,000 Btu/hr, ≥20 gal and ≤55 gal | 0.675 -0.0015\*Tank Volume | Energy Factor |
| Size: ≤ 75,000 Btu/hr, >55 gal and ≤100 gal | 0.8012 -0.00078\*Tank Volume | Energy Factor |
| Size: >75,000 Btu/hr and ≤ 155,000 Btu/hr | 80% | Thermal Efficiency |
| Size: >155,000 Btu/hr | 80% | Thermal Efficiency |

Where:

Tank Volume = custom input, if unknown assume 60 gallons for Size: ≤ 75,000 Btu/hr

Please note: Units in base case must match units in efficient case. If Energy Factor used in base case, Energy Factor to be used in efficient case. If Themal Efficiency is used in base case, Thermal Efficiency must be used in efficient case.

Eff ee = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (Eff t)

= custom input, if unknown assume 0.84[[242]](#footnote-249)

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[[243]](#footnote-250)

|  |  |
| --- | --- |
| **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[[244]](#footnote-251)



###### Measure Code: CI-HWE-TKWH-V03-190101

###### Review Deadline: 1/1/2022

### 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 (O3), 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.[[245]](#footnote-252)

###### 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[[246]](#footnote-253).

###### 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[[247]](#footnote-254).

∆kWhPUMP = HP \* HPCONVERSION \* Hours \* %water\_savings

Where:

∆kWhPUMP = Electric savings from reduced pumping load

HP = Brake horsepower of boiler feed water pump;

= Actual or use 5 HP if unknown[[248]](#footnote-255)

HPCONVERSION = Conversion from Horsepower to Kilowatt

= 0.746

Hours = Actual associated boiler feed water pump hours

= 800 hours if unknown[[249]](#footnote-256)

%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%[[250]](#footnote-257)

Using defaults above:

∆kWhPUMP = 5 \* 0.746 \* 800 \* 0.25

= 746 kWh

Default per lb capacity: = ∆kWhPUMP / lb capacity

Where:

Lbs-Capacity = Average Capacity in lbs of washer

=254.38[[251]](#footnote-258)

∆kWhPUMP / lb capacity = 746/254.38

= 2.93 kWh/lb-capacity

Secondary kWh Savings for Water Supply and Wastewater Treatment

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

ΔkWhwater = ΔWater / 1,000,000 \* Ewater total

Where

Ewater total = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[[252]](#footnote-259)

Deemed savings using defaults:

ΔkWhwater = 464,946/1,000,000\*5,010

= 2,329 kWh

###### Summer Coincident Peak Demand Savings

Past project documentation and data collection is not sufficient to determine summer coincident peak demand savings for this measure. Value should continue to be studied and monitored through additional studies due to 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.

∆kW = 0

###### Natural Gas Savings

∆Therm = ThermBaseline \* %hot\_water\_savings

Where:

∆Therm = Gas savings resulting from a reduction in hot water use, in therm.

ThermBaseline = Annual Baseline Gas Consumption

= WHE \* WUtiliz \* WUsage\_hot

Where:

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

= 0.00885 therm/gallon[[253]](#footnote-260)

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

= actual, if unknown use 916,150 lbs laundry[[254]](#footnote-261), 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[[255]](#footnote-262)

Using defaults above:

ThermBaseline = 0.00885 \* 916,150 \* 1.19

= 9,648 therms

Default per lb capacity:

ThermBaseline / 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%[[256]](#footnote-263)

Savings using defaults above:

∆Therm = ThermBaseline \* %hot\_water\_savings

= 9648 \* 0.81

= 7,815 therms

Default per lb capacity:

∆Therm / lb-capacity = 7815 / 254.38

= 30.7 therms / lb-capacity

###### Water Impact Descriptions and Calculation

The water savings calculations listed here account for the combination of hot and cold water used. Savings calculations for this measure were based on the reduction in total water use from implementing an ozone washing system to the base case. There are three main components in obtaining this value:

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[[257]](#footnote-264)

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

= actual, if unknown use 916,150 lbs laundry[[258]](#footnote-265), 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%[[259]](#footnote-266)

Savings using defaults above:

∆Gallons = WUsage \* WUtiliz \* %water\_savings

= 2.03 \* 916,150 \* 0.25

= 464,946 gallons

Default per lb capacity:

∆ 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:[[260]](#footnote-267)

* Ozone Generator: filter replacement, check valve replacement, fuse replacement, reaction chamber inspection/cleaning, reaction chamber o-ring replacement
* Air Preparation – Heat Regenerative: replacement of two medias
* Air Preparation – Oxygen Concentrators: filter replacement, pressure relief valve replacement, compressor rebuild
* Venturi Injector: check valve replacement

Maintenance is expected to cost $0.79 / lbs capacity.

###### References

1 "Lodging Report", December 2008, California Travel & Tourism Commission, http://tourism.visitcalifornia.com/media/uploads/files/editor/Research/CaliforniaTourism\_200812.pdf

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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-V02-190101

###### Review Deadline: 1/1/2020

### 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%.[[261]](#footnote-268)

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.[[262]](#footnote-269)

###### 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[[263]](#footnote-270)** |
| <300kBtuh | $65 per kBTUh |
| 300 – 2500 kBtuh | $38 per kBTUh |
| >2500 kBtuh | $32 per kBTUh |

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

There are no anticipated electrical savings from this measure.

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

Time of Sale:

ΔTherms = Hot Water Savings + Standby Loss Savings

= [(MFHH \* #Units \* GPD \* Days/yr \* עWater \* (Tout – Tin) \* (1/Eff\_base – 1/Eff\_ee)) / 100,000] + [((SL \* Hours/yr \* (1/Eff\_base – 1/Eff\_ee)) / 100,000]

Early Replacment[[264]](#footnote-271):

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

= [(MFHH \* #Units \* GPD \* Days/yr \* עWater \* (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 \* עWater \* (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[[265]](#footnote-272)

#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[[266]](#footnote-273)

Days/yr = 365.25

עWater = 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

= 54°F[[267]](#footnote-274)

Eff\_base = thermal efficiency of base unit

= 80%[[268]](#footnote-275)

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%[[269]](#footnote-276)

SL = Standby Loss[[270]](#footnote-277)

= (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

**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 \* עWater \* (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

### 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[[271]](#footnote-278).

###### 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.[[272]](#footnote-279)

###### Loadshape

Loadshape C02 - Non-Residential Electric DHW

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

Deemed at 656 kWh[[273]](#footnote-280).

###### 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[[274]](#footnote-281).

∆Therms = Boiler Input Capacity \* (tnormal occ \* Rnormal occ + tlow occ \* Rlow 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%[[275]](#footnote-282) of total boiler input capacity for Multi-Family Buildings and 16.48%[[276]](#footnote-283) of total boiler input capacity for Dormitories, as domestic hot water load.

= If unknown capcity use 4,938 BTU/hr per room for Dormitories[[277]](#footnote-284) and 12,493 BTU/hr per apartment for Multi-Family Buildings[[278]](#footnote-285)

tnormal occ = Total operating hours of domestic hot water burner, when the facility has normal occupancy. If unknown, assume 1,688 hours for Dormitories[[279]](#footnote-286) and 2,089 hours for Multi-Family buildings[[280]](#footnote-287).

tlow occ = Total operating hours of domestic hot water burner, when the facility has low occupancy[[281]](#footnote-288). If unknown, assume 520 hours for Dormitories and 0 hours for Multi-Family buildings.

Rnormal 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

Rlow 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:

∆Therms = 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 -

∆Therms = 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

### 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[[282]](#footnote-289) and no heat recovery.

###### Deemed Lifetime of Efficient Equipment

###### The expected measure life is assumed to be 15 years.[[283]](#footnote-290)

###### 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[[284]](#footnote-291):

|  |  |
| --- | --- |
| Location | CF  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

###### Calculation of Energy Savings

###### Electric Energy Savings

For electric hot water heaters:

ΔkWh = [(Meal/Day \* HW/Meal \* Days/Year) \* lbs/gal \* BTU/lb.°F \* (ΔT/filter \* Qty\_Filter) \* 0.00293] /(ηHeaterElec)

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[[285]](#footnote-292)

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[[286]](#footnote-293)

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[[287]](#footnote-294)** | **Assumed days/Year** | **Number of Filters[[288]](#footnote-295)** |
| 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 |

ηHeaterElec = 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

###### 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[[289]](#footnote-296)** |
| 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[[290]](#footnote-297):

|  |  |
| --- | --- |
| Location | CF  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] / (ηHeaterGas \* 100,000)

Where:

ηHeaterGas = 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

###### 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

### 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[[291]](#footnote-298) 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.[[292]](#footnote-299)

###### Deemed Measure Cost

The cost of this measure is $0.83/MBtu/hr per tune-up.[[293]](#footnote-300)

###### Loadshape

N/A

###### Coincidence Factor

N/A

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

ΔTherms = ((Tout - Tin) \* HotWaterUseGallon \* γwater \* 1 \* (1/Effbefore – 1/Effafter))/100,000

Where:

Tout = Hot water storage tank temperature

= 125°F

Tin = Incoming water temperature from well or municipal system

= 54°F[[294]](#footnote-301)

HotWaterUseGallon = 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[[295]](#footnote-302):

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:

|  |  |
| --- | --- |
| **Building Type[[296]](#footnote-303)** | **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 |

1. Consumption per unit area by building type

= (Area/1000) \* Consumption/1,000 sq.ft.

Where:

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

= Actual

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

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

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

= 8.33 lbs/gal

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

Effbefore = Efficiency of the boiler before tune-up

Effafter = 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.

∆Therms = ((Tout - Tin) \* HotWaterUseGallon \* γwater \* 1 \* (1/Effbefore – 1/Effafter))/100,000

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

= 13.3 therms

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HWE-DBTU-V01-180101

###### Review Deadline: 1/1/2024

## 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[[297]](#footnote-304), applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant[[298]](#footnote-305), the EFLH calculation was finalized by the Subcommittee to be the annual total (heating or cooling) output (in Btu) divided by the 95th percentile hourly peak output (heating or cooling) demand (in Btu/hr). This calculation keeps EFLH independent of modeled systems efficiency (which is utilized in the TRM savings calculation) and buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings. See “EFLH Description 2015-02-11.doc” for further explanation.

The building characteristics can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

| **Building Type** | **Heating EFLH** | | | | | **Model Source** |
| --- | --- | --- | --- | --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Assembly | 1,787 | 1,831 | 1,635 | 1,089 | 1,669 | eQuest |
| Assisted Living | 1,683 | 1,646 | 1,446 | 1,063 | 1,277 | eQuest |
| College | 1,530 | 1,430 | 1,276 | 709 | 849 | eQuest |
| Convenience Store | 1,481 | 1,368 | 1,214 | 871 | 973 | eQuest |
| Elementary School | 1,781 | 1,736 | 1,531 | 1,057 | 1,283 | eQuest |
| Garage | 985 | 969 | 852 | 680 | 752 | eQuest |
| Grocery | 1,608 | 1,602 | 1,404 | 876 | 1,047 | eQuest |
| Healthcare Clinic | 1,579 | 1,620 | 1,414 | 963 | 1,019 | eQuest |
| High School | 1,845 | 1,857 | 1,666 | 1,187 | 1,388 | eQuest |
| Hospital - CAV no econ[[299]](#footnote-306) | 1,764 | 1,818 | 1,549 | 1,332 | 1,512 | eQuest |
| Hospital - CAV econ[[300]](#footnote-307) | 1,788 | 1,853 | 1,580 | 1,369 | 1,555 | eQuest |
| Hospital - VAV econ[[301]](#footnote-308) | 731 | 695 | 522 | 314 | 340 | eQuest |
| Hospital - FCU | 1,325 | 1,512 | 1,232 | 1,448 | 1,946 | eQuest |
| Hotel/Motel | 1,761 | 1,712 | 1,544 | 1,056 | 1,290 | eQuest |
| Hotel/Motel - Common | 1,601 | 1,626 | 1,548 | 1,260 | 1,323 | eQuest |
| Hotel/Motel - Guest | 1,758 | 1,702 | 1,521 | 1,018 | 1,252 | eQuest |
| Manufacturing Facility | 1,048 | 1,013 | 939 | 567 | 634 | eQuest |
| MF - High Rise | 1,526 | 1,506 | 1,373 | 1,169 | 1,172 | eQuest |
| MF - High Rise - Common | 1,815 | 1,762 | 1,580 | 1,089 | 1,406 | eQuest |
| MF - High Rise - Residential | 1,475 | 1,464 | 1,330 | 1,152 | 1,123 | eQuest |
| MF - Mid Rise | 1,742 | 1,704 | 1,498 | 1,208 | 1,429 | OpenStudio |
| Movie Theater | 1,916 | 1,905 | 1,718 | 1,288 | 1,538 | eQuest |
| Office - High Rise - CAV no econ | 2,020 | 2,050 | 1,869 | 1,252 | 1,363 | eQuest |
| Office - High Rise - CAV econ | 2,089 | 2,132 | 1,960 | 1,351 | 1,487 | eQuest |
| Office - High Rise - VAV econ | 1,528 | 1,558 | 1,284 | 759 | 846 | eQuest |
| Office - High Rise - FCU | 1,118 | 1,102 | 952 | 505 | 530 | eQuest |
| Office - Low Rise | 1,428 | 1,425 | 1,132 | 692 | 793 | eQuest |
| Office - Mid Rise | 1,683 | 1,538 | 1,319 | 1,313 | 1,206 | OpenStudio |
| Religious Building | 1,603 | 1,504 | 1,440 | 1,054 | 1,205 | eQuest |
| Restaurant | 1,350 | 1,354 | 1,216 | 920 | 1,091 | eQuest |
| Retail - Department Store | 1,123 | 979 | 852 | 697 | 689 | OpenStudio |
| Retail - Strip Mall | 1,332 | 1,233 | 1,090 | 751 | 810 | eQuest |
| Warehouse | 1,338 | 1,098 | 976 | 771 | 810 | OpenStudio |
| Unknown | 1,553 | 1,539 | 1,369 | 982 | 1,139 | n/a |

Equivalent Full Load Hours for Cooling (EFLHcooling) :

| **Building Type** | **Cooling EFLH** | | | | | **Model Source** |
| --- | --- | --- | --- | --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Assembly | 725 | 796 | 937 | 1,183 | 932 | eQuest |
| Assisted Living | 1,475 | 1,457 | 1,773 | 2,110 | 1,811 | eQuest |
| College | 475 | 481 | 662 | 746 | 806 | eQuest |
| Convenience Store | 1,088 | 1,067 | 1,368 | 1,541 | 1,371 | eQuest |
| Elementary School | 725 | 764 | 905 | 1,142 | 956 | eQuest |
| Garage | 934 | 974 | 1,226 | 1,582 | 1,383 | eQuest |
| Grocery | 1,033 | 1,000 | 1,236 | 1,499 | 1,286 | eQuest |
| Healthcare Clinic | 1,282 | 1,305 | 1,519 | 1,767 | 1,571 | eQuest |
| High School | 675 | 721 | 840 | 1,060 | 920 | eQuest |
| Hospital - CAV no econ | 4,166 | 4,275 | 4,319 | 4,692 | 4,445 | eQuest |
| Hospital - CAV econ | 1,751 | 1,814 | 2,120 | 2,411 | 2,112 | eQuest |
| Hospital - VAV econ | 1,531 | 1,592 | 1,853 | 2,163 | 1,876 | eQuest |
| Hospital - FCU | 3,245 | 3,291 | 3,451 | 4,128 | 3,806 | eQuest |
| Hotel/Motel | 1,233 | 1,186 | 1,436 | 1,274 | 1,616 | eQuest |
| Hotel/Motel - Common | 2,186 | 2,103 | 2,344 | 1,391 | 2,651 | eQuest |
| Hotel/Motel - Guest | 1,042 | 1,019 | 1,269 | 1,216 | 1,418 | eQuest |
| Manufacturing Facility | 1,010 | 1,055 | 1,209 | 1,453 | 1,273 | eQuest |
| MF - High Rise | 921 | 845 | 1,048 | 1,779 | 1,099 | eQuest |
| MF - High Rise - Common | 914 | 839 | 1,055 | 2,893 | 1,132 | eQuest |
| MF - High Rise - Residential | 899 | 831 | 1,011 | 1,569 | 1,055 | eQuest |
| MF - Mid Rise | 694 | 747 | 927 | 983 | 961 | OpenStudio |
| Movie Theater | 876 | 745 | 1,036 | 1,178 | 1,010 | eQuest |
| Office - High Rise - CAV no econ | 1,688 | 1,708 | 1,811 | 1,865 | 1,725 | eQuest |
| Office - High Rise - CAV econ | 1,454 | 1,452 | 1,551 | 1,568 | 1,416 | eQuest |
| Office - High Rise - VAV econ | 875 | 919 | 1,057 | 1,275 | 1,077 | eQuest |
| Office - High Rise - FCU | 1,117 | 1,170 | 1,277 | 1,642 | 1,412 | eQuest |
| Office - Low Rise | 949 | 1,010 | 1,182 | 1,452 | 1,281 | eQuest |
| Office - Mid Rise | 907 | 909 | 1083 | 1057 | 1060 | OpenStudio |
| Religious Building | 861 | 817 | 967 | 1,159 | 1,067 | eQuest |
| Restaurant | 1,074 | 1,134 | 1,279 | 1,627 | 1,325 | eQuest |
| Retail - Department Store | 884 | 885 | 1076 | 1195 | 1108 | OpenStudio |
| Retail - Strip Mall | 950 | 919 | 1,149 | 1,351 | 1,215 | eQuest |
| Warehouse | 287 | 308 | 400 | 467 | 448 | OpenStudio |
| Unknown | 1,215 | 1,221 | 1,408 | 1,670 | 1,480 | n/a |

### 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.[[302]](#footnote-309)

###### Deemed Measure Cost

The incremental capital cost for this measure is $35[[303]](#footnote-310) per ton.

###### Loadshape

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[304]](#footnote-311)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[305]](#footnote-312)

**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[[306]](#footnote-313) of the baseline equipment prior to tune-up

=Actual

EERafter = Energy Efficiency Ratio of the baseline equipment after to tune-up

=Actual

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

ΔkWh = (kBtu/hr) / EERbefore \* EFLH \* %Savings

Where:

%Savings = Deemed percent savings per Tune-Up component. These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed (totals provided below)[[307]](#footnote-314)

| **Tune-Up Component** | **% savings** |
| --- | --- |
| Condenser Cleaning | 6.10% |
| Evaporator Cleaning | 0.22% |
| Refrig. Charge Off. <=20% | 0.68% |
| Refrig. Charge Off. >20% | 8.44% |
| Combined (Refrig. Charge Off. <=20%) | 7.00% |
| 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

ΔkWSSP = (kBtu/hr \* (1/EERbefore - 1/EERafter)) \* CFSSP

ΔkWPJM = (kBtu/hr \* (1/ EERbefore - 1/EERafter)) \* CFPJM

Where:

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[308]](#footnote-315)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[309]](#footnote-316)

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

ΔkW = (kBtu/hr) / EERbefore \* %Savings \* CF

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-ACTU-V05-180101

###### Review Deadline: 1/1/2021

### 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[[310]](#footnote-317) 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[[311]](#footnote-318)

###### Deemed Measure Cost

The cost of this measure is $0.83/MBtu/hr[[312]](#footnote-319) per tune-up

###### 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

### 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[[313]](#footnote-320) 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[[314]](#footnote-321)

###### Deemed Measure Cost

The cost of this measure is $0.83/MBtu/hr[[315]](#footnote-322) per tune-up

###### 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

ΔTherms =((Ngi \* 8766\*UF)/100) \* (1- (Effpre/Effmeasured))

Where:

Ngi = Boiler gas input size (kBtu/hr)

= custom

UF = Utilization Factor

= 41.9%[[316]](#footnote-323) or custom

Effpre = 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.*

Effmeasured = Boiler Combustion Efficiency After Tune-Up

= Actual

100 =converstion from kBtu to therms

8766 = hours a year

EXAMPLE

For example, a 80% 1050 kBtu boiler is tuned-up resulting in final efficiency of 81.3%:

Δtherms =((1050 \* 8766\*0.419)/100) \* (1- (0.80/0.813))

= 617 therms

###### 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

### 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[[317]](#footnote-324)

###### Deemed Measure Cost

The cost of this measure is $612[[318]](#footnote-325)

###### 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

ΔTherms = Binput \* SF \* EFLH /( 100)

Where:

Binput = Boiler Input Capacity (kBtu/hr)

= custom

SF = Savings factor

= 8%[[319]](#footnote-326) 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

### 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[[320]](#footnote-327)

###### Deemed Measure Cost

The incremental capital cost for a unit heater is $676[[321]](#footnote-328)

###### 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.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-CUHT-V01-190101

###### Review Deadline: 1/1/2022

### 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 23 years [[322]](#footnote-329).

###### 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[[323]](#footnote-330) |
| Water cooled, electrically operated, positive displacement (reciprocating) | All capacities | $22/ton[[324]](#footnote-331) |
| Water cooled, electrically operated, positive displacement (rotary screw and scroll) | < 150 tons | $351/ton[[325]](#footnote-332) |
| >= 150 tons and < 300 tons | $127/ton |
| >= 300 tons | $87/ton |

###### 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.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[326]](#footnote-333)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[327]](#footnote-334)

**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[[328]](#footnote-335) = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[[329]](#footnote-336)

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) ,in a low-rise office building in Rockford with a building permit dated on 1/1/2015 would save:

ΔkWH = 100 \* ((0.96) – (0.86)) \* 949

= 9,490 kWh

###### Summer Coincident Peak Demand Savings

ΔkWSSP = TONS \* ((PEbase) – (PEee)) \* CFSSP

ΔkWPJM = TONS \* ((PEbase) – (PEee)) \* CFPJM

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

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%

CFPJM = 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:

ΔkWSSP = 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)

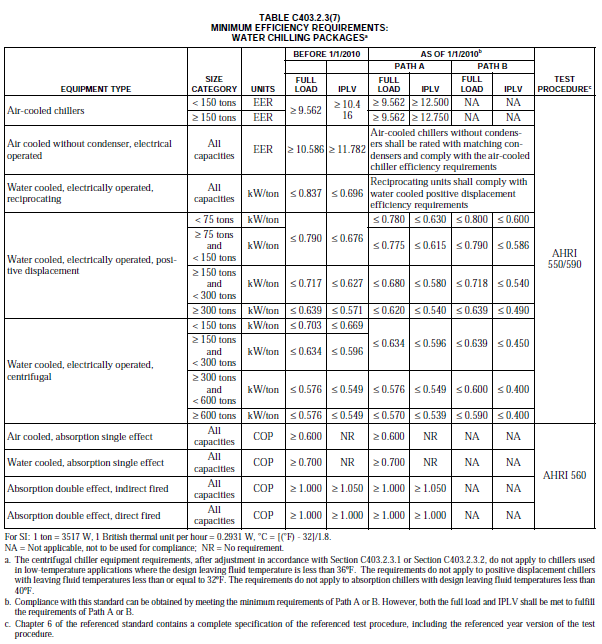
COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

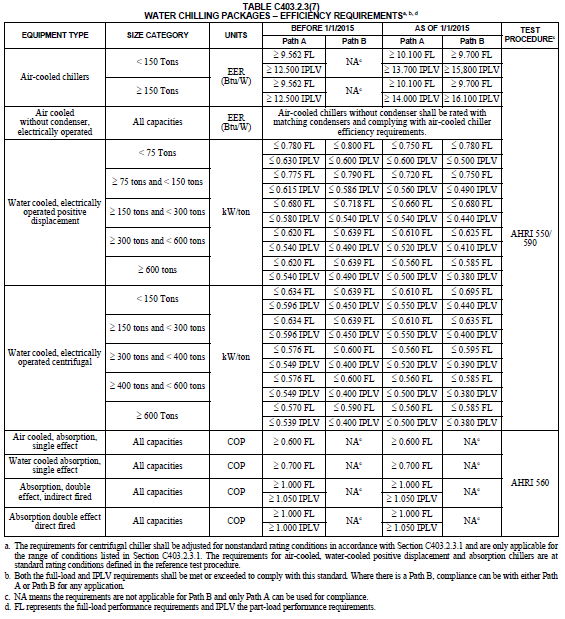
EER = 12 / kW/ton

EER = COP x 3.412

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity



2015 IECC Baseline Efficiency Values by Chiller Type and Capacity



###### Measure Code: CI-HVC-CHIL-V06-190101

###### Review Deadline: 1/1/2022

### ENERGY STAR and CEE Super Efficient Room Air Conditioner

###### Description

This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE Super Efficient minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:[[330]](#footnote-337)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Product Class (Btu/H) | Federal Standard CEER, with louvered sides | Federal Standard CEER, without louvered sides | ENERGY STAR CEER, with louvered sides | ENERGY STAR CEER, without louvered sides | CEE Super Efficient  CEER |
| < 8,000 | 11.0 | 10.0 | 12.1 | 11.0 | 12.7 |
| 8,000 to 10,999 | 10.9 | 9.6 | 12.0 | 10.6 | 12.5 |
| 11,000 to 13,999 | 9.5 | 10.5 |
| 14,000 to 19,999 | 10.7 | 9.3 | 11.8 | 10.2 | 12.3 |
| 20,000 to 27,999 | 9.4 | 9.4 | 10.3 | 10.3 | 10.8 |
| >= 28,000 | 9.0 | 9.9 | 10.4 |

|  |  |  |
| --- | --- | --- |
| **Casement** | **Federal Standard (CEER)** | **ENERGY STAR (CEER)** |
| Casement-only | 9.5 | 10.5 |
| Casement-slider | 10.4 | 11.4 |

| Reverse Cycle -  Product Class (Btu/H) | Federal Standard CEER, with louvered sides | Federal Standard CEER, without louvered sides | ENERGY STAR CEER, with louvered sides | ENERGY STAR CEER, without louvered sides |
| --- | --- | --- | --- | --- |
| < 14,000 | N/A | 9.3 | N/A | 10.2 |
| >= 14,000 | N/A | 8.7 | N/A | 9.6 |
| < 20,000 | 9.8 | N/A | 10.8 | N/A |
| >= 20,000 | 9.3 | N/A | 10.2 | N/A |

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

###### Definition of Efficient Equipment

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

###### Definition of Baseline Equipment

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

###### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 9 years.[[331]](#footnote-338)

###### Deemed Measure Cost

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE Super Efficient unit.[[332]](#footnote-339)

###### 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.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[333]](#footnote-340)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[334]](#footnote-341)

**Algorithm**

###### Calculation of Savings

###### Energy Savings

ΔkWh = (FLHRoomAC \* Btu/H \* (1/CEERbase - 1/CEERee))/1000

Where:

FLHRoomAC = Full Load Hours of room air conditioning unit

= dependent on location:[[335]](#footnote-342)

|  |  |
| --- | --- |
| Zone | FLHRoomAC |
| 1 (Rockford) | 253 |
| 2-(Chicago) | 254 |
| 3 (Springfield) | 310 |
| 4-(Belleville) | 391 |
| 5-(Marion) | 254 |

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr [[336]](#footnote-343)

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR or CEE Super Efficient unit

= Actual. If unknown assume minimum qualifying standard as provided in tables above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford:

ΔkWHENERGY STAR = (253 \* 8500 \* (1/10.9 – 1/12.0)) / 1000

= 18.1 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = Btu/H \* ((1/CEERbase - 1/CEERee))/1000) \* CF

Where:

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[337]](#footnote-344)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[338]](#footnote-345)

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

ΔkWENERGY STAR = (8500 \* (1/10.9 – 1/12.0)) / 1000 \* 0.913

= 0.065 kW

###### Fossil Fuel Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-ESRA-V02-190101

###### Review Deadline: 1/1/2022

### 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[[339]](#footnote-346).

###### 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[[340]](#footnote-347).

###### Deemed O&M Cost Adjustments

N/A

###### Loadshape

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

A coincidence factor is not used in the determination of coincident peak kW savings.

**Algorithm**

###### Calculation of Savings

Below are the annual kWh savings per installed EMS for different sizes and types of HVAC units. The savings are achieved based on GREM’s ability to automatically adjust the guest room’s set temperatures and control the HVAC 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[[341]](#footnote-348). Model outputs are normalized to the installed capacity and reported here as kWh/Ton, coincident peak kW/Ton and Therms/Ton.

###### Electric Energy Savings

| **Motel Electric Energy Savings** | | | |
| --- | --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **Heating Source** | **Baseline** | **Electric Savings**  **(kWh/Ton)** |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 744 |
| No Housekeeping Setback | 1,786 |
| PTAC w/ Gas Heating | Housekeeping Setback | 63 |
| No Housekeeping Setback | 155 |
| PTHP | Housekeeping Setback | 385 |
| No Housekeeping Setback | 986 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 506 |
| No Housekeeping Setback | 1,582 |
| PTAC w/ Gas Heating | Housekeeping Setback | 51 |
| No Housekeeping Setback | 163 |
| PTHP | Housekeeping Setback | 211 |
| No Housekeeping Setback | 798 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 462 |
| No Housekeeping Setback | 1,382 |
| PTAC w/ Gas Heating | Housekeeping Setback | 65 |
| No Housekeeping Setback | 198 |
| PTHP | Housekeeping Setback | 202 |
| No Housekeeping Setback | 736 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 559 |
| No Housekeeping Setback | 1,877 |
| PTAC w/ Gas Heating | Housekeeping Setback | 85 |
| No Housekeeping Setback | 287 |
| PTHP | Housekeeping Setback | 260 |
| No Housekeeping Setback | 1,023 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 388 |
| No Housekeeping Setback | 1,339 |
| PTAC w/ Gas Heating | Housekeeping Setback | 81 |
| No Housekeeping Setback | 274 |
| PTHP | Housekeeping Setback | 174 |
| No Housekeeping Setback | 682 |

| **Hotel Electric Energy Savings** | | | |
| --- | --- | --- | --- |
| **Climate Zone (City based upon)** | **Heating Source** | **Baseline** | **Electric Savings (kWh/Ton)** |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 204 |
| No Housekeeping Setback | 345 |
| PTAC w/ Gas Heating | Housekeeping Setback | 121 |
| No Housekeeping Setback | 197 |
| PTHP | Housekeeping Setback | 152 |
| No Housekeeping Setback | 253 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 177 |
| No Housekeeping Setback | 296 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 94 |
| No Housekeeping Setback | 148 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 188 |
| No Housekeeping Setback | 342 |
| PTAC w/ Gas Heating | Housekeeping Setback | 119 |
| No Housekeeping Setback | 195 |
| PTHP | Housekeeping Setback | 145 |
| No Housekeeping Setback | 250 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 161 |
| No Housekeeping Setback | 294 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 92 |
| No Housekeeping Setback | 147 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 182 |
| No Housekeeping Setback | 291 |
| PTAC w/ Gas Heating | Housekeeping Setback | 123 |
| No Housekeeping Setback | 197 |
| PTHP | Housekeeping Setback | 145 |
| No Housekeeping Setback | 233 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 153 |
| No Housekeeping Setback | 240 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 94 |
| No Housekeeping Setback | 146 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 182 |
| No Housekeeping Setback | 308 |
| PTAC w/ Gas Heating | Housekeeping Setback | 125 |
| No Housekeeping Setback | 199 |
| PTHP | Housekeeping Setback | 146 |
| No Housekeeping Setback | 240 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 152 |
| No Housekeeping Setback | 255 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 95 |
| No Housekeeping Setback | 147 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 171 |
| No Housekeeping Setback | 295 |
| PTAC w/ Gas Heating | Housekeeping Setback | 122 |
| No Housekeeping Setback | 199 |
| PTHP | Housekeeping Setback | 140 |
| No Housekeeping Setback | 235 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 141 |
| No Housekeeping Setback | 243 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 92 |
| No Housekeeping Setback | 146 |

###### Summer Coincident Peak Demand Savings

| **Motel Coincident Peak Demand Savings** | | | |
| --- | --- | --- | --- |
| **Climate Zone**  **(City based upon)** | **Heating Source** | **Baseline** | **Coincident Peak Demand Savings**  **(kW/Ton)** |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.17 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.17 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.17 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.06 |
| No Housekeeping Setback | 0.17 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.06 |
| No Housekeeping Setback | 0.17 |
| PTHP | Housekeeping Setback | 0.06 |
| No Housekeeping Setback | 0.17 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.17 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.17 |
| PTHP | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.17 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |
| PTHP | Housekeeping Setback | 0.10 |
| No Housekeeping Setback | 0.28 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.21 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.21 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.21 |

| **Hotel Coincident Peak Demand Savings** | | | |
| --- | --- | --- | --- |
| **Climate Zone (City based upon)** | **Heating Source** | **Baseline** | **Coincident Peak Demand Savings (kW/Ton)** |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.11 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.11 |
| PTHP | Housekeeping Setback | 0.07 |
| No Housekeeping Setback | 0.11 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.07 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.07 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.07 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.07 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| PTHP | Housekeeping Setback | 0.08 |
| No Housekeeping Setback | 0.11 |
| Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| No Housekeeping Setback | 0.08 |

###### Natural Gas Energy Savings

For PTACs with gas heating:

|  |  |  |
| --- | --- | --- |
| **Motel Natural Gas Energy Savings** | | |
| **Climate Zone (City based upon)** | **Baseline** | **Gas Savings (Therms/Ton)** |
| 1 (Rockford) | Housekeeping Setback | 30 |
| No Housekeeping Setback | 71 |
| 2 (Chicago) | Housekeeping Setback | 20 |
| No Housekeeping Setback | 62 |
| 3 (Springfield) | Housekeeping Setback | 17 |
| No Housekeeping Setback | 52 |
| 4 (Belleville) | Housekeeping Setback | 21 |
| No Housekeeping Setback | 70 |
| 5 (Marion-Williamson) | Housekeeping Setback | 13 |
| No Housekeeping Setback | 47 |

| **Hotel Natural Gas Energy Savings** | | | |
| --- | --- | --- | --- |
| **Climate Zone (City based upon)** | **Heating Source** | **Baseline** | **Gas Savings (Therms/Ton)** |
| 1 (Rockford) | PTAC w/ Gas Heating | Housekeeping Setback | 3.6 |
| No Housekeeping Setback | 6.4 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 3.6 |
| No Housekeeping Setback | 6.4 |
| 2 (Chicago) | PTAC w/ Gas Heating | Housekeeping Setback | 3.0 |
| No Housekeeping Setback | 6.5 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 3.0 |
| No Housekeeping Setback | 6.5 |
| 3 (Springfield) | PTAC w/ Gas Heating | Housekeeping Setback | 2.6 |
| No Housekeeping Setback | 4.1 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.6 |
| No Housekeeping Setback | 4.1 |
| 4 (Belleville) | PTAC w/ Gas Heating | Housekeeping Setback | 2.5 |
| No Housekeeping Setback | 4.8 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.5 |
| No Housekeeping Setback | 4.8 |
| 5 (Marion-Williamson) | PTAC w/ Gas Heating | Housekeeping Setback | 2.1 |
| No Housekeeping Setback | 4.2 |
| Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.1 |
| 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

### 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 baseline and meets program requirements.

###### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, water source, ground water source, or ground source heat pump system that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date unknown assume current Code minimum). The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Note: new Federal Standards affecting Heat Pumps become effective January 1, 2023.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[[342]](#footnote-349) except for geothermal heat pump systems which have an expected measures life of 25 years[[343]](#footnote-350).

###### Deemed Measure Cost

For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.[[344]](#footnote-351) 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.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[345]](#footnote-352)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[346]](#footnote-353)

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

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

ΔkWh= Annual kWh Savingscool + Annual kWh Savingsheat

Annual kWh Savingscool = (kBtu/hrcool) \* [(1/SEERbase) – (1/SEERee)] \* EFLHcool

Annual kWh Savingsheat = (kBtu/hrheat) \* [(1/HSPFbase) – (1/HSPFee)] \* EFLHheat

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

ΔkWh= Annual kWh Savingscool + Annual kWh Savingsheat

Annual kWh Savingscool = (kBtu/hrcool) \* [(1/EERbase) – (1/EERee)] \* EFLHcool

Annual kWh Savingsheat = (kBtu/hrheat)/3.412 \* [(1/COPbase) – (1/COPee)] \* EFLHheat

Where:

kBtu/hrcool = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

SEERbase =Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment.

= Actual installed

EFLHcool = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

HSPFbase = Heating Seasonal Performance Factor of the baseline equipment

= HSPF from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

HSPFee = Heating Seasonal Performance Factor of the energy efficient equipment.

= Actual installed. If rating is COP, HSPF = COP \* 3.413

EFLHheat  = heating mode equivalent full load hours are provided in section 4.4 HVAC End Use.

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[[347]](#footnote-354)

EER = (-0.02 \* SEER2) + (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/hrheat = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPbase = coefficient of performance of the baseline equipment

= COP from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). If rating is HSPF, COP = HSPF / 3.413

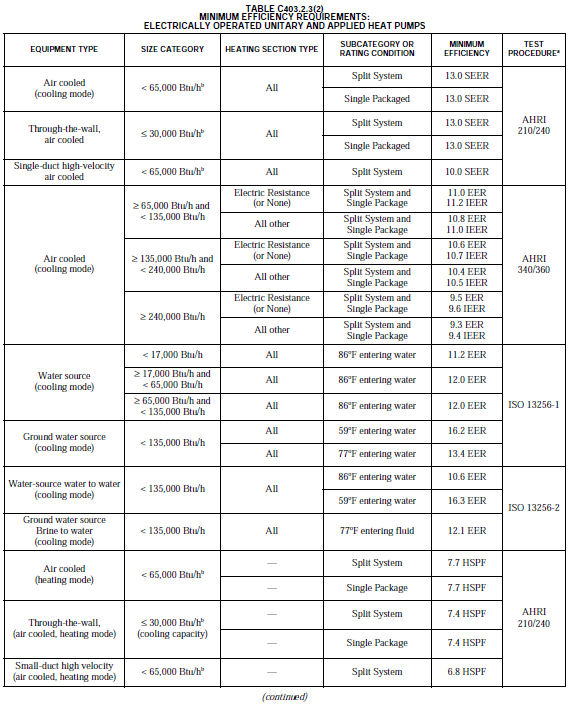
COPee = coefficient of performance of the energy efficient equipment.

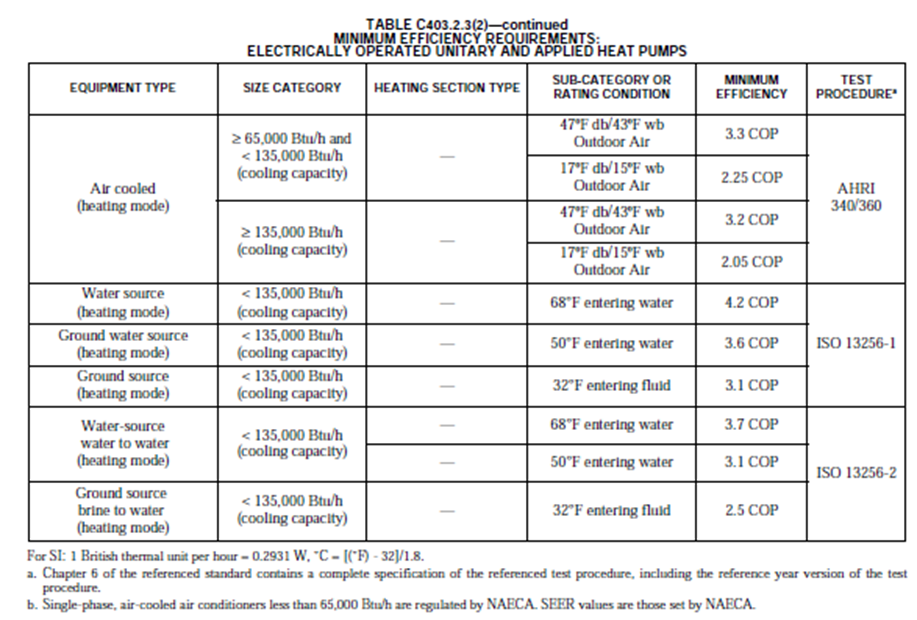
= Actual installed

**Code of Federal Redulations (baseline effective 1/1/2019):**

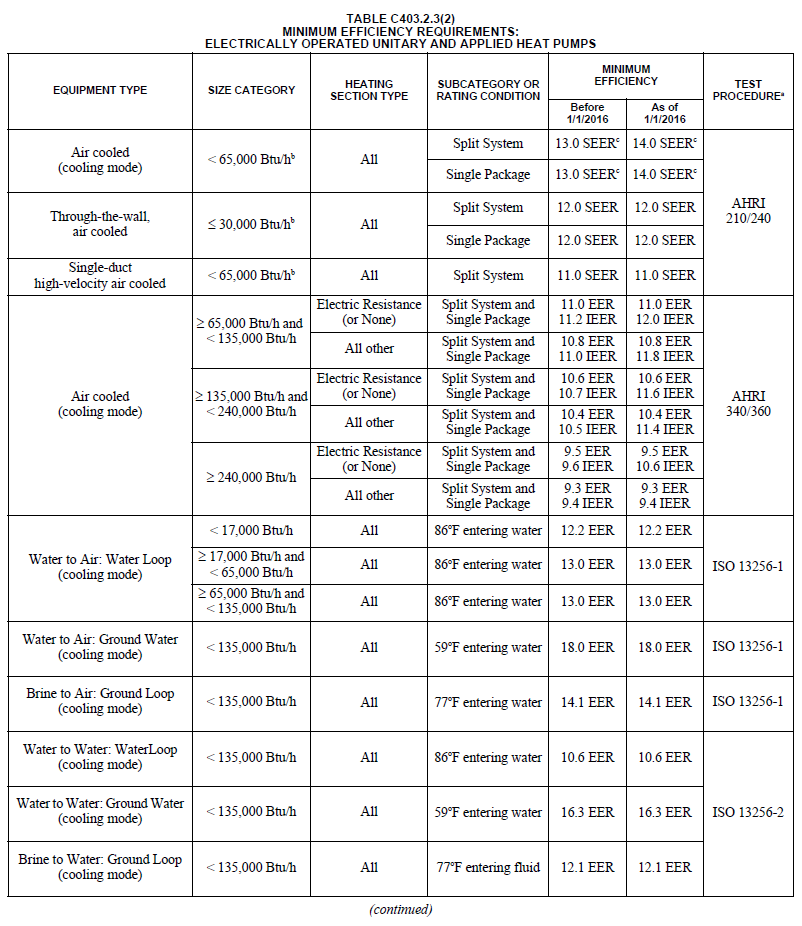
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Equipment type** | **Cooling capacity** | **Heating type** | **Cooling Efficiency level** | **Heating Efficiency level** | **Compliance date** |
| Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥65,000 Btu/h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

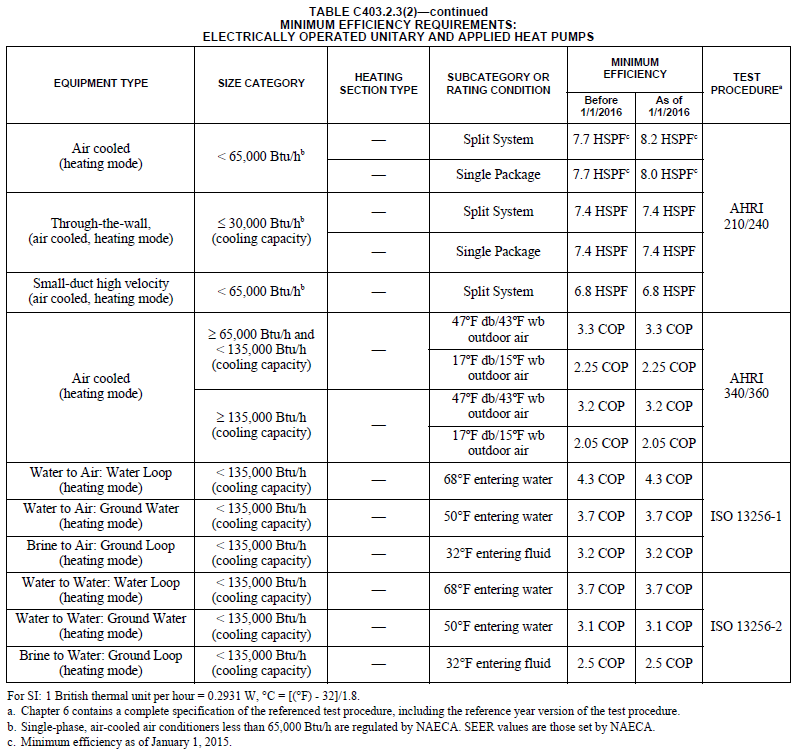
Minimum Efficiency Requirements: 2012 IECC





Minimum Efficiency Requirements: 2015 IECC





For example a 5 ton cooling unit with 60 kbtu heating, an efficient SEER of 16, and an efficient HSPF of 9.5, at a restaurant in Chicago with a building permit dated after 1/1/2016 saves:

ΔkWh = [(60) \* [(1/14) – (1/16)] \* 1134] + [(60) \* [(1/8.2) – (1/9.5)] \* 1354]

= 1963.2 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ((kBtu/hrcool) \* (1/EERbase – 1/EERee)) \*CF

Where CF value is chosen between:

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[348]](#footnote-355)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[349]](#footnote-356)

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-V06-190101

###### Review Deadline: 1/1/2022

### 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[[350]](#footnote-357) | 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[[351]](#footnote-358) | 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 |

Note: a new Federal Standard, applicable only to gas-fired, natural draft steam packaged boilers, becomes effective March 2, 2022.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years[[352]](#footnote-359)

###### Deemed Measure Cost

The incremental capital cost for this measure depends on efficiency as listed below[[353]](#footnote-360)

| 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% |
| 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-V05-190101

###### Review Deadline: 1/1/2021

### 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:

* 1. 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)[[354]](#footnote-361).
    - All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

* + - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
    - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
    - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a furnace with input energy less than 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating and fan electrical efficiency exceeding the program requirements:

###### Definition of Baseline Equipment

Time of Sale: Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. As discussed above we estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%

Note: a new Federal Standard will become effective January 1, 2023 and be applicable to all gas furnaces.

###### Definition of Measure Life

The expected measure life is assumed to be 16.5 years[[355]](#footnote-362)

Remaining life of existing equipment is assumed to be 5.5 years[[356]](#footnote-363).

###### Deemed Measure Cost

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below[[357]](#footnote-364):

|  |  |  |
| --- | --- | --- |
| **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[[358]](#footnote-365). 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[[359]](#footnote-366)

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[[360]](#footnote-367)

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[[361]](#footnote-368).

| **Building Type** | **HOURSyear** | **Model source** |
| --- | --- | --- |
| Assembly | 2150 | eQuest |
| Assisted Living | 4373 | eQuest |
| College | 1605 | eQuest |
| Convenience Store | 2084 | eQuest |
| Elementary School | 3276 | eQuest |
| Garage | 2102 | eQuest |
| Grocery | 2096 | eQuest |
| Healthcare Clinic | 1987 | eQuest |
| High School | 3141 | eQuest |
| Hospital - VAV econ | 2788 | eQuest |
| Hospital - CAV econ | 2881 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |
| Hospital - FCU | 8729 | eQuest |
| Manufacturing Facility | 2805 | eQuest |
| MF - High Rise | 4237 | eQuest |
| MF - Mid Rise | 2899 | eQuest |
| Hotel/Motel – Guest | 4479 | eQuest |
| Hotel/Motel - Common | 8712 | eQuest |
| Movie Theater | 2120 | eQuest |
| Office - High Rise - VAV econ | 2038 | eQuest |
| Office - High Rise - CAV econ | 4849 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 3069 | eQuest |
| Office - Low Rise | 2481 | eQuest |
| Office - Mid Rise | 3036 | OpenStudio |
| Religious Building | 2830 | eQuest |
| Restaurant | 3350 | eQuest |
| Retail - Department Store | 2528 | eQuest |
| Retail - Strip Mall | 2266 | eQuest |
| Warehouse | 770 | eQuest |
| Unknown | 2718 | n/a |

CF =Summer Peak Coincidence Factor for measure is provided below for different building types[[362]](#footnote-369):

| **HVAC Pumps** | **CF** |
| --- | --- |
| Assembly | 48.3% |
| Assisted Living | 52.9% |
| College | 14.2% |
| Convenience Store | 57.1% |
| Elementary School | 33.3% |
| Garage | 61.9% |
| Grocery | 47.5% |
| Healthcare Clinic | 61.9% |
| High School | 28.8% |
| Hospital - VAV econ | 57.6% |
| Hospital - CAV econ | 61.5% |
| Hospital - CAV no econ | 64.8% |
| Hospital - FCU | 60.9% |
| Manufacturing Facility | 43.3% |
| MF - High Rise - Common | 43.7% |
| MF - Mid Rise | 24.3% |
| Hotel/Motel - Guest | 62.9% |
| Hotel/Motel - Common | 64.6% |
| Movie Theater | 41.9% |
| Office - High Rise - VAV econ | 43.2% |
| Office - High Rise - CAV econ | 48.3% |
| Office - High Rise - CAV no econ | 50.3% |
| Office - High Rise - FCU | 46.2% |
| Office - Low Rise | 47.4% |
| Office - Mid Rise | 42.8% |
| Religious Building | 43.3% |
| Restaurant | 48.8% |
| Retail - Department Store | 50.5% |
| Retail - Strip Mall | 52.8% |
| Warehouse | 22.5% |
| Unknown | 42.4% |

EXAMPLE

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

ΔkW = (241 / 2481) \* 0.474

= 0.05 kW

###### Natural Gas Energy Savings

Time of Sale:

ΔTherms = EFLH \* Capacity \* ((AFUE(eff) – AFUE(base))/AFUE(base))/ 100,000 Btu/Therm

Early replacement[[363]](#footnote-370):

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% **[[364]](#footnote-371)**.

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

Dependent on program type as listed below[[365]](#footnote-372):

|  |  |
| --- | --- |
| **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%[[366]](#footnote-373)

**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-V07-190101

###### Review Deadline: 1/1/2022

### 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[[367]](#footnote-374)

###### Deemed Measure Cost

The incremental capital cost for this measure is $1716[[368]](#footnote-375)

###### 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[[369]](#footnote-376)

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-IRHT-V01-190101

###### Review Deadline: 1/1/2022

### 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:

1. Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
2. Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

###### Definition of Baseline Equipment

Time of Sale: the baseline condition is equipment that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

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

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years. [[370]](#footnote-377)

Remaining life of existing equipment is assumed to be 3 years[[371]](#footnote-378)

###### Deemed Measure Cost

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[[372]](#footnote-379)

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[[373]](#footnote-380).

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton[[374]](#footnote-381). This cost should be discounted to present value using the nominal discount rate.

###### Loadshape

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.  Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[375]](#footnote-382)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[376]](#footnote-383)

**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[[377]](#footnote-384)= Annual kWh Savingscool

PTHP ΔkWh= Annual kWh Savingscool + Annual kWh Savingsheat

Annual kWh Savingscool = (kBtu/hrcool) \* [(1/EERbase) – (1/EERee)] \* EFLHcool

Annual kWh Savingsheat = (kBtu/hrheat)/3.412 \* [(1/COPbase) – (1/COPee)] \* EFLHheat

Early Replacement:

ΔkWh for remaining life of existing unit (1st 5years) = Annual kWh Savingscool + Annual kWh Savingsheat

Annual kWh Savingscool = (kBtu/hrcool) \* [(1/EERexist) – (1/EERee)] \* EFLHcool

Annual kWh Savingsheat = (kBtu/hrheat)/3.412 \* [(1/COPexist) – (1/COPee)] \* EFLHheat

ΔkWh for remaining measure life (next 10 years) = Annual kWh Savingscool + Annual kWh Savingsheat

Annual kWh Savingscool = (kBtu/hrcool) \* [(1/EERbase) – (1/EERee)] \* EFLHcool

Annual kWh Savingsheat = (kBtu/hrheat)/3.412 \* [(1/COPbase) – (1/COPee)] \* EFLHheat

Where:

kBtu/hrcool = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

EFLHcool = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use:

EFLHheat  = 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[[378]](#footnote-385)

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

= Based on applicable Code on date of equipment purchase(if unknown assume current Code

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment Type** | **IECC 2012**  **Minimum Efficiency** | **IECC 2015**  **Minimum Efficiency** | **Federal Regulations**  **Minimum Efficiency (baseline effective 1/1/2019)** |
| PTAC (Cooling mode)  New Construction | 13.8 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER  Compliance date: 1/1/2017 |
| PTAC (Cooling mode)  Replacements | 10.9 – (0.213 x Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER  Compliance date: 10/7/2010 |
| PTHP (Cooling mode)  New Construction | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER  Complainace date: 10/8/2012 |
| PTHP (Cooling mode)  Replacements | 10.8 – (0.213 x Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER  Compliance date: 10/7/2010 |
| PTHP (Heating mode)  New Construction | 3.2 – (0.026 x Cap/1000) COP | 3.2 – (0.026 x Cap/1000) COP | 3.7 – (0.052 x Cap/1000) COP  Compliance date: 10/8/2012 |
| PTHP (Heating mode)  Replacements | 2.9 – (0.026 x Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP  Compliance date: 10/7/2010 |

“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[[379]](#footnote-386): EER = (-0.02 \* SEER2) + (1.12 \* SEER)

= Actual installed

kBtu/hrheat = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPexist = coefficient of performance of the existing equipment

= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP[[380]](#footnote-387) for PTHPs.

COPbase = coefficient of performance of the baseline equipment; see table above for values.

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed

**EXAMPLE:**

Time of Sale (assuming new construction baseline):

For example a 1 ton PTAC with an efficient EER of 12 at a guest hotel in Rockford with a building permit dated before 1/1/2016 saves:

= [(12) \* [(1/10.4) – (1/12)] \* 1,042

= 160 kWh

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

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

ΔkWh for remaining life of existing unit (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:

ΔkW = (kBtu/hrcool) \* [(1/EERbase) – (1/EERee)] \*CF

Early Replacement:

ΔkW for remaining life of existing unit (1st 5years) = (kBtu/hrcool) \* [(1/EERexist) – (1/EERee)] \*CF

ΔkW for remaining measure life (next 10 years) = (kBtu/hrcool) \* [(1/EERbase) – (1/EERee)] \*CF

Where:

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[381]](#footnote-388)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[382]](#footnote-389)

**EXAMPLE**

Time of Sale:

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

ΔkWSSP = (12 \* (1/10.4 – 1/12) \*0.913

= 0.14 kW

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 replacing a PTAC unit with unknown efficiency saves:

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

ΔkWSSP = 12 \* (1/8.1 – 1/12) \* 0.913

= 0.44 kW

ΔkW for remaining measure life (next 10 years):

ΔkWSSP = 12 \* (1/8.3 – 1/12) \* 0.913

= 0.41 kW

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-PTAC-V09-190101

###### Review Deadline: 1/1/2022

### 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.[[383]](#footnote-390)

###### 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.[[384]](#footnote-391)

###### Deemed Measure Cost

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means[[385]](#footnote-392) pricing reference materials may be used.[[386]](#footnote-393) 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[[387]](#footnote-394) = [((Qbase – Qeff) \* EFLH) / (100,000 \* ηBoiler)] \* TRF

= [Modeled or provided by tables below] \* TRF

Δtherms = (Lsp + Loc,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 |
| Zone 1 (Rockford) | 5,039 |

Qbase = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

Qeff = 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 [[388]](#footnote-395)

= 80.7% for steam boilers, except multifamily low-pressure [[389]](#footnote-396)

= 64.8% for multifamily low-pressure steam boilers [[390]](#footnote-397)

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [[391]](#footnote-398)

= 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.[[392]](#footnote-399)

| **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 |

Lsp = Length of straight pipe to be insulated (linear foot)

= actual installed ((linear foot)

Loc,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 (Qbase and Qeff) were developed using the 3E Plus v4.0 software program.[[393]](#footnote-400) 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 Qbase and Qeff.

|  |  |  |
| --- | --- | --- |
| **Insulation Type** | **Conductivity  (Btu.in / hr.ft2.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.ft2.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 |

|  | **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)[[394]](#footnote-401) | 75 | 75 | 75 | 75 | 48.6 | 48.6 | 48.6 |
| Wind speed (mph)[[395]](#footnote-402) | 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

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 |
| 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 |
| 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 |
| 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)

|  |  |  | **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)** |
| Outdoor | Hot Water Space Heating with outdoor reset – non-recirculation | Assembly | 7.58 | 7.77 | 6.94 | 4.62 | 7.08 |
| Assisted Living | 7.14 | 6.98 | 6.13 | 4.51 | 5.42 |
| College | 6.49 | 6.07 | 5.41 | 3.01 | 3.60 |
| Convenience Store | 6.28 | 5.80 | 5.15 | 3.70 | 4.13 |
| Elementary School | 7.56 | 7.36 | 6.50 | 4.49 | 5.44 |
| Garage | 4.18 | 4.11 | 3.61 | 2.88 | 3.19 |
| Grocery | 6.82 | 6.80 | 5.96 | 3.72 | 4.44 |
| Healthcare Clinic | 6.70 | 6.87 | 6.00 | 4.09 | 4.32 |
| High School | 7.83 | 7.88 | 7.07 | 5.03 | 5.89 |
| Hospital - CAV no econ | 7.49 | 7.71 | 6.57 | 5.65 | 6.41 |
| Hospital - CAV econ | 7.59 | 7.86 | 6.70 | 5.81 | 6.60 |
| Hospital - VAV econ | 3.10 | 2.95 | 2.22 | 1.33 | 1.44 |
| Hospital - FCU | 5.62 | 6.42 | 5.23 | 6.14 | 8.26 |
| Hotel/Motel | 7.47 | 7.26 | 6.55 | 4.48 | 5.47 |
| Hotel/Motel - Common | 6.79 | 6.90 | 6.57 | 5.34 | 5.61 |
| Hotel/Motel - Guest | 7.46 | 7.22 | 6.45 | 4.32 | 5.31 |
| Manufacturing Facility | 4.45 | 4.30 | 3.98 | 2.41 | 2.69 |
| MF - High Rise | 6.48 | 6.39 | 5.83 | 4.96 | 4.97 |
| MF - High Rise - Common | 7.70 | 7.48 | 6.70 | 4.62 | 5.96 |
| MF - High Rise - Residential | 6.26 | 6.21 | 5.64 | 4.89 | 4.77 |
| MF - Mid Rise | 7.07 | 7.15 | 6.15 | 4.53 | 5.16 |
| Movie Theater | 7.71 | 7.60 | 7.10 | 5.40 | 6.43 |
| Office - High Rise - CAV no econ | 8.57 | 8.70 | 7.93 | 5.31 | 5.78 |
| Office - High Rise - CAV econ | 8.86 | 9.04 | 8.32 | 5.73 | 6.31 |
| Office - High Rise - VAV econ | 6.48 | 6.61 | 5.45 | 3.22 | 3.59 |
| Office - High Rise - FCU | 4.75 | 4.67 | 4.04 | 2.14 | 2.25 |
| Office - Low Rise | 6.06 | 6.05 | 4.80 | 2.94 | 3.36 |
| Office - Mid Rise | 6.73 | 6.73 | 5.70 | 3.63 | 4.03 |
| Religious Building | 6.80 | 6.38 | 6.11 | 4.47 | 5.11 |
| Restaurant | 5.73 | 5.75 | 5.16 | 3.90 | 4.63 |
| Retail - Department Store | 5.91 | 5.42 | 5.09 | 3.31 | 3.78 |
| Retail - Strip Mall | 5.65 | 5.23 | 4.62 | 3.19 | 3.44 |
| Warehouse | 6.18 | 5.76 | 5.94 | 3.71 | 4.57 |
| Unknown | 6.59 | 6.53 | 5.81 | 4.17 | 4.83 |
| Hot Water Space Heating without outdoor reset – non-recirculation | Assembly | 9.59 | 9.83 | 8.77 | 5.85 | 8.96 |
| Assisted Living | 9.04 | 8.83 | 7.76 | 5.70 | 6.86 |
| College | 8.21 | 7.68 | 6.85 | 3.80 | 4.56 |
| Convenience Store | 7.95 | 7.34 | 6.52 | 4.68 | 5.22 |
| Elementary School | 9.56 | 9.32 | 8.22 | 5.68 | 6.89 |
| Garage | 5.28 | 5.20 | 4.57 | 3.65 | 4.04 |
| Grocery | 8.63 | 8.60 | 7.54 | 4.70 | 5.62 |
| Healthcare Clinic | 8.47 | 8.70 | 7.59 | 5.17 | 5.47 |
| High School | 9.90 | 9.97 | 8.94 | 6.37 | 7.45 |
| Hospital - CAV no econ | 9.47 | 9.76 | 8.31 | 7.15 | 8.11 |
| Hospital - CAV econ | 9.60 | 9.95 | 8.48 | 7.35 | 8.34 |
| Hospital - VAV econ | 3.93 | 3.73 | 2.80 | 1.68 | 1.82 |
| Hospital - FCU | 7.11 | 8.12 | 6.61 | 7.77 | 10.45 |
| Hotel/Motel | 9.45 | 9.19 | 8.29 | 5.67 | 6.92 |
| Hotel/Motel - Common | 8.59 | 8.73 | 8.31 | 6.76 | 7.10 |
| Hotel/Motel - Guest | 9.44 | 9.13 | 8.16 | 5.47 | 6.72 |
| Manufacturing Facility | 5.63 | 5.44 | 5.04 | 3.05 | 3.40 |
| MF - High Rise | 8.19 | 8.08 | 7.37 | 6.27 | 6.29 |
| MF - High Rise - Common | 9.74 | 9.46 | 8.48 | 5.85 | 7.54 |
| MF - High Rise - Residential | 7.92 | 7.86 | 7.14 | 6.18 | 6.03 |
| MF - Mid Rise | 8.94 | 9.05 | 7.78 | 5.73 | 6.53 |
| Movie Theater | 9.76 | 9.61 | 8.99 | 6.83 | 8.14 |
| Office - High Rise - CAV no econ | 10.84 | 11.01 | 10.03 | 6.72 | 7.32 |
| Office - High Rise - CAV econ | 11.21 | 11.44 | 10.52 | 7.25 | 7.98 |
| Office - High Rise - VAV econ | 8.20 | 8.36 | 6.89 | 4.07 | 4.54 |
| Office - High Rise - FCU | 6.00 | 5.91 | 5.11 | 2.71 | 2.84 |
| Office - Low Rise | 7.67 | 7.65 | 6.08 | 3.72 | 4.25 |
| Office - Mid Rise | 8.51 | 8.52 | 7.21 | 4.59 | 5.10 |
| Religious Building | 8.61 | 8.07 | 7.73 | 5.66 | 6.47 |
| Restaurant | 7.25 | 7.27 | 6.53 | 4.94 | 5.85 |
| Retail - Department Store | 7.47 | 6.86 | 6.44 | 4.19 | 4.78 |
| Retail - Strip Mall | 7.15 | 6.62 | 5.85 | 4.03 | 4.35 |
| Warehouse | 7.81 | 7.29 | 7.52 | 4.69 | 5.78 |
| Unknown | 8.34 | 8.26 | 7.35 | 5.27 | 6.11 |
| Hot Water with outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 21.38 | 21.06 | 19.07 | 17.06 | 17.61 |
| Hot Water without outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 27.05 | 26.64 | 24.13 | 21.58 | 22.28 |
| Hot Water with outdoor reset | All buildings, Recirculation year round (All hours) | 31.30 | 31.30 | 31.30 | 31.30 | 31.30 |
| Hot Water without outdoor reset | All buildings, Recirculation year round (All hours) | 47.02 | 47.02 | 47.02 | 47.02 | 47.02 |
| LP Steam – non-recirculation | Assembly | 15.01 | 15.38 | 13.73 | 9.15 | 14.02 |
| Assisted Living | 14.14 | 13.82 | 12.15 | 8.93 | 10.73 |
| College | 12.85 | 12.01 | 10.72 | 5.95 | 7.13 |
| Convenience Store | 12.44 | 11.49 | 10.20 | 7.32 | 8.17 |
| Elementary School | 14.96 | 14.58 | 12.86 | 8.88 | 10.78 |
| Garage | 8.27 | 8.14 | 7.15 | 5.71 | 6.32 |
| Grocery | 13.51 | 13.46 | 11.80 | 7.36 | 8.79 |
| Healthcare Clinic | 13.26 | 13.61 | 11.88 | 8.09 | 8.56 |
| High School | 15.50 | 15.60 | 13.99 | 9.97 | 11.66 |
| Hospital - CAV no econ | 14.82 | 15.27 | 13.01 | 11.19 | 12.70 |
| Hospital - CAV econ | 15.02 | 15.57 | 13.27 | 11.50 | 13.06 |
| Hospital - VAV econ | 6.14 | 5.84 | 4.39 | 2.64 | 2.85 |
| Hospital - FCU | 11.13 | 12.71 | 10.35 | 12.16 | 16.35 |
| Hotel/Motel | 14.80 | 14.38 | 12.97 | 8.87 | 10.84 |
| Hotel/Motel - Common | 13.45 | 13.66 | 13.00 | 10.58 | 11.12 |
| Hotel/Motel - Guest | 14.77 | 14.29 | 12.78 | 8.56 | 10.52 |
| Manufacturing Facility | 8.80 | 8.51 | 7.89 | 4.77 | 5.32 |
| MF - High Rise | 15.97 | 15.76 | 14.37 | 12.23 | 12.26 |
| MF - High Rise - Common | 18.99 | 18.44 | 16.53 | 11.39 | 14.71 |
| MF - High Rise - Residential | 15.43 | 15.31 | 13.92 | 12.05 | 11.75 |
| MF - Mid Rise | 17.43 | 17.63 | 15.17 | 11.16 | 12.72 |
| Movie Theater | 15.27 | 15.05 | 14.07 | 10.69 | 12.73 |
| Office - High Rise - CAV no econ | 16.97 | 17.22 | 15.70 | 10.51 | 11.45 |
| Office - High Rise - CAV econ | 17.55 | 17.91 | 16.47 | 11.35 | 12.49 |
| Office - High Rise - VAV econ | 12.83 | 13.09 | 10.79 | 6.37 | 7.11 |
| Office - High Rise - FCU | 9.40 | 9.26 | 8.00 | 4.25 | 4.45 |
| Office - Low Rise | 12.00 | 11.97 | 9.51 | 5.82 | 6.66 |
| Office - Mid Rise | 13.32 | 13.33 | 11.28 | 7.18 | 7.98 |
| Religious Building | 13.47 | 12.64 | 12.10 | 8.86 | 10.13 |
| Restaurant | 11.34 | 11.38 | 10.21 | 7.73 | 9.16 |
| Retail - Department Store | 11.69 | 10.74 | 10.08 | 6.56 | 7.48 |
| Retail - Strip Mall | 11.19 | 10.36 | 9.15 | 6.31 | 6.80 |
| Warehouse | 12.23 | 11.40 | 11.77 | 7.35 | 9.05 |
| 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[[396]](#footnote-403)** | **Straight Tee[[397]](#footnote-404)** |
| 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 (Loc)**

|  |  |  |
| --- | --- | --- |
| **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** | | | | |  | **Flanges** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Class (psi)** | **150** | **300** | **600** | **900** |  | **Class (psi)** | **150** | **300** | **600** | **900** |
| **NPS (in)** | **ft2** | **ft2** | **ft2** | **ft2** |  | **NPS (in)** | **ft2** | **ft2** | **ft2** | **ft2** |
| 1 | 0.69 | 1.8 | 1.8 | 2.4 |  | 1 | 0.36 | 0.36 | 0.4 | 1.23 |
| 2 | 2.21 | 2.94 | 2.94 | 5.2 |  | 2 | 0.71 | 0.84 | 0.88 | 1.54 |
| 2.5 | 2.97 | 3.51 | 3.91 | 6.6 |  |  |  |  |  |  |
| 3 | 3.37 | 4.39 | 4.69 | 6.5 |  | 3 | 1.06 | 1.32 | 1.36 | 1.85 |
| 4 | 4.68 | 6.06 | 7.64 | 9.37 |  | 4 | 1.44 | 1.83 | 2.23 | 2.64 |
| 6 | 7.03 | 9.71 | 13.03 | 15.8 |  | 6 | 2.04 | 2.72 | 3.6 | 4.37 |
| 8 | 10.3 | 13.5 | 18.4 | 23.8 |  | 8 | 2.92 | 3.74 | 4.89 | 6.4 |
| 10 | 13.8 | 18 | 26.5 | 32.1 |  | 10 | 3.68 | 4.8 | 6.93 | 8.47 |
| 12 | 16.1 | 24.1 | 31.9 | 41.9 |  | 12 | 5.01 | 6.34 | 7.97 | 10.43 |

**Equivalent Length of Other Components - Flanges and Valves (Loc)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ANSI Class (psi)** | **Equivalent Length of Other Components (ft)** | | | |
| **1” Valve** | **1” Flange** | **2” Valve** | **2” Flange** |
| 150 | 2.00 | 1.04 | 3.56 | 1.14 |
| 300 | 5.22 | 1.04 | 4.73 | 1.35 |
| 600 | 5.22 | 1.16 | 4.73 | 1.42 |
| 900 | 6.96 | 3.57 | 8.37 | 2.48 |
| **ANSI Class (psi)** | 3" Valve | 3" Flange | 4" Valve | 4" Flange |
| 150 | 3.67 | 1.16 | 3.98 | 1.22 |
| 300 | 4.79 | 1.44 | 5.15 | 1.56 |
| 600 | 5.11 | 1.48 | 6.49 | 1.90 |
| 900 | 7.09 | 2.02 | 7.96 | 2.24 |

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-PINS-V05-190101

###### Review Deadline: 1/1/2023

### Single-Package and Split System Unitary Air Conditioners

###### Description

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively-cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiency requirements can significantly reduce energy consumption. This measure could apply to the replacing of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

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

###### Definition of Efficient Equipment

The efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively-cooled air conditioner that exceeds the energy efficiency requirements as prescribed by the program.

###### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively-cooled air conditioner that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

For Early Replacement programs, use the actual efficiency of the existing unit or assume IECC code base in place at the original time of existing unit installation. To qualify under the early replacement characterization, baseline equipment must meet these additional qualifications:

* The existing unit is operational when replaced or the existing unit would be operational with minor repairs[[398]](#footnote-405).

Note: new Federal Standards become effective January 1, 2023

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[[399]](#footnote-406)

For early replacement, the remaining life of existing equipment is assumed to be 5 years[[400]](#footnote-407).

###### Deemed Measure Cost

The incremental capital cost for this measure is based upon capacity and efficiency level (defined be CEE specifications[[401]](#footnote-408)), as outlined in the following table:[[402]](#footnote-409)

|  | **Incremental cost ($/ton)** | |
| --- | --- | --- |
| **Capacity** | **Up to and including**  **CEE Tier 1 units** | **CEE Tier 2 and above** |
| < 135,000 Btu/hr | $63 | $127 |
| 135,000 Btu/hr to > 250,000 Btu/hr | $63 | $127 |
| 250,000 Btu/hr and greater | $19 | $38 |

For early replacement the full cost of the installed unit should be used. If unknown use defaults below. The assumed deferred cost (after 5 years) of replacing existing equipment with a new baseline unit is also provided. This future cost should be discounted to present value using the real discount rate:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **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.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[403]](#footnote-410)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[404]](#footnote-411)

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

Time of Sale:

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

ΔkWH = (kBtu/hr) \* [(1/SEERbase) – (1/SEERee)] \* EFLH

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

ΔkWH = (kBtu/hr) \* [(1/IEERbase) – (1/IEERee)] \* EFLH

Early replacement[[405]](#footnote-412):

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

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

ΔkWH = (kBtu/hr) \* [(1/SEERexist) – (1/SEERee)] \* EFLH

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) \* [(1/SEERbase) – (1/SEERee)] \* EFLH

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

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

ΔkWH = (kBtu/hr) \* [(1/IEERexist) – (1/IEERee)] \* EFLH

NOTE: If the existing equipment age is such that IEER ratings are not available, EER may be substitued when necessary. In such instances both existing and efficient unit efficiencies should be specified in EER.

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) \* [(1/IEERbase) – (1/IEERee)] \* EFLH

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr)

SEERbase = Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER values from tables below, based on applicable Code on date of equipment purchase (if unknown assume current Code).

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

SEERexist = Seasonal Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

IEERbase = Integrated Energy Efficiency Ratio of the baseline equipment. See table below based on applicable Code on date of equipment purchase (if unknown assume current Code).

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

IEERexist = Integrated Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

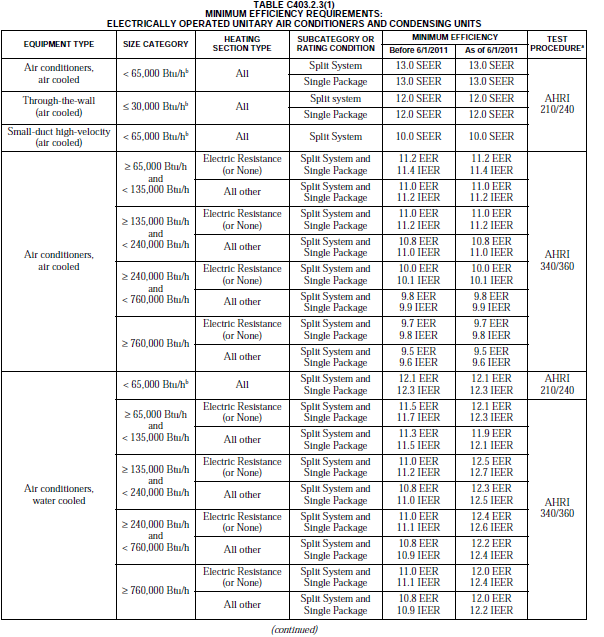
EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

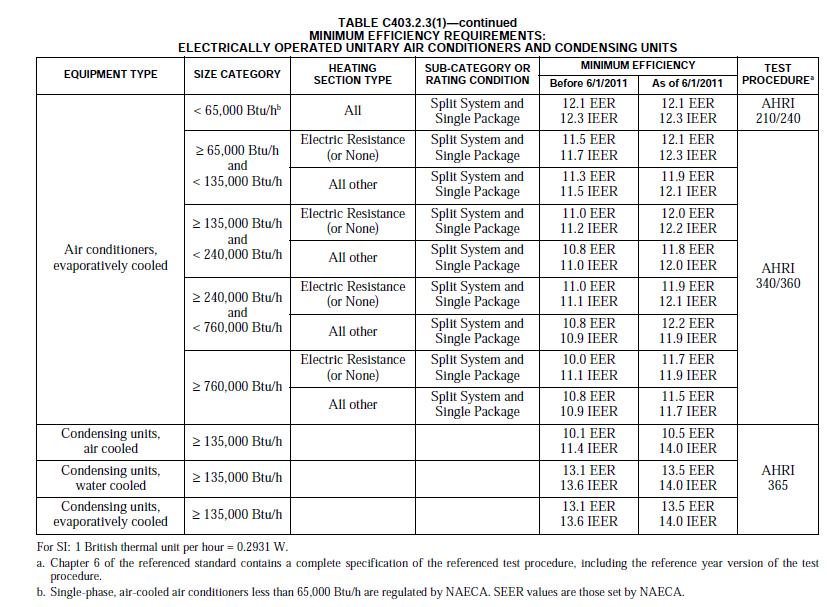
The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

**Code of Federal Redulations (baseline effective 1/1/2019):**

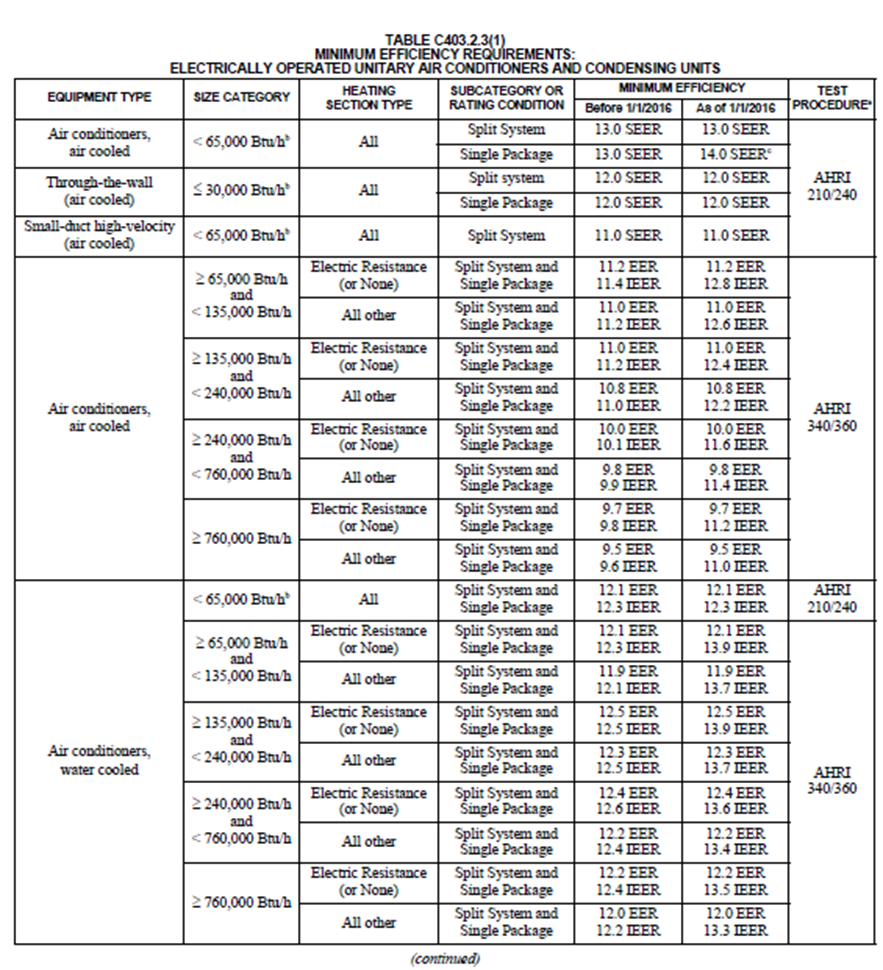
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment type** | **Cooling capacity** | **Heating type** | **Efficiency level** | **Compliance date** |
| Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥65,000 Btu/h and <135,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 12.9 | 1/1/2018 |
| All Other Types of Heating | IEER = 12.7 | 1/1/2018 |
| Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥135,000 Btu/h and <240,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 12.4 | 1/1/2018 |
| All Other Types of Heating | IEER = 12.2 | 1/1/2018 |
| Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥240,000 Btu/h and <760,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 11.6 | 1/1/2018 |
| All Other Types of Heating | IEER = 11.4 | 1/1/2018 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System) | <65,000 Btu/h | All | SEER = 13.0 | 6/16/2008 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package) | <65,000Btu/h | All | SEER = 14.0 | 1/1/2017 |

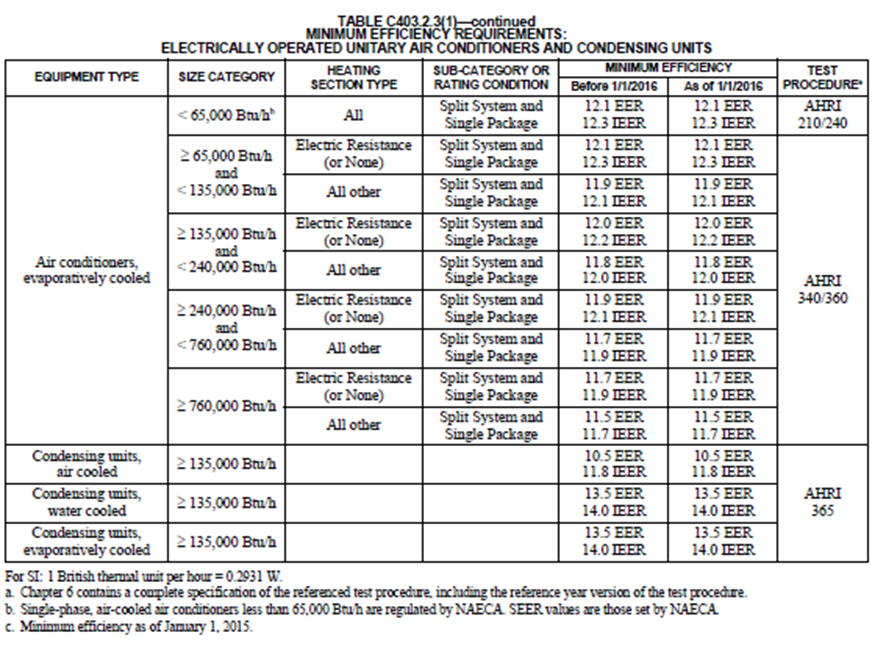
2012 IECC Minimum Efficiency Requirements





2015 IECC Minimum Efficiency Requirements





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 above, based on applicable Code on date of equipment purchase (if unknown assume current Code). (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[[406]](#footnote-413) EER = (-0.02 \* SEER2) + (1.12 \* SEER))

EERee = Energy Efficiency Ratio of the energy efficient equipment. If the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above).

= Actual installed

EERexist = Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[407]](#footnote-414)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[408]](#footnote-415)

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

ΔkWSSP = (60) \* [(1/11.2) – (1/12.3)] \* .913

= 0.437 kW

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Measure Code: CI-HVC-SPUA-V06-190101

###### Review Deadline: 1/1/2022

### 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[[409]](#footnote-416)

###### Deemed Measure Cost

| **Steam System** | **Cost per trap**[[410]](#footnote-417) **($)** |
| --- | --- |
| 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

###### 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 D² x A x FF

Where:

24.24 = Constant lb/(hr-psia-in2)

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%,[[411]](#footnote-418) all steam systems. This factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor).

FF = Flow Factor. In addition to the Adjustment factor (A), an additional 50 percent flow factor adjustment is recommended for medium and high pressure steam systems to address industrial float and thermostatic style traps where additional blockage is possible.

| **Steam System** | **Average Steam Trap Inlet Pressure psig**[[412]](#footnote-419) | **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**[[413]](#footnote-420) **(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 [[414]](#footnote-421)

= 64.8% for multifamily low-pressure steam boilers [[415]](#footnote-422)

Hours = Annual operating hours of steam plant

= custom, if unknown:

| **Steam System** | **Zone (where applicable)** | **Hours/Yr**[[416]](#footnote-423) |
| --- | --- | --- |
| 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[[417]](#footnote-424) | 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 (%)**[[418]](#footnote-425) |
| Custom | Custom |
| Commercial Dry Cleaners | 27% |
| Commercial Heating (including Multifamily) LPS | 27% |
| Industrial and Process Low Pressure ≤15 psig | 16% |
| Medium Pressure >15 psig < 30 psig | 16% |
| Medium Pressure ≥30 <75 psig | 16% |
| High Pressure ≥75 <125 psig | 16% |
| High Pressure ≥125 <175 psig | 16% |
| High Pressure ≥175 <250 psig | 16% |
| High Pressure > 300 psig | 16% |

EXAMPLE

For example, a commercial dry cleaning facility with the default hours of operation and boiler efficiency;

ΔTherms = Sa \* (Hv/B) \* Hours \* L

= 19.1 lbs/hr/trap \* (890 Btu/lb / 80%)/100,000 \* 2,425 \* 27%

= 138.8 therms per trap

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-STRE-V05-180101

###### Review Deadline: 1/1/2020

### 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;[[419]](#footnote-426) measure life for process is 10 years.[[420]](#footnote-427)

###### Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs[[421]](#footnote-428) 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 C42 - VFD - Boiler feedwater pumps <10 HP |
| Loadshape C43 - VFD - Chilled water pumps <10 HP |
| Loadshape C44 - VFD Boiler circulation pumps <10 HP |
| Loadshape C48 - VFD Boiler draft fans <10 HP |
| Loadshape C49 - VFD Cooling Tower Fans <10 HP |

###### Coincidence Factor

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = BHP /EFFi \* Hours \* ESF

Where:

BHP = System Brake Horsepower

(Nominal motor HP \* Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined[[422]](#footnote-429). 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.[[423]](#footnote-430)

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type[[424]](#footnote-431). When available, actual hours should be used.

| **Building Type** | **Heating Run Hours** | **Cooling Run Hours** | **Model Source** |
| --- | --- | --- | --- |
| Assembly | 4888 | 2150 | eQuest |
| Assisted Living | 4711 | 4373 | eQuest |
| College | 3990 | 1605 | eQuest |
| Convenience Store | 4136 | 2084 | eQuest |
| Elementary School | 5105 | 3276 | eQuest |
| Garage | 4849 | 2102 | eQuest |
| Grocery | 4200 | 2096 | eQuest |
| Healthcare Clinic | 5481 | 1987 | eQuest |
| High School | 5480 | 3141 | eQuest |
| Hospital - VAV econ | 3718 | 2788 | eQuest |
| Hospital - CAV econ | 7170 | 2881 | eQuest |
| Hospital - CAV no econ | 7139 | 8760 | eQuest |
| Hospital - FCU | 5844 | 8729 | eQuest |
| Manufacturing Facility | 3821 | 2805 | eQuest |
| MF - High Rise | 4522 | 4237 | eQuest |
| MF - Mid Rise | 5749 | 2899 | eQuest |
| Hotel/Motel - Guest | 4480 | 4479 | eQuest |
| Hotel/Motel - Common | 3292 | 8712 | eQuest |
| Movie Theater | 5063 | 2120 | eQuest |
| Office - High Rise - VAV econ | 4094 | 2038 | eQuest |
| Office - High Rise - CAV econ | 5361 | 4849 | eQuest |
| Office - High Rise - CAV no econ | 5331 | 5682 | eQuest |
| Office - High Rise - FCU | 3758 | 3069 | eQuest |
| Office - Low Rise | 3834 | 2481 | eQuest |
| Office - Mid Rise | 6155 | 3036 | OpenStudio |
| Religious Building | 5199 | 2830 | eQuest |
| Restaurant | 4579 | 3350 | eQuest |
| Retail - Department Store | 4249 | 2528 | eQuest |
| Retail - Strip Mall | 4475 | 2266 | eQuest |
| Warehouse | 4606 | 770 | eQuest |
| Unknown | 4649 | 2718 | n/a |

The type of hours to apply depends on the VFD application, according to the table below.

|  |  |
| --- | --- |
| Application | Hours Type |
| Hot Water Pump | Heating |
| Chilled Water Pump | Cooling |
| Cooling Tower Fan | Cooling |

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

| **Application** | **ESF** |
| --- | --- |
| Hot Water Pump | 0.424[[425]](#footnote-432) |
| Chilled Water Pump | 0.411[[426]](#footnote-433) |
| Cooling Tower Fan | 0.126[[427]](#footnote-434) |

###### Summer Coincident Peak Demand Savings

ΔkW =BHP/EFFi \* DSF

Where:

DSF = Demand Savings Factor varies by VFD application.[[428]](#footnote-435) Units are kW/HP. Values listed below are based on typical peak load for the listed application.

| **Application** | **DSF** |
| --- | --- |
| Hot Water Pump | 0 |
| Chilled Water Pump | 0.299 |
| Cooling Tower Fan | 0.378 |

###### Fossil Fuel Impact Descriptions and Calculation

There are no expected fossil fuel impacts for this measure.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-VSDHP-V04-180101

###### Review Deadline: 1/1/2021

### 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[[429]](#footnote-436) based upon equipment life only[[430]](#footnote-437). 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[[431]](#footnote-438). 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

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings[[432]](#footnote-439)

∆kWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] \* Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Electric Energy Use Equations (kWh / ton)**

| **Building Type** | **Fan Mode During Occupied Period (*Fo*)** | **Equation** |
| --- | --- | --- |
| **Assembly** | Continuous | ***CZ***+***Fu***\*(0.83\****Tc***+0.83\****Th***+1.67\****Ws***-293.018)-0.0922\****Tc***\****Th***+1.291\****Ws*** |
| Intermittent | ***CZ***+***Fu***\*(1.911-0.12\****Tc***)+***Tc***\*(0.00311\****Ws***-0.229)+0.11\****Ws*** |
| **Convenience Store** | Continuous | ***CZ***+***Fu***\*(-28.629\****Tc***-11.69\****Th***+19.118\****Ws***-2935.12)+0.909\****Ws*** |
| Intermittent | ***CZ***+***Tc***\*(0.0863\****Ws***-12.688)+***Th***\*(0.043\****Ws***-6.38)+1.669\****Ws*** |
| **Office – Low Rise** | Continuous | ***CZ***+***Fu***\*(7.082\****Tc***-41.199\****Th***+18.734\****Ws***-3288.55)+***Tc***\*(0.205\****Ws***-34.929) |
| Intermittent | ***CZ***+***Tc***\*(0.0806\****Ws***-8.984)+***Th***\*(0.0864\****Ws***-9.558)+1.178\****Ws*** |
| **Religious** | Continuous | ***CZ***+***Fu***\*(-1.579\****Tc***-18.14\****Th***+15.01\****Ws***-2417.74)+***Tc***\*(0.177\****Ws***-26.412) |
| Intermittent | ***CZ***+***Fu***\*(0.266\****Tc***-2.067)+***Tc***\*(0.0295\****Ws***-4.502)+***Th***\*(0.0517\****Ws***-8.251)+0.735\****Ws*** |
| **Restaurant –**  **Fast Food** | Continuous | ***CZ***+***Fu***\*(0.678\****Tc***+0.257\****Th***+2.88\****Ws***-494.006)+***Tc***\*(0.0231\****Ws***-4.074)+***Th***\*(0.00936\****Ws***-1.655)+0.918\****Ws*** |
| Intermittent | ***CZ***+***Fu***\*(0.377\****Tc***+0.124\****Th***+0.13\****Ws***-24.893)+***Tc***\*(-0.0143\****Th***+0.0166\****Ws***-2.691)+0.898\****Ws*** |
| **Restaurant –**  **Full Service** | Continuous | ***CZ***+***Fu***\*(-8.41\****Th***+11.766\****Ws***-1910.81)+***Tc***\*(0.282\****Ws***-43.851) |
| Intermittent | ***CZ***+0.123\****Fu***\****Tc***+***Tc***\*(0.0561\****Ws***-8.237)+***Th***\*(0.0219\****Ws***-3.284)+1.038\****Ws*** |
| **Retail – Department Store** | Continuous | ***CZ***+***Fu***\*(-1.475\****Th***+0.755\****Ws***-114.373)+***Th***\*(0.151\****Ws***-24.016)+1.612\****Ws*** |
| Intermittent | ***CZ***+***Tc***\*(0.0173\****Ws***-1.912)+***Th***\*(0.0249\****Ws***-3.29)+0.511\****Ws*** |
| **Retail – Strip Mall** | Continuous | ***CZ***+***Fu***\*(1.077\****Tc***-10.697\****Th***+6.91\****Ws***-1117.18)+***Tc***\*(0.0583\****Ws***-7.54)+1.231\****Ws*** |
| Intermittent | ***CZ***+0.0894\****Fu***\****Tc***+***Th***\*(-0.0142\****Tc***+0.04\****Ws***-5.278)+0.884\****Ws*** |

Where:

CZ = Climate Zone Coefficient

=Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Fu = Fan Mode During Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Ws = Weekly Hours thermostat is in Occupied mode

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)

(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

**Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| **Building Type** | **Fan Mode During Occupied Period (*Fo*)** | **Climate Zone Coefficient (*CZ*)**[[433]](#footnote-440) | | | | | **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 |

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.

∆kWh = [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

∆kWh = [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

∆Therms = [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*** |
| **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*)** | | | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **Minimum *Ws*** |
| **Assembly** | Continuous | 19.872 | 17.83 | 15.828 | 15.282 | 13.482 | 98 |
| Intermittent | 0.237 | 0.0989 | 0.0267 | -0.0131 | -0.0871 |
| **Convenience Store** | Continuous | 1.493 | 1.081 | 0.782 | 0.544 | 0.114 | 108 |
| Intermittent | 1.128 | 0.854 | 0.619 | 0.437 | 0.0854 |
| **Office - Low Rise** | Continuous | 1.718 | 1.317 | 0.971 | 0.739 | 0.319 | 55 |
| Intermittent | 3.447 | 3.022 | 2.503 | 2.251 | 1.646 |
| **Religious Facility** | Continuous | 6.294 | 5.55 | 4.678 | 4.202 | 3.122 | 133 |
| Intermittent | 5.914 | 5.368 | 4.557 | 4.137 | 3.246 |
| **Restaurant – Fast Food** | Continuous | 8.383 | 7.211 | 6.034 | 5.767 | 4.71 | 108 |
| Intermittent | 1.227 | 0.636 | 0.302 | 0.102 | -0.262 |
| **Restaurant – Full Service** | Continuous | 5.247 | 4.484 | 3.753 | 3.465 | 2.627 | 117 |
| Intermittent | 0.951 | 0.704 | 0.51 | 0.381 | 0.0746 |
| **Retail – Department Store** | Continuous | 4.385 | 3.854 | 3.192 | 2.784 | 1.858 | 93 |
| Intermittent | 3.061 | 2.672 | 2.182 | 1.829 | 1.008 |
| **Retail – Strip Mall** | Continuous | 3.917 | 3.394 | 2.728 | 2.394 | 1.617 | 93 |
| Intermittent | 2.659 | 2.292 | 1.811 | 1.543 | 0.909 |

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-PROG-V02-180101

###### Review Deadline: 1/1/2022

### Demand Controlled Ventilation

###### Description

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO2) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

Demand controlled ventilation controls can also be added to the exhaust fans to enclosed parking garages. The fans modulate the ventilation airflow based on pollutant concentrations (primarily carbon monoxide) in the space.

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

###### Definition of Efficient Equipment

The efficient equipment condition is defined by new CO2 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. [[434]](#footnote-441)

###### Deemed Measure Cost

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost ($500) and installation ($1000 labor) for a total of $1500[[435]](#footnote-442).

Adding demand controlled ventilation to parking garages is assumed to cost $500 per sensor including the cost of the controller. The installation cost is estimated at $1,000 for labor[[436]](#footnote-443).

###### Loadshape

Commercial ventilation C23

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

For facilities heated by natural gas,

∆kWh = Condition Space/1000 \* SFcooling

For facilities heated by heat pumps,

∆kWh = Condition Space/1000 \* SFcooling+ Condition Space/1000 \* SFHeat HP

For facilities heated by electric resistance,

∆kWh = Condition Space/1000 \* SFcooling+ Condition Space/1000 \* SFHeat ER

Where:

Conditioned Space = actual square footage of conditioned space controlled by sensor

SFcooling = Cooling Savings Factor

= value in table below based on building type and weather zone

SFHeat HP = Heating Savings factor for facilities heated by Heat Pump (HP)

= value in table below based on building type and weather zone

SFHeat ER = Heating Savings factor for facilities heated by Electric Resistance (ER)

= value in table below based on building type and weather zone

Saving Factor Tables[[437]](#footnote-444)

| **Building Type** | **SFcooling (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 |
| Manufacturing | 481 | 482 | 482 | 477 | 482 |
| Special Assembly Auditorium | 410 | 427 | 479 | 494 | 514 |
| Default (non-garage) | 451 | 458 | 475 | 482 | 490 |
| Enclosed Parking Garage[[438]](#footnote-445) | 925 | 925 | 925 | 925 | 925 |

| **Building Type** | **SF Heat HP (kWh/1000 SqFt)** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Office - Low-rise | 234 | 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

∆therms = Condition Space/1000 \* SF Heat Gas

Where:

SF Heat Gas = value in table below based on building type and weather zone[[439]](#footnote-446)

| **Building Type** | **SFHeat Gas (Therm/1000 sq ft)** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Zone 1**  **(Rockford)** | **Zone 2**  **(Chicago)** | **Zone 3**  **(Springfield)** | **Zone 4**  **(Belleville)** | **Zone 5**  **(Marion)** |
| Office - Low-rise | 30 | 26 | 23 | 22 | 19 |
| Office - Mid-rise | 20 | 17 | 15 | 15 | 13 |
| Office- High-rise | 27 | 23 | 21 | 20 | 17 |
| Religious BuiIding | 191 | 169 | 150 | 143 | 128 |
| Restaurant | 135 | 122 | 106 | 104 | 91 |
| RetaiI - 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

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure code: CI-HVC-DCV-V05-190101

###### Review Deadline: 1/1/2024

### High Turndown Burner for Space Heating Boilers

###### Description

This measure is for a non-residential boilers equipped with linkageless controls providing space heating with burners having a turndown less than 6:1.[[440]](#footnote-447) Turndown is the ratio of the high firing rate to the low firing rate. When boilers are subjected to loads below the low firing rate, the boiler must cycle on/off to meet the load requirements. A higher turndown ratio reduces burner startups, provides better load control, saves wear-and-tear on the burner, and reduces purge-air requirements, all of these benefits result in better overall efficiency.

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

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

###### Definition of Efficient Equipment

To qualify the boiler linkageless burner must operate with a turndown greater than or equal to 10:1 and be subjected to loads less than or equal to 30%[[441]](#footnote-448) of the full fire input MBH for greater than 60%[[442]](#footnote-449) of the operating hours.

###### Definition of Baseline Equipment

The baseline boiler utilizes a linkageless burner with a turndown ration of 6:1 or less and is used primarily for space heating. Redundant boilers do not qualify.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 21 years.[[443]](#footnote-450)

###### Deemed Measure Cost

The deemed installed measure cost including labor is approximately $2.53/MBtu/hr.[[444]](#footnote-451)

###### Deemed O&M Cost Adjustments

N/A

###### 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 = Ngi \* SF \* EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings Factor = Percentage of energy loss per hour

= (∑ ((EL\_base – EL\_eff) \* H\_cycling)) / H)\*100

Where:

EL\_base = Base Boiler Percentage of energy loss due to cycling at % of Base Boiler Load where BL\_base ≤ TDR\_base

= 0.003 \* (Cycles\_base)2 – 0.001 \* Cycles\_base [[445]](#footnote-452)

Where:

Cycles\_base = Number of Cycles/hour of base boiler

= TDR\_base / BL

Where:

BL = % of full boiler load at bin hours being evaluated. This is assumed to be a straight line based on 0% load at the building balance point (assumed to be 55F), and full load corrected for the oversizing (OSF) at the lowest temperature bin of -10 to -5F.

OSF = Oversizing Factor = 1.3[[446]](#footnote-453) or custom

TDR\_base = Turndown ratio = 0.33[[447]](#footnote-454) or custom

EL\_eff = Efficient Boiler Percentage of energy loss due to cycling at % of Efficient Boiler Load

= 0.003 \* (Cycles\_eff)2 – 0.001 \* Cycles\_eff

Where:

Cycles\_eff = Number of Cycles/hour

= TDR\_eff / BL

Where:

TDR\_eff = Turndown ratio = 0.10[[448]](#footnote-455) 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)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temp**erature** | 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

### Linkageless Boiler Controls for Space Heating

###### Description

This measure is for a non-residential boiler providing space heating and currently having single point positioning combustion control. In single-point positioning control, the fuel valve is linked to the combustion air damper via a jackshaft mechanism to maintain correspondence between fuel and combustion air input. Most boilers with single point positioning control do not maintain low excess air levels over their entire firing range. Generally these boilers are calibrated at high fire, but due to the non-linearity required for efficient combustion, excess air levels tend to dramatically increase as the firing rate decreases. Boiler efficiency drops as the excess air levels are increased.

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

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

###### Definition of Efficient Equipment

To qualify the boiler burner must have a linkageless control system allowing the combustion air damper position to be adjusted and set for optimal efficiency at several firing rates throughout the burner’s firing range. This requires the fuel valve and combustion air damper to each be powered by a separate actuator. An alternative to the combustion air damper is a Variable Speed Drive on the combustion air fan.

###### Definition of Baseline Equipment

The baseline boiler utilizes single point positioning for the burner combustion control.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[[449]](#footnote-456)

###### Deemed Measure Cost

The deemed measure cost is estimated at $2.50/MBtu/hr burner input.[[450]](#footnote-457)

###### 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.

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

ΔTherms = Ngi \* SF \* EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings factor

Note: Savings factor is the percentage increase in efficiency as a result of the addition of linkageless burner controls. At an average boiler load of 35%, single point controls are assumed to have excess air of 91%, while linkageless controls are assumed to have 34% excess air.[[451]](#footnote-458) The difference between controls types is 57% at this average operating condition. A 15% reduction in excess air is approximately a 1% increase in efficiency.[[452]](#footnote-459) 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

### Oxygen Trim Controls for Space Heating Boilers

###### Description

This measure is for a non-residential boiler providing space heating without oxygen trim combustion controls. Oxygen trim controls limit the amount of excess oxygen provided to the burner for combustion. This oxygen level is dependent upon the amount of air provided. Oxygen trim control converts parallel positioning, linkageless controls, into a closed-loop control configuration with the addition of an exhaust gas analyzer and PID controller. Boilers with oxygen trim controls can maintain a predetermined excess air rate (generally 15% to 30% excess air) over the entire burner firing rate. Boilers without these controls typically have excess air rates around 30% over the entire firing rate. Boiler efficiency drops as the excess air levels are increased.

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

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

###### Definition of Efficient Equipment

To qualify the boiler burner must have an oxygen control system allowing the combustion air to be adjusted to maintain a predetermined excess oxygen level in the flue exhaust at all firing rates throughout the burner’s firing range. This requires an oxygen sensor in the flue exhaust and linkageless fuel valve and combustion air controls.

###### Definition of Baseline Equipment

The baseline boiler utilizes single point positioning for the burner combustion control.

###### Deemed Lifetime of Efficient Equipment

The measure life for the O2 Trim controls is 18 years.[[453]](#footnote-460)

###### Deemed Measure Cost

The deemed measure cost is approximately $23,250.[[454]](#footnote-461)

###### 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

ΔTherms = Ngi \* SF \* EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

Note: Savings factor is the percentage reduction in gas consumption as a result of the addition of O2 trim controls. Linkageless controls have an excess air rate of 28% over the entire firing range.[[455]](#footnote-462) O2 trim controls have an excess air rate of 15%.[[456]](#footnote-463) The average difference is 13%. A 15% reduction in excess air is approximately a 1% increase in efficiency.[[457]](#footnote-464) Therefore the nominal combustion efficiency increase is 13 / 15 \* 1% = 0.87%.

= 0.87%

EFLH = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

The deemed annual Operations and Maintenance cost is $800.[[458]](#footnote-465)

###### Measure Code: CI-HVC-O2TC-V01-140601

###### Review Deadline: 1/1/2022

### Shut Off Damper for Space Heating Boilers or Furnaces

###### Description

This measure is for non-residential atmospheric boilers or furnaces providing space heating without a shut off damper. When appliances are on standby mode warm room air is drawn through the stack via the draft hood or dilution air inlet at a rate proportional to the stack height, diameter and outdoor temperature. More air is drawn through the vent immediately after the appliance shuts off and the flue is still hot. Installation of a new shut off damper can prevent heat from being drawn up the warm vent and reducing the amount of air that passes through the furnace or boiler heat exchanger. This reduction in air can slightly increase overall operating efficiency by reducing the time needed to achieve steady-state operating conditions.

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

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

###### Definition of Efficient Equipment

To qualify the space heating boiler or furnace must have a new electrically or thermally activated shut off damper installed on either the exhaust flue or combustion air intake. Barometric dampers do not qualify. The damper actuation shall be interlocked with the firing controls.

###### Definition of Baseline Equipment

The baseline boiler or furnace incorporates no shut off damper on the combustion air intake or flue exhaust.

###### Deemed Lifetime of Efficient Equipment

The measure life for the shut off damper is 15 years.[[459]](#footnote-466)

###### Deemed Measure Cost

The deemed measure cost for this approximately $1,500.[[460]](#footnote-467)

###### 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

ΔTherms = Ngi \* SF \* EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%[[461]](#footnote-468)

Note: The savings factor assumes the boiler or furnace is located in an unconditioned space. The savings factor can be higher for those units located within conditioned space.

EFLH = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

The deemed annual Operations and Maintenance cost is $112.[[462]](#footnote-469)

###### Measure Code: CI-HVC-SODP-V01-140601

###### Review Deadline: 1/1/2020

### Small Pipe Insulation

###### Description

This measure provides rebates for adding insulation to bare pipes with inner diameters of ½” and ¾”. Insulation must be at least one inch thick. Since new construction projects are required by code to have pipe insulation, this measure is only for retrofits of existing facilities. This covers bare straight pipe as well as all fittings.

Default savings are provided on a per linear foot basis. It is assumed that the majority of pipes less than one inch in commercial facilities are used for domestic hot water. However, this measure can cover hydronic heating systems as well as low and high pressure steam systems.

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

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

###### Definition of Efficient Equipment

The efficient case is a ½“or ¾“ diameter pipe with at least one inch of insulation. Insulation must be protected from damage which includes moisture, sunlight, equipment maintenance and wind. Outdoor pipes should have a weather protective jacket. Insulation must be continuous over straight pipe, elbows and tees.

###### Definition of Baseline Equipment

The base case for savings estimates is a bare hot water or steam pipe with a fluid temperature of 105 degrees Fahrenheit or greater. Current new construction code requires insulation amounts similar to this measure though this base case is commonly found in older existing buildings.

###### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years.[[463]](#footnote-470)

###### Deemed Measure Cost

The incremental measure cost for insulation is the full cost of adding insulation to the pipe. Actual installation costs should be used for the measure cost. For planning purposes, the following costs can be used to estimate the full cost of materials and labor.[[464]](#footnote-471)

|  |  |  |
| --- | --- | --- |
| **Insulation Thickness** | **¾” pipe** | **½” pipe** |
| 1” | $4.45 | $4.15 |

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

ΔTherms per foot[[465]](#footnote-472) = [((Qbase – Qeff) \* EFLH) / (100,000 \* ηBoiler)] \* TRF

= [Modeled or provided by tables below] \* TRF

ΔTherms = (Lsp + Loc,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 |

Qbase = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

Qeff = Heat Loss from Insulated Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000 = conversion factor (1 therm = 100,000 Btu)

ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe

= 81.9% for water boilers [[466]](#footnote-473)

= 80.7% for steam boilers, except multifamily low-pressure [[467]](#footnote-474)

= 64.8% for multifamily low-pressure steam boilers [[468]](#footnote-475)

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [[469]](#footnote-476)

= See table below for base TRF values by pipe location

May vary seasonally such as: TRF[summer] \* summer hours + TRF[winter] \* winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.[[470]](#footnote-477)

|  |  |  |
| --- | --- | --- |
| **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 |

Lsp = Length of straight pipe to be insulated (linear foot)

Loc,i = Total equivalent length of (elbows and tees) of pipe to be insulated. Use table below to determine equivalent lengths.

|  |  |  |
| --- | --- | --- |
| **Nominal Pipe Diameter** | **Equivalent Length (ft)** | |
| **90 Degree Elbow** | **Straight Tee** |
|
| 1/2" | 0.04 | 0.03 |
| 3/4" | 0.06 | 0.05 |

The table below shows the deemed therm savings by building type and region on a per linear foot basis for both ½” and ¾” copper pipe.

The following table provides deemed values for 1/2" copper pipe, temperatures are assumed by category below, and insulation is assumed to be one inch fiberglass.

| **Piping Use** | **Building Type** | **Annual Therms Saved / Linear Foot** | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Space Heating 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 |
| 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

### Small Commercial Programmable Thermostat Adjustments

###### Description

This measure involves reprogramming existing commercial programmable thermostats or building automation systems for reduced energy consumption through adjustments of unoccupied heating/cooling setpoints and/or fan control. This measure is limited to packaged HVAC units that are controlled by a commercial thermostat or building automation system. The measure is limited to select building types presented below.

**Eligible Small Commercial Building Types**

|  |
| --- |
| **Building Type** |
| Assembly |
| Convenience Store |
| Office - Low Rise |
| Restaurant - Fast Food |
| Religious Facility |
| Restaurant - Full Service |
| Retail - Strip Mall |
| Retail - Department Store |

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

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

###### Definition of Efficient Equipment

The criteria for this measure is established by optimizing heating/cooling temperature setbacks and fan operation with a commercial programmable thermostat or building automation system, which reprogrammed to match actual facility occupancy.

###### Definition of Baseline Equipment

The baseline for this measure is a commercial programmable thermostat or building automation system that is currently operating packaged HVAC units with heating/cooling temperature setbacks and fan operation that do not align with a facilities actual occupancy.

###### Deemed Lifetime of Efficient Equipment

The expected measure life of a programmable thermostat is assumed to be 8 years[[471]](#footnote-478). For the purposes of claiming savings for a adjustment of an existing programmable thermostat, this is reduced to a 25% persistence factor to give a final measure life of 2 years. It is recommended that this assumption be evaluated by future energy measurement and verification activities.

###### Deemed Measure Cost

Actual labor costs should be used if the implementation method allows. If unknown the labor cost for this measure is assumed to be $70.34[[472]](#footnote-480) per thermostat, as summarized in the table below.

| **Measure** | **Units** | **Materials** | **Labor** | **Total Cost (including O&P)** | **City Cost Index (Install Only)\*** | **Total** | **Source** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Adjust Temperature Set Points | 4 | $0.00 | $5.95 | $6.55 | 134.5% | $35.24 | RS Means 2010 (pg 255, Section 23-09-8100) |
| Adjust Fan Schedule | 2 | $0.00 | $11.86 | $13.05 | 134.5% | $35.10 | RS Means 2010 (pg 255, Section 23-09-8120) |
| **Totals** |  |  |  |  |  | **$70.34** |  |
| \* Chicago, IL - Division 23 | |  |  |  |  |  |  |

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings[[473]](#footnote-481)

∆kWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] \* Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Electric Energy Use Equations (kWh / ton)**

| **Building Type** | **Fan Mode During Occupied Period (*Fo*)** | **Equation** |
| --- | --- | --- |
| **Assembly** | Continuous | ***CZ***+***Fu***\*(0.83\****Tc***+0.83\****Th***+1.67\****Ws***-293.018)-0.0922\****Tc***\****Th***+1.291\****Ws*** |
| Intermittent | ***CZ***+***Fu***\*(1.911-0.12\****Tc***)+***Tc***\*(0.00311\****Ws***-0.229)+0.11\****Ws*** |
| **Convenience Store** | Continuous | ***CZ***+***Fu***\*(-28.629\****Tc***-11.69\****Th***+19.118\****Ws***-2935.12)+0.909\****Ws*** |
| Intermittent | ***CZ***+***Tc***\*(0.0863\****Ws***-12.688)+***Th***\*(0.043\****Ws***-6.38)+1.669\****Ws*** |
| **Office – Low Rise** | Continuous | ***CZ***+***Fu***\*(7.082\****Tc***-41.199\****Th***+18.734\****Ws***-3288.55)+***Tc***\*(0.205\****Ws***-34.929) |
| Intermittent | ***CZ***+***Tc***\*(0.0806\****Ws***-8.984)+***Th***\*(0.0864\****Ws***-9.558)+1.178\****Ws*** |
| **Religious** | Continuous | ***CZ***+***Fu***\*(-1.579\****Tc***-18.14\****Th***+15.01\****Ws***-2417.74)+***Tc***\*(0.177\****Ws***-26.412) |
| Intermittent | ***CZ***+***Fu***\*(0.266\****Tc***-2.067)+***Tc***\*(0.0295\****Ws***-4.502)+***Th***\*(0.0517\****Ws***-8.251)+0.735\****Ws*** |
| **Restaurant –**  **Fast Food** | Continuous | ***CZ***+***Fu***\*(0.678\****Tc***+0.257\****Th***+2.88\****Ws***-494.006)+***Tc***\*(0.0231\****Ws***-4.074)+***Th***\*(0.00936\****Ws***-1.655)+0.918\****Ws*** |
| Intermittent | ***CZ***+***Fu***\*(0.377\****Tc***+0.124\****Th***+0.13\****Ws***-24.893)+***Tc***\*(-0.0143\****Th***+0.0166\****Ws***-2.691)+0.898\****Ws*** |
| **Restaurant –**  **Sit Down** | Continuous | ***CZ***+***Fu***\*(-8.41\****Th***+11.766\****Ws***-1910.81)+***Tc***\*(0.282\****Ws***-43.851) |
| Intermittent | ***CZ***+0.123\****Fu***\****Tc***+***Tc***\*(0.0561\****Ws***-8.237)+***Th***\*(0.0219\****Ws***-3.284)+1.038\****Ws*** |
| **Retail – Large** | Continuous | ***CZ***+***Fu***\*(-1.475\****Th***+0.755\****Ws***-114.373)+***Th***\*(0.151\****Ws***-24.016)+1.612\****Ws*** |
| Intermittent | ***CZ***+***Tc***\*(0.0173\****Ws***-1.912)+***Th***\*(0.0249\****Ws***-3.29)+0.511\****Ws*** |
| **Retail – Strip Mall** | Continuous | ***CZ***+***Fu***\*(1.077\****Tc***-10.697\****Th***+6.91\****Ws***-1117.18)+***Tc***\*(0.0583\****Ws***-7.54)+1.231\****Ws*** |
| Intermittent | ***CZ***+0.0894\****Fu***\****Tc***+***Th***\*(-0.0142\****Tc***+0.04\****Ws***-5.278)+0.884\****Ws*** |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Fu = Fan Mode during Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Ws = Weekly Hours thermostat is in Occupied mode,

= Minimum values depend on Building Type (see table below), maximum value of 168 (24/7)  
 ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59

**Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| **Building Type** | **Fan Mode During Occupied Period (*Fo*)** | **Climate Zone Coefficient (*CZ*)** | | | | | **Minimum *Ws*** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** |
| **Assembly** | Continuous | 911.366 | 928.924 | 1152.83 | 1208.999 | 1210.173 | 98 |
| Intermittent | 735.752 | 762.831 | 966.562 | 998.927 | 1028.906 |
| **Convenience Store** | Continuous | 4817.094 | 4832.784 | 5139.133 | 5182.161 | 5208.608 | 108 |
| Intermittent | 1478.133 | 1514.568 | 1784.384 | 1843.463 | 1930.47 |
| **Office - Low Rise** | Continuous | 5047.662 | 5039.592 | 5187.924 | 5217.672 | 5177.449 | 55 |
| Intermittent | 825.072 | 808.965 | 946.571 | 979.421 | 945.418 |
| **Religious Facility** | Continuous | 4197.117 | 4172.858 | 4380.025 | 4370.008 | 4356.054 | 133 |
| Intermittent | 632.404 | 603.395 | 678.294 | 664.717 | 616.853 |
| **Restaurant – Fast Food** | Continuous | 1342.988 | 1378.661 | 1664.018 | 1714.201 | 1727.841 | 108 |
| Intermittent | 993.764 | 1039.643 | 1307.8 | 1340.544 | 1389.791 |
| **Restaurant – Full Service** | Continuous | 4070.35 | 4094.742 | 4428.966 | 4501.829 | 4522.522 | 117 |
| Intermittent | 1472.014 | 1516.05 | 1856.108 | 1938.441 | 2056.45 |
| **Retail – Department Store** | Continuous | 1510.201 | 1496.47 | 1706.105 | 1716.128 | 1688.464 | 93 |
| Intermittent | 701.27 | 702.129 | 847.735 | 875.12 | 881.677 |
| **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.

∆kWh = [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

∆kWh = [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

∆Therms = [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.

∆Therms = [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

∆Therms = [2.17495 (Therms/kBtuh output) – 2.07895 (Therms/kBtuh output)] \* 150kBtuh output

= 0.096 (Therms/kBtuh output) \* 150kBtuh output

= 14.4 Thermsrr

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-PRGA-V03-190101

###### Review Deadline: 1/1/2022

### 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;[[474]](#footnote-482) measure life for process is 10 years.[[475]](#footnote-483)

###### Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs**[[476]](#footnote-484)** are noted below for up to 75 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

| **HP** | **Cost** |
| --- | --- |
| 5 HP | $ 2,250 |
| 15 HP | $ 3,318 |
| 25 HP | $ 4,386 |
| 50 HP | $ 6,573 |
| 75 HP | $ 8,532 |

###### Loadshape

|  |
| --- |
| Loadshape C39 - VFD - Supply fans <10 HP |
| Loadshape C40 - VFD - Return fans <10 HP |
| Loadshape C41 - VFD - Exhaust fans <10 HP |

###### Coincidence Factor

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings[[477]](#footnote-485)

|  |  |
| --- | --- |
| kWhBase = |  |
| kWhRetrofit = |  |
| ∆kWhfan = |  |
| ∆kWhtotal = |  |

Where:

= Baseline annual energy consumption (kWh/yr)

= Retrofit annual energy consumption (kWh/yr)

= Fan-only annual energy savings

= Total project annual energy savings

= Conversion factor for HP to kWh

= Nominal horsepower of controlled motor

= Load Factor; Motor Load at Fan Design CFM (Default = 65%)[[478]](#footnote-486)

= Installed nominal/nameplate motor efficiency

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

**NEMA Premium Efficiency Motors Default Efficiencies[[479]](#footnote-487)**

| **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 |

= Annual operating hours for fan motor based on building type

Default hours are provided for HVAC applications which vary by HVAC application and building type[[480]](#footnote-488). When available, actual hours should be used.

| **Building Type** | **Total Fan Run Hours** | **Model Source** |
| --- | --- | --- |
| Assembly | 7235 | eQuest |
| Assisted Living | 8760 | eQuest |
| College | 6103 | eQuest |
| Convenience Store | 7004 | eQuest |
| Elementary School | 7522 | eQuest |
| Garage | 7357 | eQuest |
| Grocery | 7403 | eQuest |
| Healthcare Clinic | 6345 | eQuest |
| High School | 7879 | eQuest |
| Hospital - VAV econ | 8760 | eQuest |
| Hospital - CAV econ | 8760 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |
| Hospital - FCU | 8760 | eQuest |
| Manufacturing Facility | 8706 | eQuest |
| MF - High Rise | 8760 | eQuest |
| MF - Mid Rise | 8760 | eQuest |
| Hotel/Motel - Guest | 8760 | eQuest |
| Hotel/Motel - Common | 8760 | eQuest |
| Movie Theater | 7505 | eQuest |
| Office - High Rise - VAV econ | 6064 | eQuest |
| Office - High Rise - CAV econ | 5697 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 6163 | eQuest |
| Office - Low Rise | 6288 | eQuest |
| Office - Mid Rise | 6856 | OpenStudio |
| Religious Building | 7380 | eQuest |
| Restaurant | 7809 | eQuest |
| Retail - Department Store | 7155 | OpenStudio |
| Retail - Strip Mall | 6846 | eQuest |
| Warehouse | 6832 | OpenStudio |
| Unknown | 7100 | n/a |

= 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% |

= Part load ratio for a given flow fraction range based on the baseline flow control type

= 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** |  |
| --- | --- |
| 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 |

= HVAC interactive effects factor for energy (default = 15.7%)

###### Summer Coincident Peak Demand Savings

|  |  |
| --- | --- |
| kWBase = |  |
| kWRetrofit = |  |
| ∆kWfan = |  |
| ∆kWtotal = |  |

Where:

= Baseline summer coincident peak demand (kW)

= Retrofit summer coincident peak demand (kW)

= Fan-only summer coincident peak demand impact

= Total project summer coincident peak demand impact

= 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%)

= 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%)

= HVAC interactive effects factor for summer coincident peak demand  
 (default = 15.7%)

###### Fossil Fuel Impact Descriptions and Calculation

There are no expected fossil fuel impacts for this measure.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-VSDF-V03-190101

###### Review Deadline: 1/1/2022

### 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.[[481]](#footnote-489)

###### 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[[482]](#footnote-490)** |
| 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

**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[[483]](#footnote-491)

= (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[[484]](#footnote-492)

= (see Table below) or custom

| **Heat Recovery Equipment Type** | **TE\_ERV (%)** |
| --- | --- |
| Fixed Plate | 0.65 |
| Rotary Equipment | 0.68 |
| Heat Pipe | 0.55 |

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

OccHour s = 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

### 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.[[485]](#footnote-493)

###### Deemed Measure Cost

The incremental and full measure cost for this measure is custom.

###### Deemed O&M Cost Adjustments

The O&M cost for this measure is custom.

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

Δtherms = SF \* MBH\_In \* EFLH / 100

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[[486]](#footnote-494) (water, 81.9% eff) or custom

= 480F3 (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)[[487]](#footnote-495) or custom

= 365°F (conventional economizer – Steam Boiler)[[488]](#footnote-496) or custom

= 280°F (condensing economizer – Water Boiler)[[489]](#footnote-497) or custom

= 308°F (condensing economizer – Steam Boiler)[[490]](#footnote-498) or custom

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

= 1%[[491]](#footnote-499) or custom

Based on defaults provided above:

|  |  |  |
| --- | --- | --- |
| **Boiler Type** | **SF[[492]](#footnote-500)** | |
| **Conventional Economizer** | **Condensing Economizer** |
| Hot Water Boiler | 2.19% average SF or custom | 3.63% average SF or custom |
| Steam Boiler | 2.88% average SF or custom | 4.31% average SF or custom |

MBH\_In = Rated boiler input capacity, in MBH

= Actual

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

###### 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

### 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.[[493]](#footnote-501)

###### Deemed Measure Cost

The incremental and full measure cost for this measure is custom.

###### Deemed O&M Cost Adjustments

The O&M cost for this measure is custom.

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

Δtherms = SF \* MBH\_In \* 8766 \* UF / 100

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[[494]](#footnote-502) (water, 81.9% eff per IL TRM) or custom

= 480F3 (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)[[495]](#footnote-503) or custom

= 365°F (conventional economizer – Steam Boiler)[[496]](#footnote-504) or custom

= 280°F (condensing economizer – Water Boiler)[[497]](#footnote-505) or custom

= 308°F (condensing economizer – Water Boiler)[[498]](#footnote-506) or custom

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

= 1%[[499]](#footnote-507) or custom

Based on defaults provided above:

|  |  |  |
| --- | --- | --- |
| **Boiler Type** | **SF[[500]](#footnote-508)** | |
| **Conventional Economizer** | **Condensing Economizer** |
| Hot Water Boiler | 2.19% average SF or custom | 3.63% average SF or custom |
| Steam Boiler | 2.88% average SF or custom | 4.31% average SF or custom |

MBH\_In = Rated boiler input capacity, in MBH

= Actual

8766 = Hours a year

UF = Utilization Factor

= 41.9%[[501]](#footnote-509) 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

### 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[[502]](#footnote-510) [[503]](#footnote-511) [[504]](#footnote-512) 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[[505]](#footnote-513) group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

For this measure it is assumed that upgrading a standard smooth v-belt with a new notched v-belt will result in a fan energy reduction of 2%.

###### Definition of Efficient Equipment

For the Notched V-Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have notched v-belts installed on the supply and/or return air fans. This can be done as a retrofit, TOS, or NC project.

For the Synchronous Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have synchronous belts installed on the supply and/or return air fans. This can be done as a TOS or NC project. Retrofit projects can also claim savings, but costs should be verified independently (typically the cost of installing synchronous belts as a retrofit is not economically viable).

###### 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[[506]](#footnote-514) 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[[507]](#footnote-515)

Occupancy Hours per year = values from Table below

The notched v-belt measure EUL is summarized by building type in the following table.

**Notched v-belt Effective Useful Life (EUL)**

| **Building Type** | **Total Fan Run Hours** | **EUL (Years)** | **Model Source** |
| --- | --- | --- | --- |
| Assembly | 7235 | 3.3 | eQuest |
| Assisted Living | 8760 | 2.7 | eQuest |
| College | 6103 | 3.9 | eQuest |
| Convenience Store | 7004 | 3.4 | eQuest |
| Elementary School | 7522 | 3.2 | eQuest |
| Garage | 7357 | 3.3 | eQuest |
| Grocery | 7403 | 3.2 | eQuest |
| Healthcare Clinic | 6345 | 3.8 | eQuest |
| High School | 7879 | 3.0 | eQuest |
| Hospital - VAV econ | 8760 | 2.7 | eQuest |
| Hospital - CAV econ | 8760 | 2.7 | eQuest |
| Hospital - CAV no econ | 8760 | 2.7 | eQuest |
| Hospital - FCU | 8760 | 2.7 | eQuest |
| Manufacturing Facility | 8706 | 2.8 | eQuest |
| MF - High Rise | 8760 | 2.7 | eQuest |
| MF - Mid Rise | 8760 | 2.7 | eQuest |
| Hotel/Motel - Guest | 8760 | 2.7 | eQuest |
| Hotel/Motel - Common | 8760 | 2.7 | eQuest |
| Movie Theater | 7505 | 3.2 | eQuest |
| Office - High Rise - VAV econ | 6064 | 4.0 | eQuest |
| Office - High Rise - CAV econ | 5697 | 4.2 | eQuest |
| Office - High Rise - CAV no econ | 5682 | 4.2 | eQuest |
| Office - High Rise - FCU | 6163 | 3.9 | eQuest |
| Office - Low Rise | 6288 | 3.8 | eQuest |
| Office - Mid Rise | 6856 | 3.5 | OpenStudio |
| Religious Building | 7380 | 3.3 | eQuest |
| Restaurant | 7809 | 3.1 | eQuest |
| Retail - Department Store | 7155 | 3.4 | OpenStudio |
| Retail - Strip Mall | 6846 | 3.5 | eQuest |
| Warehouse | 6832 | 3.5 | OpenStudio |
| Unknown | 7100 | 3.4 | n/a |

The lifetime of a synchronous belt system is the same as the lifetime of the equipment it is installed on because it is a permanent upgrade, involving the installation of toothed pulleys. Typical HVAC RTU lifetime is 15 years, which applies to synchronous belts as well. This is not to suggest that the actual belt component has an equivalent lifetime because they do require replacement. However, their O&M cost savings (derived from not having to tension, etc.) are assumed to offset the replacement cost of the belt, resulting in a net cost of zero. As a result, neither a separate lifetime nor O&M savings are quantified for synchronous belts and lifetime can therefore be considered as the lifetime of the equipment they’re installed on because it would not be possible to install a traditional or notched belt on the synchronous pulleys.

###### Deemed Measure Cost

A review of the Grainger online[[508]](#footnote-516) pricing for “A,” “B,” “AX,” and “BX” v-belts showed the incremental cost to upgrade to notched v-belts would result in a 28% price increase. The notched v-belt incremental cost is summarized in the table below:

**Notched V-belt Incremental Cost Summary**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Smooth V-Belt Industry Number** | **Outside Length (Inches)** | **Dayton Smooth V-Belt\*** | **Notched V-belt Industry Number** | **Dayton Notched v-belt\*** | **Price Increase** | **% Increase** |
| A30 (Item # 1A095) | 32 | $12.70 | AX29 (Item # 3GWU4) | $17.65 | $4.95 | 28% |
| B29 (Item # 6L208) | 32 | $16.75 | BX29 (Item # 5TXL4) | $23.23 | $6.48 | 28% |
| \* Pricing based on Dayton Belts as found on Grainger Website 10/30/14 | | | | | | |

Note that the incremental cost for notched V-Belts assumes that the notched belt is purchased and installed instead of a smooth v-belt. There is no difference in the cost of installation, only the material.

**Synchronous Belt Incremental Cost Summary**

| **Smooth V-Belt Industry Number** | **Smooth belt system Price\*** | **Synchronous Belt Industry Number** | **Synchronous System Price\*** | **Price Difference** |
| --- | --- | --- | --- | --- |
| Belt A30 (Item # 1A095) | $12.70 | Belt 1DHL5 (Item # 322L050) | $20.51 | $7.81 |
| Gearbelt pulley BK47 (Item #5UHD5) | $45.90 | Gearbelt sprocket  GTR-36G-8M-12 (Item # 2UWH6) | $113.00 | $67.10 |
| \* Costs based on Grainger pricing. | | | | |

Incremental cost for a NC or TOS project is $142. This is the price of synchronous equipment (belt, two sprockets) subtract v-belt equipment (belt, two pulleys). Labor cost is assumed to be equal in the baseline and efficient cases.

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor[[509]](#footnote-517) 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

ΔkWh = kWconnected\* Hours \* ESF

Where:

kWConnected =kW of equipment is calculated using motor efficiency[[510]](#footnote-518).

= (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[[511]](#footnote-519). 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**[[512]](#footnote-520)**. Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

| **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[[513]](#footnote-521) are provided in table below for HVAC fan operation which varies by building type:

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Total Fan Run Hours** | **Model Source** |
| Assembly | 7235 | eQuest |
| Assisted Living | 8760 | eQuest |
| College | 6103 | eQuest |
| Convenience Store | 7004 | eQuest |
| Elementary School | 7522 | eQuest |
| Garage | 7357 | eQuest |
| Grocery | 7403 | eQuest |
| Healthcare Clinic | 6345 | eQuest |
| High School | 7879 | eQuest |
| Hospital - VAV econ | 8760 | eQuest |
| Hospital - CAV econ | 8760 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |
| Hospital - FCU | 8760 | eQuest |
| Manufacturing Facility | 8706 | eQuest |
| MF - High Rise | 8760 | eQuest |
| MF - Mid Rise | 8760 | eQuest |
| Hotel/Motel - Guest | 8760 | eQuest |
| Hotel/Motel - Common | 8760 | eQuest |
| Movie Theater | 7505 | eQuest |
| Office - High Rise - VAV econ | 6064 | eQuest |
| Office - High Rise - CAV econ | 5697 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 6163 | eQuest |
| Office - Low Rise | 6288 | eQuest |
| Office - Mid Rise | 6856 | OpenStudio |
| Religious Building | 7380 | eQuest |
| Restaurant | 7809 | eQuest |
| Retail - Department Store | 7155 | OpenStudio |
| Retail - Strip Mall | 6846 | eQuest |
| Warehouse | 6832 | OpenStudio |
| Unknown | 7100 | n/a |

ESF = Energy Savings Factor, the ESF for notched v-belt Installation is assumed to be 2%

= the ESF for notched Synchronous Belt Installation is assumed to be 3.1%[[514]](#footnote-522)

###### Summer Coincident Peak Demand Savings

**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;

ΔkWh = kWconnected\* 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

ΔkW = kWconnected\* ESF

Where:

kWConnected = 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;

ΔkW = kWconnected\* 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

### 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[[515]](#footnote-523) 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.[[516]](#footnote-524)

###### 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

###### Coincidence Factor

N/A

**Algorithms**

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh = ΔTherms \* Fe \* 29.3

Where:

ΔTherms = as calculated below

Fe = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[[517]](#footnote-525)

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

**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

### 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)[[518]](#footnote-526) 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:

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.

ECHP = 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.

FtotalCHP = Total annual fuel consumed by the CHP system

For further definition of the terms, please see “Calculation of Energy Savings” Section below.

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

1. **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):

SFuelCHP = 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.

= (Fgrid + FthermalCHP) – Ftotal CHP

Where:

Fgrid = 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.

= ECHP \* Hgrid

Where:

ECHP  = 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. [[519]](#footnote-527)

= ( CHPcapacity \* Hours ) - EParasitic

CHPcapacity = CHP nameplate capacity

= Custom input

Hours = Annual operating hours of the system

= Custom input

Eparasitic = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

= Custom input

Hgrid = 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)[[520]](#footnote-528). 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.

FthermalCHP = 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. [[521]](#footnote-529)

= CHPthermal / Boilereff  (or CHPthermal / Furnaceeff)

CHPthermal = 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

Boilereff /Furnaceeff= 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

Ftotal CHP = Total fuel in Btus consumed by the CHP system

= 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 (ECHP), the used thermal output of the CHP system (FthermalCHP), and the CHP system efficiency (CHPEff(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[[522]](#footnote-530) and gas[[523]](#footnote-531) Energy Efficiency Portfolio Standard (EEPS)[[524]](#footnote-532) 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 ECHP (kWh) | No gas savings |
| >60% to 65% | 65% of ECHP (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of ECHP in kWh) | No gas Savings |
| >65% | 70% of Echp (kWh) | 2.5% of Fthermal (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 ECHP measured over 12 months, and Gas savings (therms) = 12.5% of Fthermal 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 ECHP (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 ECHP measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

3)      For systems participating in only a gas EEPS program:

|  |  |  |
| --- | --- | --- |
| CHP Annual System Efficiency (HHV) | Allocated Electric Savings | Allocated Gas Savings |
| 60% or greater | No electric savings | 2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%. |

Example: System with measured annual system efficiency (HHV) of 70%:  No Electric savings (kWh). Gas savings (therms) = 25% of Fthermal 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[[525]](#footnote-533) 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[[526]](#footnote-534).

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%.

1. **Waste-Heat-to-Power CHP Systems :**

###### Electric Energy Savings:

ΔkWh = ECHP

Where:

ECHP = 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

ΔkW = CF \* CHPcapacity

Where:

CF = Summer Coincidence factor. This factor should also consider any displaced chiller capacity[[527]](#footnote-535)

= Custom input

CHPCapacity = CHP nameplate capacity

= Custom input

###### Natural Gas Energy Savings:

ΔTherms = FthermalCHP ÷ 100,000

Where:

FthermalCHP = 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[[528]](#footnote-536).

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[[529]](#footnote-537).

###### 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: ECHP + ΔkW + Fthermal\_CHP

Costs: Ftotal\_CHP + CHPCOSTS +O&MCOSTS

Where:

CHPCosts = CHP equipment and installation costs as defined in the “Deemed Measure Costs” section

O&MCosts = CHP operations and maintenance costs as defined in the “Deemed O&M Cost Adjustment Calculation” section

###### Measure Code: CI-HVC-CHAP-V03-190101

###### Review Deadline: 1/1/2022

### 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.[[530]](#footnote-538)

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.

###### 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.[[531]](#footnote-539)

###### 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.[[532]](#footnote-540)

|  |  |
| --- | --- |
| **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

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[[533]](#footnote-541)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[534]](#footnote-542)

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.[[535]](#footnote-543) The calculation 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).[[536]](#footnote-544)  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 < P < -10 Pa.[[537]](#footnote-545) 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 P of above -30 Pa.[[538]](#footnote-546)

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

kWhcooling = [(Qtbc – Qtac) / EER – (HP \* 0.7457)] \* topen \* CD

kWhHPheating = [(Qtbc – Qtac) / HSPF – (HP \* 0.7457)] \* topen \* HD

kWhGasheating = - (HP \* 0.7457) \* topen \* HD

Where:

Qtbc = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)

Qtac = 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 |
| 16’w x 16’h | 12 |

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

topen = 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[[539]](#footnote-547)

| **.** | **CD**  **(Balance Point Temperature)** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 1 - Rockford AP / Rockford | 194 | 168 | 148 | 124 | 97 |
| 2 - Chicago O'Hare AP / Chicago | 194 | 173 | 153 | 127 | 95 |
| 3 - Springfield #2 / Springfield | 214 | 194 | 174 | 148 | 114 |
| 4 - Belleville SIU RSCH / Belleville | 258 | 229 | 208 | 174 | 138 |
| 5 - Carbondale Southern IL AP / Marion | 222 | 201 | 181 | 158 | 130 |

HSPF = Heating System Performance Factor of heat pump equipment

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

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

= use table below to select an appropriate value[[540]](#footnote-548):

|  | **HD** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 1 -Rockford AP / Rockford | 142 | 160 | 183 | 204 | 228 |
| 2 - Chicago O'Hare AP / Chicago | 150 | 166 | 192 | 219 | 253 |
| 3 - Springfield #2 / Springfield | 125 | 142 | 167 | 194 | 230 |
| 4 - Belleville SIU RSCH / Belleville | 101 | 115 | 134 | 156 | 180 |
| 5 - Carbondale Southern IL AP / Marion | 103 | 123 | 148 | 174 | 205 |

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

Qtbc = 4.5 \* CFMtot \*(hoc – hic) / (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))

CFMtot = Total air flow through entryway (cfm), see calculation below

hoc = 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.[[541]](#footnote-549)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **hoc** | | |
| **Climate Zone -**  **Weather Station/City** | **67 oF** | **72 oF** | **77 oF** |
| 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 |

hic = 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.

|  | **hic** | | |
| --- | --- | --- | --- |
| **Relative Humidity (%)** | **67 oF** | **72 oF** | **77 oF** |
| 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 oF 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, CFMtot, includes both infiltration due to wind as well as thermal forces, as follows:

CFMtot = sqrt[ (CFMw)2 + (CFMt2) ]

Where:

CFMw = Infiltration due to the wind (cfm)

CFMt = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFMw = (vwc \* Cwc)\* Cv \* Ad \* (88 fpm/mph)

Where:

vwc = 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[[542]](#footnote-550):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **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 |

Cwc = 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.

Cv = effectiveness of openings,

= 0.3, assumes diagonal wind20

Ad = area of the doorway (ft2)

= user defined

The infiltration due to thermal forces is calculated as follows:

CFMt = Ad \* Cdc \* (60 sec/min) \* sqrt[2 \* g \* H/2 \* (Toc - Tic) / (459.7 + Toc)]

Where:

Cdc = the discharge coefficient during the cooling season[[543]](#footnote-551)

= 0.4 + 0.0025 \* |Tic – Toc|

= 0.42, Illinois average at indoor air temp of 72oF

Note, values for Cdc 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/sec2

H = the height of the entryway (ft)

= user input

Tic = Average indoor air temperature during cooling season

= User input, can assume indoor cooling temperature set-point

Toc = 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[[544]](#footnote-552):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Toc** | | | | |
| **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)***

Qtac = Qtbc \* (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[[545]](#footnote-553)

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWhcooling / (CD \*24)) \* CF

Where:

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[[546]](#footnote-554)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[547]](#footnote-555)

###### 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.

therms = (Qbc - Qac) \* topen \* HD / η

Where:

Qbc = rate of sensible heat transfer through the open entryway, before air curtain (therm/hr)

Qac = rate of sensible heat transfer through the open entryway, after air curtain (therm/hr)

topen = 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[[548]](#footnote-556):

|  | **HD** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 1 -Rockford AP / Rockford | 142 | 160 | 183 | 204 | 228 |
| 2 - Chicago O'Hare AP / Chicago | 150 | 166 | 192 | 219 | 253 |
| 3 - Springfield #2 / Springfield | 125 | 142 | 167 | 194 | 230 |
| 4 - Belleville SIU RSCH / Belleville | 101 | 115 | 134 | 156 | 180 |
| 5 - Carbondale Southern IL AP / Marion | 103 | 123 | 148 | 174 | 205 |

η = efficiency of heating equipment

= Actual. If unknown, assume 0.8

***Heat Transfer Through Open Entryway without Air Curtain (Heating Season)***

Qbc = (1.08 Btu/(hr\*oF\*cfm)) \* CFMtot \* (Tih – Toh) / (100,000 Btu/therm)

Where:

1.08 = sensible heat transfer coefficient (specific heat of air and unit conversions)

CFMtot = Total air flow through entryway (cfm)

Tih = Average indoor air temperature during heating season

= User input, can assume indoor heating temperature set-point

Toh = Average outdoor temp during heating season (oF)

= use table below, based on binned data from TMY3 & balance point temperature

|  | **Avg Outdoor Air Temp - Heating Season** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 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, CFMtot, includes both infiltration due to wind as well as thermal forces, as follows:

CFMtot = sqrt[ (CFMw)2 + (CFMt2) ]

Where:

CFMw = Infiltration due to the wind (cfm)

CFMt = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

CFMw = (vwh \* Cwh)\* Cv \* Ad \* (88 fpm/mph)

Where:

vwh = 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 |

Cwh = 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.

Cv = effectiveness of openings,

= 0.3, assumes diagonal wind24

Ad = area of the doorway (ft2)

= user input

The infiltration due to thermal forces is calculated as follows:

CFMt = Ad \* Cdh \* (60 sec/min) \* sqrt[2 \* g \* H/2 \* (Tih – Toh) / (459.7 + Tih)]

Where:

Cdh = the discharge coefficient during the heating season

= 0.4 + 0.0025 \* |Tih – Toh|

= 0.49, Illinois average at indoor air temp of 72oF

Note, values for Cdh 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/sec2

H = the height of the entryway (ft)

= user defined

***Heat Transfer Through Open Entryway without Air Curtain (Heating Season)***

Qac = Qbc \* (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[[549]](#footnote-557)

###### 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[[550]](#footnote-558).

###### Measure Code: CI-MSC-AIRC-V01-160601

###### Review Deadline: 1/1/2022

### 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 - 3oF[[551]](#footnote-559). 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, Aeff, 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[[552]](#footnote-560).

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.

###### 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[[553]](#footnote-561)

###### 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[[554]](#footnote-562):

|  |  |
| --- | --- |
| **Fan Diameter (ft)** | **Incremental Cost** |
| 14 | $6,600 |
| 16 | $6,650 |
| 18 | $6,700 |
| 20 | $6,750 |
| 22 | $6,800 |
| 24 | $6,850 |

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

###### Loadshape

Loadshape C04: Commercial Electric Heating.

###### Coincidence Factor

N/A due to no savings attributable to cooling during the summer peak period.

**Algorithm**

###### Calculation of Savings

The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

###### Electric Energy Savings

The algorithm for this measure was developed for natural gas heating applications, however, for electric heating applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:

| **System Type** | **Age of Equipment** | **HSPF Estimate** | **η (Effective COP Estimate) (HSPF/3.413)** |
| --- | --- | --- | --- |
| Heat Pump | Before 2006 | 6.8 | 2.0 |
| 2006 - 2014 | 7.7 | 2.3 |
| 2015 on | 8.2 | 2.40 |
| 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:

∆kWh = - (Wfan \* Nfan) \* teff

Wfan = fan input power (kW)

Nfan = number of fans

teff = 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

∆Therms = [(∆Qr + ∆Qw) \* teff] / (100,000 \* η)

Where:

Qr = the heat loss reduction through the roof due to the destratification fan (Btu/hr)

= See calculation section below

Qw = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)

= See calculation section below

teff = effective annual operation time, based on balance point temperature (hr)

= use table below to select an appropriate value[[555]](#footnote-563):

| **Climate Zone -**  **Weather Station/City** | **teff** | | | | |
| --- | --- | --- | --- | --- | --- |
| **45 oF** | **50 oF** | **55 oF** | **60  oF** | **65  oF** |
| 1 -Rockford AP / Rockford | 3810 | 4226 | 4880 | 5571 | 6436 |
| 2 - Chicago O'Hare AP / Chicago | 3593 | 3986 | 4603 | 5254 | 6070 |
| 3 - Springfield #2 / Springfield | 3038 | 3370 | 3891 | 4442 | 5131 |
| 4 - Belleville SIU RSCH / Belleville | 2243 | 2488 | 2873 | 3280 | 3789 |
| 5 - Carbondale Southern IL AP / Marion | 2271 | 2519 | 2909 | 3320 | 3836 |

100,000 = conversion factor (1 therm = 100,000 Btu)

η = thermal efficiency of heating equipment

= 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 55oF the therms savings for the facility would be estimated as:

∆Therms = [(∆Qr + ∆Qw) \* teff] / (100,000 \* η)

= [(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***

∆Qr = Qr,s – Qr,d

= (1/Rr) \* Ar \* [(Tr,s – Toa) – (Tr,d – Toa)]

= (1/Rr) \* Ar \* (Tr,s – Tr,d)

Where:

Qr,s = roof heat loss for stratified space

Qr,d = roof heat loss for destratified space

Rr = overall thermal resistance through the roof (hr \* ft2 \* oF / Btu)

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

|  |  |  |
| --- | --- | --- |
| **Thermal Resistance Factor (R-Factor) for Roof** | **Retrofit[[556]](#footnote-564)** | **New Construction[[557]](#footnote-565)**  **(2010 or newer)** |
| Rr | 10.0  (hr \* ft2 \* oF / Btu) | 20.0  (hr \* ft2 \* oF / Btu) |

Ar = roof area (ft2)

= user input

= can be approximated with floor area

Toa = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

Tr,s = indoor temperature at roof deck, stratified case (oF)

= Actual. If unknown, use the following equation

= ms \* hr + Tf,s

hr = ceiling height/roof deck (ft)

ms = estimated heat gain per foot elevation, stratified case (oF/ft)

= 0.8 oF/ft

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[[558]](#footnote-566),[[559]](#footnote-567). Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 oF/ft heat gain.

Tf,s = estimated floor temperature, stratified case (oF)

= Ttstat – ms \* htstat

= Ttstat – 4 oF

Ttstat = temperature set point at the thermostat

htstat = vertical distance between the floor and the thermostat, assumed 5ft

Tr,d = indoor temp at roof, destratified case

= actual value, or may be estimated using the following:[[560]](#footnote-568),[[561]](#footnote-569)

= Ttstat + 1 oF

EXAMPLE:

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

∆Qr = (1/Rr) \* Ar \* (Tr,s – Tr,d) = (1/Rr) \* Ar \* [(ms \* hr + Ttstat – 4 oF) – (Ttstat + 1 oF)]

= (1/Rr) \* Ar \* [(0.8oF/ft \* hr) – 5 oF]

= 1/(10 hr \* ft2 \* oF / Btu) \* (50,000 ft2) \* [(0.8oF/ft \* 30 ft) – 5 oF]

= 95,000 Btu/hr

***Heat loss reduction through exterior walls***

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%.[[562]](#footnote-570)

∆Q\_w = Qw,s – Qw,d

= (1/Rw) \* Aw \* (Tw,s – Tw,d)

Where:

Rw = overall thermal resistance through the exterior walls (hr \* ft2\* oF / Btu)

= Actual or estimated based on construction type[[563]](#footnote-571). If unknown, assume the following

|  |  |  |
| --- | --- | --- |
| **Thermal Resistance Factor (R-Factor) for Wall** | **Retrofit[[564]](#footnote-572)** | **New Construction[[565]](#footnote-573)**  **(2010 or newer)** |
| Rw | 6.5 (hr \* ft2 \* oF / Btu) | 13.0 (hr \* ft2 \* oF / Btu) |

Aw = area of exterior walls (ft2)

= user input

Tw,s = average indoor air temperature for wall heat loss, stratified case

= If actual Tr,s measurement is available[[566]](#footnote-574)

= [(Tr,s \* ha) + (Ttstat \* hb)] / hr

ha = vertical distance between the heat source and the ceiling

hb = vertical distance between the floor and the heat source

= Otherwise, use the linear stratification equation at average space height, see definition above.

= ms \* (hr / 2) + Tf,s

= ms\* (hr / 2) + (Ttstat – 4)

Tw,d = average indoor air temperature for wall heat loss, destratified case

= Ttstat + 0.5

= conservative estimate using engineering judgment based on the same assumption used for Tr,f estimate.

**EXAMPLE:**

For a 50,000 ft2 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:

∆Qw = (1/Rw) \* Aw \* (Tw,s – Tw,d)

= (1/Rw) \* Aw \* [([(Tr,s \* ha) + (Ttstat \* hb)] / hr) – (Ttstat + 0.5 oF)]

= 1/(6.5 hr\*ft2\*oF/Btu) \* (1200 \* 30) \* [([(85oF \* 10ft) + (65 oF \* 20ft)] / 30ft) – (65 + 0.5 oF)]

= 1/(6.5 hr\*ft2\*oF/Btu) \* (36,000ft2) \* (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, Aeff, is the area over which a fan or a group of fans can be expected to effectively destratify a space. If Aeff is less than the roof area, Ar, 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[[567]](#footnote-575). Effective area, is calculated as follows:

Aeff = [π \* (5\*Dfan)2) / 4] \* Nfan

= 6.25 \* π \* Dfan2 \* Nfan

Where:

Aeff = the effective area fan area on the floor (ft2)

Dfan = fan diameter

Nfan = 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

### 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)[[568]](#footnote-576).

Figure 1 – Baseline ASHRAE High-Limit Shutoff Control Settings

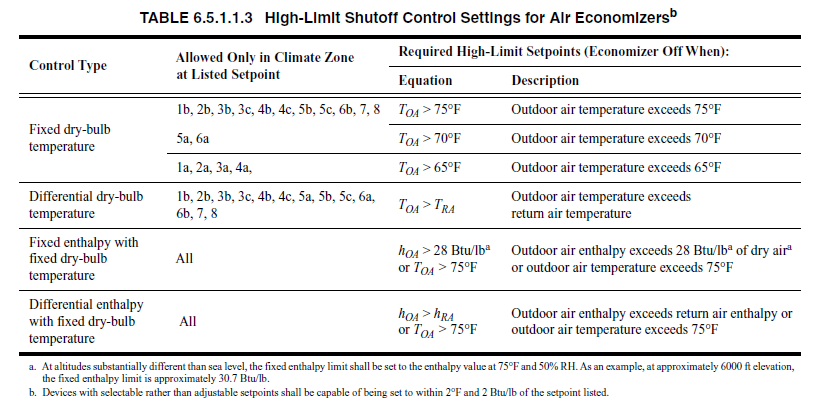
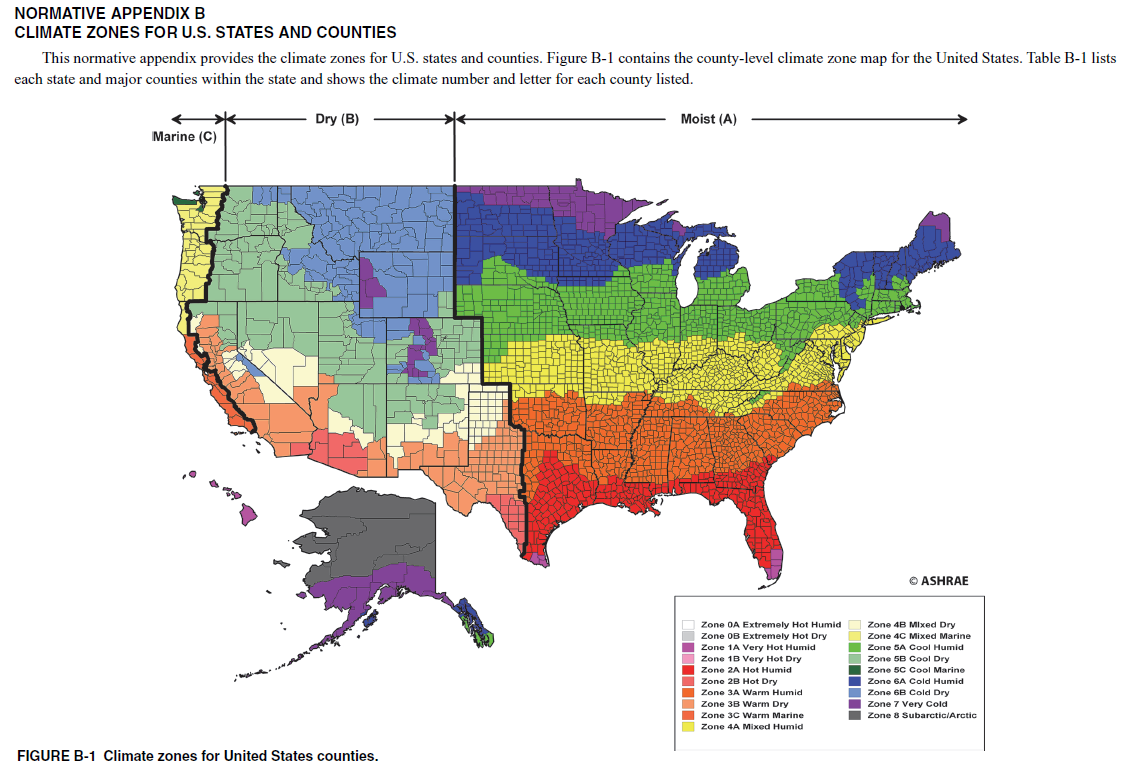


Figure 2 – ASHRAE Climate Zone Map



###### 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[[569]](#footnote-577).

###### Deemed Measure Cost

The cost for this measure can vary considerably depending upon the existing condition of the economizer and the work required to achieve the required efficiency levels. Measure cost should be determined on a site-specific basis.

###### Loadshape

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

N/A

Algorithm

###### Calculation of Energy Savings

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations[[570]](#footnote-578). 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

∆kWh = [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[[571]](#footnote-579).

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 |
| 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 |
| Enth | 1343.56 | 1377.52 | 1710.11 | 1783.66 | 1821.67 |
| ABCD | 1373.72 | 1407.70 | 1740.43 | 1814.74 | 1852.55 |
| Retail - Department Store | DB | 717.89 | 730.07 | 968.85 | 1034.78 | 1035.06 |
| DTDB | 628.83 | 641.70 | 883.37 | 951.09 | 951.33 |
| DTEnth | 629.35 | 641.90 | 882.84 | 951.33 | 951.44 |
| Enth | 705.06 | 717.99 | 956.42 | 1020.57 | 1024.45 |
| ABCD | 728.60 | 741.47 | 980.19 | 1045.30 | 1048.57 |
| Retail - Strip Mall | DB | 800.69 | 818.68 | 1070.39 | 1129.87 | 1133.84 |
| DTDB | 692.97 | 711.31 | 965.63 | 1026.68 | 1030.41 |
| DTEnth | 698.12 | 716.34 | 970.06 | 1031.78 | 1035.72 |
| Enth | 784.54 | 803.35 | 1054.37 | 1112.72 | 1120.74 |
| ABCD | 810.10 | 828.86 | 1080.11 | 1139.39 | 1146.95 |

CSP = Economizer Changeover Setpoint (°F or Btu/lb) (actual in ranges below)

|  |  |  |
| --- | --- | --- |
| **Economizer Control Type** | | **Economizer Changeover Setpoint** |
| Dry-Bulb | | 60°F - 80°F |
| Dual Temperature Dry-Bulb | | 0°F -5°F delta |
| Dual Temperature Enthalpy | | 0 Btu/lb -5 Btu/lb delta |
| Enthalpy | | 18 Btu/lb – 28 Btu/lb |
| Analog ABCD Economizers | A | 73°F |
| B | 70°F |
| C | 67°F |
| D | 63°F |
| E | 55°F |

EL = Integrated Economizer Operation (Economizer Lockout)

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

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

Oan = Minimum Outside Air (% OSA)[[572]](#footnote-580)

= 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)[[573]](#footnote-581))

Oax = Maximum Outside Air (%)i

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

Functional Economizer – 70%

Non functional Economizer (Damper failed closed) – 15%

Non functional Economizer (Damper failed open) –– 30% (Assume Minimum Ventilation (Three Fingers))

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found that the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

∆kWh = [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

∆kWh = [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

∆Therms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use (Therms/kBtuh)] \* Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed electric energy use.

Natural Gas Energy Use Equations (therms / kbtu output)

| **Building Type** | **Changeover Type** | **Equation** |
| --- | --- | --- |
| Assembly | Fixed Dry-Bulb (DB) | cz+OAn\*0.0853 |
| Dual Temperature Dry-Bulb (DTDB) | cz+OAn\*0.0866 |
| Dual Temperature Enthalpy (DTEnth) | cz+OAn\*0.0866 |
| Fixed Enthalpy (Enth) | cz+OAn\*0.0855 |
| Analog ABCD Economizers (ABCD) | cz+OAn\*0.0855 |
| Convenience Store | DB | cz+OAn\*0.26 |
| DTDB | cz+OAn\*0.263 |
| DTEnth | cz+OAn\*0.263 |
| Enth | cz+OAn\*0.261 |
| ABCD | cz+OAn\*0.261 |
| Office - Low Rise | DB | cz+OAn\*0.3 |
| DTDB | cz+OAn\*0.301 |
| DTEnth | cz+OAn\*0.301 |
| Enth | cz+OAn\*0.3 |
| ABCD | cz+OAn\*0.3 |
| Religious Facility | DB | cz+OAn\*0.35 |
| DTDB | cz+OAn\*0.348 |
| DTEnth | cz+OAn\*0.348 |
| Enth | cz+OAn\*0.349 |
| ABCD | cz+OAn\*0.349 |
| Restaurant | DB | cz+OAn\*0.0867 |
| DTDB | cz+OAx\*-0.038+OAn\*OAx\*0.00149 |
| DTEnth | cz+OAx\*-0.038+OAn\*OAx\*0.00149 |
| Enth | cz+OAn\*0.0878 |
| ABCD | cz+OAn\*0.0878 |
| Retail - Department Store | DB | cz+OAn\*0.319 |
| DTDB | cz+OAn\*0.318 |
| DTEnth | cz+OAn\*0.318 |
| Enth | cz+OAn\*0.318 |
| ABCD | cz+OAn\*0.318 |
| Retail - Strip Mall | DB | cz+OAn\*0.215 |
| DTDB | cz+OAn\*0.216 |
| DTEnth | cz+OAn\*0.216 |
| Enth | cz+OAn\*0.215 |
| ABCD | cz+OAn\*0.215 |

Where:

CZ = Climate Zone Coefficient

*=* Depends on Building Type and Changover Type (see table below)

|  |  | **Natural Gas Climate Zone Coefficients** | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Building Type** | **Changeover Type** | **CZ1**  **(Rockford)** | **CZ2**  **(Chicago)** | **CZ3 (Springfield)** | **CZ4 (Belleville)** | **CZ5 (Marion)** |
| Assembly | DB | -0.03 | -0.55 | -1.06 | -1.28 | -1.71 |
| DTDB | -0.02 | -0.57 | -1.11 | -1.34 | -1.79 |
| DTEnth | -0.02 | -0.57 | -1.11 | -1.34 | -1.79 |
| Enth | -0.03 | -0.55 | -1.06 | -1.29 | -1.72 |
| ABCD | -0.03 | -0.55 | -1.06 | -1.29 | -1.72 |
| Convenience Store | DB | 2.95 | 0.50 | -1.48 | -2.96 | -5.56 |
| DTDB | 3.06 | 0.52 | -1.56 | -3.11 | -5.81 |
| DTEnth | 3.06 | 0.52 | -1.56 | -3.11 | -5.81 |
| Enth | 2.96 | 0.50 | -1.49 | -2.98 | -5.59 |
| 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.

∆Therms = [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

∆Therms = [14.8(Therms/kBtuh output) – 14.8 (Therms/kBtuh output)] \* 92kBtuh output

= 0.0 (Therms/kBtuh output) \* 92kBtuh output

= 0 Therms

###### Water Impact Descriptions and Calculation

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ECRP-V03-180101**

###### Review Deadline: 1/1/2023

### Multi-Family Space Heating Steam Boiler Averaging Controls

###### Description

This measure covers multi-family space heating boiler averaging controls. Temperature sensors are placed in interior spaces to monitor the average temperature of the building. At minimum a sensor must be placed at each corner and at one central location. Additionally, a temperature sensor must monitor the outside air temperature. These sensors shall provide data to the averaging controls. The averaging controls will adjust the boiler operation based upon an average of the indoor sensors and the outside air temperature. These controls shall also incorporate a night-time setback capability. Buildings utilizing thermostatic radiator valves, or other modulating control valves or sequences to control the temperature in individual spaces are not eligible.

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

###### Definition of Efficient Equipment

To qualify the boiler(s) must incorporate an averaging control system utilizing at least 4 indoor sensors and 1 outdoor sensor. The controls shall have the capability to incorporate a nighttime setback throughout the building.

###### Definition of Baseline Equipment

The baseline is a boiler system without averaging controls or other steam supply modulating controls. Current boiler control system can utilize a single thermostat or aquastat and timer.

###### Deemed Lifetime of Efficient Equipment

The measure life for the domestic hot water boilers is 20 years.[[574]](#footnote-582)

###### Deemed Measure Cost

As a retrofit measure, the actual installed cost should be used for screening purposes. A deemed retrofit measure cost of $5,060[[575]](#footnote-583) can be used if the actual installed cost is unknown.

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Energy Savings

ΔTherms = Capacity x EFLH x SF / 100,000

Where:

Capacity = Boiler gas input size (Btu/h)

= Actual

EFLH = Effective Full Load Hours for heating are provided in section 4.4. HVAC End Use

SF = Savings Factor

= 10.2%[[576]](#footnote-584) or custom if savings can be substantiated

100,000 = converts Btu/h to therm

###### Water Impact Descriptions and Calculation

For Example:

A 1,000,000 btu/h steam boiler in a Mid-Rise Multi-Family building in Chicago has averaging controls installed.

ΔTherms = 1,000,000 x 1,685 x 0.102 / 100,000

= 1,719 therms

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-SBAC-V02-190101

###### Review Deadline: 1/1/2023

### 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)**[[577]](#footnote-585)**.

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[[578]](#footnote-586). 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[[579]](#footnote-587). In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[[580]](#footnote-588) that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.

Note: new Federal Standards applicable to all gas furnaces become effective January 1, 2023.

###### 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[[581]](#footnote-589). 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[[582]](#footnote-590). 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)[[583]](#footnote-591) weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 oF 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 oF and 65 oF 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)[[584]](#footnote-592) 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 oF), and likewise for the annual heating loads for HDD45 (HDD at base temperature of 45 oF) and HDD65 (HDD at base temperature of 65 oF), 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 HDD458** | **NCDC 30 Year Average HDD551,8** | **NCDC 30 Year Average HDD658** |
| 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 HDD457** | **TMY3 HDD557** | **TMY3 HDD657** |
| 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.

∆kWh = - (tFAN \* cfm \* P) / (FAN/MOTOR \* 8520)

Where:

tFAN = annual fan runtime (hr), refer to Tables 1 through 4

cfm = airflow (cfm), use actual or rated system airflow

P = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known

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:

∆kWh = - (tFAN \* cfm \* P) / (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.

kW = (kWh / tFAN) \* CF

Where:

CF = 1.0

###### Natural Gas Energy Savings

**EXAMPLE:**

Continuing the previous example:

∆kW = (kWh / tFAN) \* CF

= (- 1285 / 8760) \* 1.0

= - 0.15 kW

∆Therms = [QOA \* cfm \* (1/TENC - 1/TEC)]/ 100,000

Where:

QOA = 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 QOA 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.

TENC = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known

TEC = 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 oF:

∆Therms = [QOA \* cfm \* (1/TENC - 1/TEC)]/ 100,000

= 303,268 \* 5,000 \* (1/0.80 – 1/0.90)/100,000

= 2,106 therms

8760 Hour Annual Operation Scenario

Table 3. 8760 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Supply Air Fan Runtime = 8760 Hours** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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 |

7300 Hour Annual Operation Scenario

Table 6. 7300 Hour Annual Operation Scenario for HDD45

| **Supply Air Fan Runtime = 7300 Hours** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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 |

5266 Hour Annual Operation Scenario

Table 9. 5266 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Supply Air Fan Runtime = 5266 Hours** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| --- | --- | --- | --- | --- |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 1 - Rockford AP / Rockford | 130,903 | 168,718 | 206,532 | 244,347 |
| 2 - Chicago O'Hare AP / Chicago | 126,339 | 162,836 | 199,333 | 235,829 |
| 3 - Springfield #2 / Springfield | 109,501 | 141,133 | 172,765 | 204,398 |
| 4 - Belleville SIU RSCH / Belleville | 87,262 | 112,470 | 137,678 | 162,886 |
| 5 - Carbondale Southern IL AP / Marion | 89,215 | 114,987 | 140,759 | 166,531 |

3911 Hour Annual Operation Scenario

Table 12. 3911 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Supply Air Fan Runtime = 3911 Hours** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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** | **Qoa (Annual Btu/cfm)**  **At Supply Air Temperature Of** | | | |
| **Climate Zone -**  **Weather Station/City** | **75oF** | **85oF** | **95oF** | **105oF** |
| 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-V01-190101

###### Review Deadline: 1/1/2022

### 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[[585]](#footnote-593).

###### 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[[586]](#footnote-594) 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

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

If the building is electrically heated, electric energy savings are calculated as follows:

ΔkWh = (Qinfiltration \* 1.08 \* (TOA – TSA) \* EFLHheat) / (3,412 \* COP)

Where:

Qinfiltration = Air infiltration (CFM) due to poor installation of window or through-the-wall AC[[587]](#footnote-595)

= ELA \* 0.000645\* (fs2 \* (TOA – TSA) + fw2 \* U2)1/2 \*2118.88

Where:

ELA = Effective Leakage Area (sq. in.)

= Can be collected on site; if unknown, assume 6 sq. in.[[588]](#footnote-596)

0.000645= Converts square inches to square meters

fs = Stack Coefficient

= 1/3 \* (9.81 \* Height \* 0.3048) / (TOA)0.5

fw = 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

TOA = Average Outside Air Temperature during heating period[[589]](#footnote-597). Use values from table below, based on facility location[[590]](#footnote-598). This figure must be in Kelvin to determine Stack Coefficient (fs) and infiltration (Qinfiltration), but in Fahrenheit to determine energy savings (ΔkWh, ΔTherms).

|  |  |  |
| --- | --- | --- |
| **Zone** | **TOA (°F)** | **TOA (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 |

A, Band C = Constants based on the facility site’s shielding and terrain parameters. Use values from the tables below[[591]](#footnote-599).

| **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

TSA = Average Indoor Air Temperature during heating period. This figure will need to be in Kelvin to calculate infiltration (Qinfiltration) 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[[592]](#footnote-600).

|  |  |
| --- | --- |
| **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 m3/s to CFM

1.08 = Sensible heat transfer constant (Btu/hr.CFM.°F)

EFLHheat = Equivalent Full Load Hours for heating from section 4.4 HVAC End Use[[593]](#footnote-601)

3,412 = Converts Btus to kWh

COP = Coefficient of Performance of the heating unit

= Collected on site. If unknown assume 2.6 for PTHP[[594]](#footnote-602)

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 |

**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,

fs = 1/3 \* (9.81 m/s2 \* 80 ft \* 0.3048 m/ft / 274.26 K)0.5 = 0.3 m/K½.s

fw = 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.

Qinfiltration = ELA \* 0.000645\* (fs2 \* (TOA – TSA) + fw2 \* U2)1/2\* 2118.88

= 96 \* 0.000645 \* (0.32 \* (296.48 K – 274.26 K) + 0.242 \* 4.672)1/2\* 2118.88

= 237 CFM

∆kWh = (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 = (Qinfiltration \* 1.08 Btu/hr.CFM.°F \* (TOA – TSA) \* EFLHheat) / (100,000 Btu/therm \* η)

Where,

η = Efficiency of heating equipment.

= Collected on site. If unknown, assume 80%[[595]](#footnote-603).

100,000 = Converts Btus to therms

Other factors as defined above

Deemed per-unit savings per unit for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

| **Multi-Family - Gas Savings per Unit (Therms/Unit)** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Floor** | **Height** | **Rockford** | **Chicago** | **Springfield** | **Belleville** | **Marion** |
| 1 | 8 | 6.12 | 5.90 | 5.07 | 3.45 | 2.85 |
| 2 | 16 | 7.56 | 7.24 | 6.23 | 4.29 | 3.62 |
| 3 | 24 | 8.64 | 8.24 | 7.09 | 4.93 | 4.21 |
| 4 | 32 | 9.54 | 9.08 | 7.81 | 5.46 | 4.71 |
| 5 | 40 | 10.33 | 9.81 | 8.44 | 5.93 | 5.14 |
| 6 | 48 | 11.04 | 10.46 | 9.01 | 6.35 | 5.54 |
| 7 | 56 | 11.69 | 11.06 | 9.53 | 6.74 | 5.90 |
| 8 | 64 | 12.30 | 11.62 | 10.01 | 7.10 | 6.24 |
| 9 | 72 | 12.87 | 12.15 | 10.46 | 7.43 | 6.55 |
| 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,

fs = 1/3 \* (9.81 m/s2 \* 80 ft \* 0.3048 m/ft / 274.26 K)0.5 = 0.3 m/K½.s

fw = 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

Qinfiltration = ELA \* 0.000645\* (fs2 \* (TOA – TSA) + fw2 \* U2)1/2 \*2118.88

= 96 \* 0.000645 \* (0.32 \* (296.48 K – 274.26 K) + 0.242 \* 4.672)1/2 \* 2118.88

= 237 CFM

∆Therms = (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

### 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[[596]](#footnote-604).

###### 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)[[597]](#footnote-605).

The incremental measure cost, assuming a baseline of standard efficiency unit heaters, is $7.43/MBtu/hr (material cost)[[598]](#footnote-606).

###### Loadshape

Loadshape C04: Commercial Electric Heating

###### Coincidence Factor

Assumed to be 0.

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

HTHV units may increase the facility’s electric energy consumption due to high pressure motors that supply air at higher velocity.

ΔkWh = - kWh/HDD \* HDD

Where:

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

= 1.04[[599]](#footnote-607)

HDD = heating degree days

|  |  |  |  |
| --- | --- | --- | --- |
| **Zone** | **City** | **HDD55[[600]](#footnote-608)** | **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.

ΔTherms = (FLHbase \* Capbase /(ηbase \* 100)) – (FLHeff \* Capeff / (ηeff \* 100))

Where:

FLHbase = LFbase \* Hours

FLHeff  = LFeff \* 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.

LFbase = load factor of baseline unit heater

= (Qinf,base + Qw,base + Qr,base)/(Capbase\*100)

LFeff = load factor of HTHVheater

= (Qinf,eff + Qw,eff + Qr,eff)/(Capeff\*100)

Capbase = existing heating unit input capacity (MBtu/hr)

= can be collected on site, or assumed to be the same as HTHV unit capacity, Capeff

Capeff = HTHV unit input capacity (MBtu/hr)

= can be collected on site or from specification sheets

ηbase = 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[[601]](#footnote-609)

ηeff = 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) | Tsetpoint = collected on site, or assumed as 65°F | |
| Ceiling Temperature[[602]](#footnote-610) (°F) | Either collected on site when the existing unit is in operation with an infrared gun, or assumed as:  Tc,base= Tsetpoint + 0.53°F/ft \* Height | Either collected on site when the proposed unit is in operation with an infrared gun, or assumed as:  Tc,eff = Tsetpoint + 2 to 4°F |
| Average Room Temperature (°F) | Tr,base= (Tsetpoint + Tc,base)/2 | Tr,eff= (Tsetpoint + Tc,eff)/2 |
| Outside Air Temperature (°F) | TOA , from local weather data[[603]](#footnote-611) | |
| Heat Loads | | |
| Infiltration Load[[604]](#footnote-612): | Qinf,base= 0.04CFM/ft2 \* (Wall Surface Area + Roof Surface Area) \* 1.08 \* (Tr,base - TOA) | Qinf,eff= 0.04CFM/ft2 \* (Wall Surface Area + Roof Surface Area) \* 1.08 \* (Tr,eff - TOA) |
| Wall Conduction Load[[605]](#footnote-613): | Qw,base = 1/R-valuewall \* (Wall Surface Area \* 1.08 \* (Tr,base - TOA)  Where R-valuewall = the insulation value of the wall. It can be collected on site, or assumed as R-15. | Qw,eff = 1/R-valuewall \* (Wall Surface Area \* 1.08 \* (Tr,eff - TOA)  Where R-valuewall = the insulation value of the wall. It can be collected on site, or assumed as R-15. |
| Roof Conduction Load: | Qr,base = 1/R-valueroof \* (Roof Surface Area \* 1.08 \* (Tr,base - TOA)  Where R-valueroof = the insulation value of the roof. It can be collected on site, or assumed as R-20. | Qr,eff = 1/R-valueroof \* (Roof Surface Area \* 1.08 \* (Tr,eff - TOA)  Where R-valueroof = 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[[606]](#footnote-614) = 41.4 sq. ft./MBtu/hr \* Capeff | |
| 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 \* Capeff | |

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.

| **Capeff (MBtu/hr)** | **Average Capeff (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 > Capeff ≥ 500 | 400 | Rockford | 3,120 | 1,996 | 1,620 |
| 500 > Capeff ≥ 900 | 757 | Rockford | 5,208 | 3,346 | 2,725 |
| 900 > Capeff ≥ 1,000 | 950 | Rockford | 6,280 | 4,047 | 3,297 |
| 1,000 > Capeff ≥ 1,400 | 1,200 | Rockford | 7,656 | 4,932 | 4,020 |
| 1,400 > Capeff ≥ 1,600 | 1,499 | Rockford | 9,249 | 5,966 | 4,872 |
| 1,600 > Capeff ≥ 2,100 | 1,850 | Rockford | 11,100 | 7,160 | 5,865 |
| 2,100 > Capeff ≥ 2,400 | 2,200 | Rockford | 12,914 | 8,338 | 6,820 |
| Capeff ≥ 2,400 | 2,718 | Rockford | 15,547 | 10,084 | 8,236 |
| 300 > Capeff ≥ 500 | 400 | Chicago | 2,820 | 1,824 | 1,488 |
| 500 > Capeff ≥ 900 | 757 | Chicago | 4,709 | 3,058 | 2,506 |
| 900 > Capeff ≥ 1,000 | 950 | Chicago | 5,681 | 3,696 | 3,031 |
| 1,000 > Capeff ≥ 1,400 | 1,200 | Chicago | 6,924 | 4,512 | 3,696 |
| 1,400 > Capeff ≥ 1,600 | 1,499 | Chicago | 8,364 | 5,456 | 4,482 |
| 1,600 > Capeff ≥ 2,100 | 1,850 | Chicago | 10,046 | 6,549 | 5,384 |
| 2,100 > Capeff ≥ 2,400 | 2,200 | Chicago | 11,682 | 7,634 | 6,292 |
| Capeff ≥ 2,400 | 2,718 | Chicago | 14,079 | 9,214 | 7,583 |
| 300 > Capeff ≥ 500 | 400 | Springfield | 2,452 | 1,588 | 1,300 |
| 500 > Capeff ≥ 900 | 757 | Springfield | 4,095 | 2,665 | 2,188 |
| 900 > Capeff ≥ 1,000 | 950 | Springfield | 4,950 | 3,221 | 2,651 |
| 1,000 > Capeff ≥ 1,400 | 1,200 | Springfield | 6,024 | 3,936 | 3,240 |
| 1,400 > Capeff ≥ 1,600 | 1,499 | Springfield | 7,285 | 4,767 | 3,912 |
| 1,600 > Capeff ≥ 2,100 | 1,850 | Springfield | 8,732 | 5,717 | 4,718 |
| 2,100 > Capeff ≥ 2,400 | 2,200 | Springfield | 10,164 | 6,666 | 5,500 |
| Capeff ≥ 2,400 | 2,718 | Springfield | 12,258 | 8,045 | 6,632 |
| 300 > Capeff ≥ 500 | 400 | Belleville | 2,456 | 1,604 | 1,320 |
| 500 > Capeff ≥ 900 | 757 | Belleville | 4,103 | 2,687 | 2,218 |
| 900 > Capeff ≥ 1,000 | 950 | Belleville | 4,950 | 3,249 | 2,689 |
| 1,000 > Capeff ≥ 1,400 | 1,200 | Belleville | 6,036 | 3,972 | 3,276 |
| 1,400 > Capeff ≥ 1,600 | 1,499 | Belleville | 7,300 | 4,812 | 3,972 |
| 1,600 > Capeff ≥ 2,100 | 1,850 | Belleville | 8,751 | 5,772 | 4,773 |
| 2,100 > Capeff ≥ 2,400 | 2,200 | Belleville | 10,186 | 6,732 | 5,566 |
| Capeff ≥ 2,400 | 2,718 | Belleville | 12,285 | 8,127 | 6,713 |
| 300 > Capeff ≥ 500 | 400 | Marion | 2,180 | 1,444 | 1,200 |
| 500 > Capeff ≥ 900 | 757 | Marion | 3,649 | 2,430 | 2,021 |
| 900 > Capeff ≥ 1,000 | 950 | Marion | 4,408 | 2,936 | 2,442 |
| 1,000 > Capeff ≥ 1,400 | 1,200 | Marion | 5,364 | 3,576 | 2,988 |
| 1,400 > Capeff ≥ 1,600 | 1,499 | Marion | 6,491 | 4,332 | 3,613 |
| 1,600 > Capeff ≥ 2,100 | 1,850 | Marion | 7,789 | 5,217 | 4,348 |
| 2,100 > Capeff ≥ 2,400 | 2,200 | Marion | 9,064 | 6,072 | 5,082 |
| Capeff ≥ 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

### Gas High Efficiency Single Package Vertical Air Conditioner

###### Description

This measure covers the installation of a single package vertical air conditional with a high efficiency gas furnace, referred to here as a through the wall (TTW) condensing gas furnace, instead of a standard efficiency gas furnace. The primary market served by TTWs are multifamily housing and hospitality in a new construction application. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, most of the flue gases condense and must be drained. Management of the acidic condensate is currently a major limiting factor for retrofit application, making the new construction the best initial market point until the industry develops better strategies for condensate management for retrofit applications. Also, TTWs are normally installed at the exterior wall to access outside air to reject heat in the cooling cycle. Placement of TTWs near the exterior might be prohibitive in retrofit applications. Furnaces equipped with ECM fan motors and with above code EER ratings provide an opportunity for additional electric energy savings.

This measure assumes unit size less than or equal to 65,000 Btu/hr.

This measure was developed to be applicable to the following program types: NC. If applied to other program types such as TOS or RF, the measure savings should be verified via a custom measure.

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an TTW condensing system with code minimum 9.0 EER cooling system (minimum code scheduled to increase to 11.0 EER on September 23, 2019) and a high-efficiency gas furnace with an annual fuel utilization efficiency (AFUE) of 90% or greater.3 Fan electrical efficiency must exceed the program requirements.4

###### Definition of Baseline Equipment

Baseline equipment for this measure are units with a cooling system that meets the current code minimum 9.0 EER efficiency rating and a heating unit with an AFUE rating of 80% or less.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16.5 years8.

###### Deemed Measure Cost

The incremental capital cost for this measure depends on efficiency as listed below9:

|  |  |
| --- | --- |
| **AFUE** | **Incremental Cost Premium** |
| 80% | $400 |
| 90% | $400 |
| 95% | $500 |

###### Loadshape

Loadshape R08 – Residential 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.4

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) 4

= 68%4

CFPJM = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)4

= 46.6%4

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

Electric savings come from a high efficiency cooling unit[[607]](#footnote-615). In some instances, the TTW unit provided by the manufacturer may not have higher efficiency cooling and fan blower motor systems integrated in to the TTW design; in these cases, electric energy savings will be zero for those components.

ΔkWhEER = FLHcool \* Capacity \* (1/EERbase - 1/EEReff) / 1000

Where:

FLHcool = Full load hours for cooling 5

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **FLHcool (multi family)** |
| 1 (Rockford) | 467 |
| 2 (Chicago) | 506 |
| 3 (Springfield) | 663 |
| 4 (Belleville) | 940 |
| 5 (Marion) | 820 |
| Weighted Average | 564 |

Capacity = Cooling capacity of the efficient unit in Btu/hr

= Actual installed

EEReff = Energy efficiency ratio of the efficient equipment

= Actual installed rating

EERbase = Energy efficiency ratio of the baseline equipment – Presently, the federal minimum efficiency level is 9.0 EER, increasing to 11.0 EER on September 23, 20196

= 9.0

***Example***: for a Rockford non-weatherized multifamily unit conditioned by a SPVAC with a 2-ton (24,000 Btu/hr) cooling capacity, a rated EER of 11.0, and an ECM fan blower motor installed.

ΔkWh = [467 \* 24,000 \* (1/9.0 – 1/11.0) / 1000] = 958 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = CF \* Capacity \* (1/EERbase - 1/EEReff) / 1000

Where:

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) 4

= 68%4

CFPJM = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)4

= 46.6%4

###### Natural Gas Savings

ΔTherms = EFLHheat \* Capacity \* (AFUEeff – AFUEbase) / AFUEbase / (100,000 Btu/Therm)

Where

EFLHheat = Equivalent Full Load Hours for heating7

|  |  |
| --- | --- |
| **Climate Zone**  **(City based upon)** | **EFLHheat** (general multi family) |
| 1 (Rockford) | 1,666 |
| 2 (Chicago) | 1,685 |
| 3 (Springfield) | 1,450 |
| 4 (Belleville) | 1,067 |
| 5 (Marion) | 1,216 |

Capacity = Nominal heating input capacity furnace size (Btu/hr) for efficient unit

= Actual

AFUEeff = Efficient furnace annual fuel utilization efficiency rating

= Actual installed rating

AFUEbase = Baseline furnace annual fuel utilization efficiency rating

= 80%

For example for a Chicago non-weatherized multifamily unit heated by an SPVAC with a 40 kBtu/hr capacity and a rated AFUE of 93%.

ΔTherms = 1,685\* 40,000 \* [(0.93 – 0.8)/0.8] / (100,000 Btu/Therm) = 110 therms

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC -SPVA-V01-190101

###### Review Deadline: 1/1/2023

### Advanced Rooftop Controls (ARC)

###### Description

The Advanced Rooftop Controls (ARC) measure installs demand-controlled ventilation with optional supply-fan speed control via a variable-frequency drive to a single-zone, packaged HVAC unit with a functioning integrated economizer already installed. The demand-controlled ventilation modulates the outside air damper based on CO2 concentration in the conditioned space. The supply-fan speed control options consist of setting the fan speed to 40% in ventilation mode and to 90% in heating and cooling modes, or of setting the fan speed to 40% in ventilation mode, to 75% in 1st stage heating and 1st stage cooling modes, and to 90% in 2nd stage heating and 2nd stage cooling modes. The measure results in fan, cooling, and heating savings compared to a baseline scenario of constant-volume, constant-ventilation operation typical of single-zone, packaged HVAC units. There are a number of off-the-shelf products available for the packaged HVAC unit market that support these control sequences, and the energy savings potential of these strategies has been studied and reported on.[[608]](#footnote-616)

Demand-controlled ventilation modulates the percentage of outside air that is delivered to a space and its occupants by controlling the position of the outside air damper. The outside air damper is set to the minimum position required for the space, and is opened further when CO2 concentration in the conditioned space increases, which indicates an increase in occupancy. The damper also opens to provide 100% outside air cooling (i.e., the unit economizes) when conditions permit. This portion of the measure saves energy by minimizing the energy required to unnecessarily heat and cool outside air. Demand-controlled ventilation can also be combined with the installation of a variable-frequency drive on the supply fan. This drive is used to reduce the speed of the supply fan when the full design airflow is not required. When the unit is only providing ventilation air (i.e., not heating or cooling), the airflow is reduced substantially, but not below the required minimum ventilation rate. The flow for heating and cooling can also be reduced a small amount in most cases. Per the fan affinity laws, the reduction in flow correlates to a near cubic reduction in fan power. In these ways, this measure is able to achieve cooling, heating, and fan energy reduction.

This measure is intended for commercial buildings served by single-zone, packaged HVAC units. This measure was developed to be applicable to the following program types: RF, DI

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

###### Definition of Efficient Equipment

The efficient equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that has been retrofitted with demand-controlled ventilation controls with optional supply-fan speed control via a variable-frequency drive.

###### Definition of Baseline Equipment

The baseline equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that lacks demand-controlled ventilation controls and lacks supply-fan speed control via a variable-frequency drive.

###### Deemed Lifetime of Efficient Equipment

The deemed measure life is 10 years and based on CO2 sensor estimated life.[[609]](#footnote-617)

###### Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used.

Table 1 – Deemed Measure Cost Details

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure** | **Material Unit (Each)** | **Material Cost / Unit** | **Labor Unit (Hours)** | **Labor Rate/ Unit** | **Total Cost** |
| DCV | 1 | $1,663.90 | 3 | $96.67 | $1,953.91 |
| DCV and VFD with two speed modes (40% ventilating & 90% heating/cooling) | 1 | $3,025.38 | 4 | $96.67 | $3,412.06 |
| DCV and VFD with three speed modes (40% ventilating, 75% 1st stage heating/cooling & 90% 2nd stage heating/cooling) | 1 | $3,487.00 | 4 | $96.67 | $3,873.68 |

###### Loadshape

Commercial ventilation C23

###### Coincidence Factor

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[610]](#footnote-618)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[611]](#footnote-619)

Algorithm

###### Calculation of Energy Savings

To determine the savings associated with the Packaged RTU Sealing measure we utilized the available IL TRM prototype eQuest models which were initially created by the Energy Center of Wisconsin[[612]](#footnote-620) but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update). These models which were used are the most up-to-date versions and are readily available on the [VEIC SharePoint site](https://portal.veic.org/projects/illinoistrm/default.aspx), under the [TRM Reference Documents Section](https://portal.veic.org/projects/illinoistrm/Shared%20Documents/Forms/AllItems.aspx?RootFolder=%2Fprojects%2Fillinoistrm%2FShared%20Documents%2FTRM%20Reference%20Documents%2FCommercial%20and%20Industrial%2FeQuest%20Models&FolderCTID=0x01200042B0ABF3AA22EE4888A0EDE62AB5CED4&View=%7B3B648E32-B974-4835-A799-C5C522F1EBE9%7D).

Upon examination of the ComEd building prototype models we found several of the baseline models did not have packaged single zone (PSZ) units. This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, we chose only models that: 1) utilized PSZ HVAC systems, and 2) aligned with the small commercial building type applicable to this measure. Once the ComEd baseline models were selected, we determined several modifications were necessary to the prototype models in order to represent the baseline scenario for this measure:

1. Multistage PSZ HVAC System with Constant Volume Supply Fan
2. Optimized Economizer Controls by Climate Zone
   1. Economizer Changeover Type – Set to fixed Dry Bulb
   2. Economizer High-Limit Control Setpoints – Setpoints based on ASHRAE Climate Zones Fixed Dry Bulb Temperature recommendations.
   3. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

Additionally, a number of the building prototype models were found to have supply fan total static pressure modeled inputs that seem excessive and atypical for packaged single zone rooftop units – these included Convenience Store (5 in. wc), Manufacturing Facility (5 in. wc), Office Low Rise (5 in. wc), Religious Building (5 in. wc), and Restaurant (5 in. wc). The remaining models had supply fan total static pressure inputs more in line with what we would expect to find for packaged single zone rooftop units, ranging from 1.3 to 2 in. wc. For each model having a supply fan total static pressure above 2 in. wc, model inputs were adjusted to set these to 2 in. wc. To implement the modifications shown above, changes were made to eQUEST keywords in the ComEd prototype models as shown in the following table. Hard-coded system capacities and supply airflows can be found in the attached “Advanced Rooftop Controls\_End Use Analysis\_IL TRM.xlsx” spreadsheet.

Table 2 – Prototype Modifications to eQuest Keywords

|  |  |  |  |
| --- | --- | --- | --- |
| **Component Adjusted** | **eQuest Keyword** | **IL TR Value** | **Modified Prototype Value** |
| System - System Type | SYSTEM:TYPE | PSZ | PVVT |
| System - Airflow and Temperature Control | SYSTEM:AIR/TEMP-CONTROL | N/A | STAGED-VOLUME |
| System – Supply Fan Total Static Pressure | SYSTEM:SUPPLY-STATIC | Varies | If >2: 2  Else: IL TR Value |
| System - Cooling and Heating Capacities | SYSTEM:COOLING-CAPACITY  SYSTEM:HEATING-CAPACITY | Auto-sized | Hard-coded (after retrieving auto-sized outputs) |
| System - Supply Fan Control | SYSTEM:FAN-CONTROL | Varies | CONSTANT-VOLUME |
| System - Supply Fan Ratios | SYSTEM:MIN-FLOW-RATIO  SYSTEM:CMIN-FLOW-RATIO  SYSTEM:HMIN-FLOW-RATIO  SYSTEM:-MAX-FAN-RATIO | N/A | 1 |
| System - Supply Airflow | SYSTEM:SUPPLY-FLOW | Auto-sized | Hard-coded (after retrieving auto-sized outputs) |
| Economizer - Changeover Type | SYSTEM:OA-CONTROL | Fixed | Single Dry-Bulb |
| Economizer - Changeover Setpoint | SYSTEM-ECONO-LIMIT-T | Varies | ASHRAE 90.1 – High-Limit Shutoff Control Settings:  ASHRAE CLIMATE ZONE – 4A = 70°F  ASHRAE CLIMATE ZONE – 5A = 65°F |
| Economizer - Integrated Operation | SYSTEM:ECONO-LOCKOUT | Yes | No |

Further modifications were then made to these baseline models in order to simulate the following measure scenarios:

1. Demand-controlled ventilation (DCV) controls
2. DCV and supply fan variable frequency drive (VFD) with two fan speed modes
   1. 40% fan speed for ventilating
   2. 90% fan speed for heating and cooling
3. DCV and supply fan VFD with three fan speed modes
   1. 40% fan speed for ventilating
   2. 75% fan speed for 1st stage heating and cooling
   3. 90% fan speed for 2nd and higher stage heating and cooling

The eQuest modifications from the baseline models to represent these measure scenarios are shown in the following table. Full modeled energy end use and savings summaries can be found in the attached “Advanced Rooftop Controls\_End Use Analysis\_IL TRM.xlsx” spreadsheet.

Table 3 – Baseline and Measure Scenario eQuest Keywords

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component Adjusted** | **eQuest Keyword** | **Baseline Value** | **Measure Scenario Values** | | |
| **1** | **2** | **3** |
| System - Minimum Outside Air Control | SYSTEM:MIN-OA-METHOD | Fraction of Design Flow | DCV Return Sensor | DCV Return Sensor | DCV Return Sensor |
| System - Supply Airflow | SYSTEM:SUPPLY-FLOW | Hard-coded | 1.0 × Hard-coded value | 0.9 × Hard-coded value | 0.9 × Hard-coded value |
| System - Supply Fan Control | SYSTEM:FAN-CONTROL | CONSTANT-VOLUME | CONSTANT-VOLUME | FAN-EIR-FPLR | FAN-EIR-FPLR |
| System - Supply Fan Ratios | SYSTEM:MIN-FLOW-RATIO  SYSTEM:CMIN-FLOW-RATIO  SYSTEM:HMIN-FLOW-RATIO  SYSTEM:-MAX-FAN-RATIO | 1  1  1  1 | 1  1  1  1 | 0.44\*  1  1  1 | 0.44\*  0.83\*\*  0.83\*\*  1 |

\*Since the total supply flow is limited by 0.9 of the baseline, a value of 0.44 for the minimum flow ratio results in a 40% fan speed: 0.4/0.9=0.44  
\*\* Since the total supply flow is limited by 0.9 of the baseline, a value of 0.83 for the minimum heating/cooling flow ratios results in a 75% fan speed: 0.75/0.9=0.83

With these modifications in place each scenario was simulated in eQuest for each chosen IL TRM prototype building type across the five TRM climate zones. Whole building electric and gas savings were determined from the simulation output and are presented in the following sections. Electric savings have been normalized by cooling tons and heating savings by furnace kBtuh output.

###### Electric Energy Savings

ΔkWh = (tons) × Normalized Electric Energy Savings

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

Normalized Electric Energy Savings

= kWh/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Electric Energy Savings Summary (kWh/ton)

Table 4 – Electric Energy Savings Summary (kWh/ton)



For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

ΔkWh = (10 tons) × (1,131.8 kWh/ton)

= 11,318 kWh

###### Summer Coincident Peak Demand Savings

ΔkWssp = (tons) × Normalized Electric Peak Demand Savings × CFssp

ΔkWpjm = (tons) × Normalized Electric Peak Demand Savings × CFpjm

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[613]](#footnote-621)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[614]](#footnote-622)

Normalized Electric Peak Demand Savings

= kW/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 5 – Electric Peak Demand Savings Summary (kW/ton)

Table 5 – Electric Peak Demand Savings Summary (kW/ton)



For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes) using the Summer System Peak Coincidence Factor:

ΔkW = (10 tons) × (0.346 kW/ton) × 91.3%

= 3.159 kW

###### Natural Gas Savings

ΔTherms = (kBtuh output) × Normalized Gas Energy Savings

Where:

kBtuh = heating output of the gas furnace in kBtuh

=Actual

Normalized Gas Energy Savings

= Therms/kBtuh output savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 6 – Gas Energy Savings Summary (Therms/kBtuh output)

Table 6 – Gas Energy Savings Summary (Therms/kBtuh output)



For example, a rooftop unit with a 148 kBtuh output gas furnace on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

ΔkWh = (148 kBtuh) × (0.9 Therms/kBtuh output)

= 133.2 Therms

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-ARTC-V01-190101

###### Review Deadline: 1/1/2023

### Advanced Thermostats for Small Commercial

###### Description

This measure characterizes the energy savings from the installation of an “Advanced Thermostat” for reduced heating and cooling consumption in a small commercial building. Advanced thermostats use a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.

The thermostat must be installed to control a single-zone HVAC system. This measure is limited to packaged HVAC units 5 tons or less. Systems larger will likely require more sophisticated controls to meet code requirements.

This class of products and services are relatively new, diverse, and rapidly changing. The savings associated with commercial installations of advanced thermostats have not been evaluated. In the absence of commercial specific assumptions, this TRM provides a deemed estimate based on the average residential savings. This is considered a reasonable starting assumption since the eligibility is limited to residential sized equipment and although on average commercial systems may be larger, it is predicted that reduced savings percentage will result in a similar average savings. It is highly recommended that the application of Advanced Thermostats in commercial settings be evaluated for future revisions.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

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

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

###### Definition of Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

###### Definition of Baseline Equipment

The baseline is either the actual type (manual or programmable) if it is known, or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed.

###### Deemed Lifetime of Efficient Equipment

The expected measure life for advanced thermostats is assumed to be 11 years[[615]](#footnote-623).

###### Deemed Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. If unknown then the average incremental cost for the new installation measure is assumed to be $175.

###### Loadshape

Loadshape C05 - Commercial Electric Heating and Cooling, or

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [[616]](#footnote-624)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [[617]](#footnote-625)

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

Deemed savings are provided based upon the average savings from the Residential version of this measure. Future evaluation on savings percentages for commercial applications should be used to improve this assumption.

ΔkWh[[618]](#footnote-626) = ΔkWhheating + ΔkWhcooling

ΔkWhheating = %ElectricHeat \* Elec\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR + (∆Therms \* Fe \* 29.3)

ΔkWhcool = %AC \* ((FLH \* Btu/hr \* 1/SEER)/1000) \* Cooling\_Reduction \* Eff\_ISR

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

ΔkWhheating = 0.065 \* 15,678 \* 0.074 \* 1 \* 1 + (66.1 \* 0.0314 \* 29.3)

= 136.2 kWh

ΔkWhcool = 1.0 \* ((629 \* 33600 \* 1/8.6) / 1000) \* 0.061 \* 1

= 149.9 kWh

ΔkWh = 136.2 + 149.9

= 289.1 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = %AC \* (Cooling\_Reduction \* Btu/hr \* (1/EER))/1000 \* EFF\_ISR \* CF

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [[619]](#footnote-627)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [[620]](#footnote-628)

ΔkWSSP = 1.0 \* (0.061 \* 33600 \* (1/8.6))/1000 \* 1.0 \* 0.457

= 0.1089 kW

ΔkWPJM = 1.0 \* (0.061 \* 33600 \* (1/8.6))/1000 \* 1.0 \* 0.239

= 0.0570 kW

###### Natural Gas Savings

∆Therms = %FossilHeat \* Gas\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR

For basis of values, see Residential measure 5.3.16.

∆Therms = 0.935 \* 955 \* 0.074 \* 1 \* 1

= 66.1 Therms

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-ADTH-V01-190101

###### Review Deadline: 1/1/2020

### Packaged RTU Sealing

###### Description

The HVAC Packaged RTU Sealing Measure targets areas of the RTU that are readily accessible and can be easily sealed. By sealing the following areas, the amount of uncontrolled infiltration will be reduced leading to increased occupant comfort and an overall reduction in energy use.

The measure seeks to target the following three areas for sealing.

1. Economizer Hood – Seal the interior and exterior seams that connect the economizer to the RTU using UL listed metal tape and/or silicone caulking.
2. RTU Curb – Seal supply and return duct seams inside of RTU with mastic along with any leaks that are found around the perimeter of the roof to RTU connection using UL listed metal tape and/or silicone caulking.
3. Non-Removable Cabinet Panels – Seal all cabinet seams that are not typically removed during basic service (i.e. control panel) using UL listed metal tape and/or silicone caulking.

Uncontrolled infiltration of non-conditioned outside air (OSA) is a known issue for packaged rooftop units (RTU). This leakage can occur thru the curb, economizer assembly connection and cabinet panels. This leakage not only influences occupant comfort but also increases energy usage by increasing the heating and cooling loads while also reducing the unit’s operating energy efficiency.

Prior to a recently released laboratory and field study developed by Robert Mowris & Associates, Inc.[[621]](#footnote-629) the energy effects of uncontrolled infiltration thru cabinet leakage were difficult to quantify. However, this study determined that uncontrolled OSA infiltration not only increases the amount of energy to condition the excess air but also reduces the unit’s operating efficiency (EER) by 5.4%. By reducing the amount of uncontrolled OSA infiltration through RTU sealing the unit’s operating efficiency (EER) can be increased reducing the amount of cooling energy.

This measure is only appropriate for packaged single zone rooftop units. Custom calculations are required for savings for built up air handling units or packaged multizone systems.

###### Definition of Efficient Equipment

The efficient equipment condition is assumed to be a packaged HVAC system that has had the Economizer Hood, Curb and Non-Access Cabinet Panels Sealed.

###### Definition of Baseline Equipment

The baseline equipment condition is assumed to be an operational packaged HVAC system that has not been previously sealed. The packaged HVAC systems must be single zone and must have a functioning economizer.

###### Deemed Lifetime of Efficient Equipment

Because the measure targets existing packaged RTU units, the deemed lifetime of the measure is assumed to be 5 years[[622]](#footnote-630).

###### Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available the deemed measure cost below listed below can be used. The deemed measure costs are detailed for each individual RTU.

| **Measure** | **Material Unit** | **Material Cost / Unit** | **Labor Unit (Hours)** | **Labor Rate / Unit** | **Total Cost** |
| --- | --- | --- | --- | --- | --- |
| HVAC Packaged RTU Sealing | 1 | $48.99 | 1.5 | $97 | $194.49 |

###### Loadshape

Loadshape C03 - Commercial Cooling

###### Coincidence Factor

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[623]](#footnote-631)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[624]](#footnote-632)

Algorithm

###### Calculation of Energy Savings

To determine the savings associated with the Packaged RTU Sealing measure available IL TRM prototype eQuest models, which were initially created by the Energy Center of Wisconsin[[625]](#footnote-633) but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update, were utilized. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update).

This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, only models that had the following characteristics were chosen: 1) Packaged-Single Zone (PSZ) HVAC systems; and 2) aligned with the small commercial building type applicable to this measure. Several modifications to the models was necessary in order to simulate a functioning airside economizer, which is assumed to be present in the baseline scenario for this measure:

1. Optimized Economizer Controls by Climate Zone
   1. Economizer Changeover Type – Set to fixed Dry Bulb
   2. Economizer High-Limit Control Setpoints – Setpoints based on ASHRAE Climate Zones Fixed Dry Bulb Temperature recommendations.
   3. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

To determine the energy use associated with an unsealed RTU the prototype models were modified using the associated reduction in efficiency reported in a Robert Mowris and Associates, Inc. study[[626]](#footnote-634) that was performed for the California Public Utilities Commission in 2016. For further detail on the full modeled energy end use and savings summaries, see: “Packaged RTU Sealing\_End Use Analysis.xlsx” spreadsheet.

After analyzing the modeled cooling annual energy usage for both the baseline (unsealed) and measure (sealed) model scenarios it was determined that the building type and climate zone variables had a minimal impact on the overall energy savings associated with the measure. As a result, the overall average savings factor of 6.11% was deemed applicable for any small commercial building type across all climate zones. This single savings value used in conjunction with the energy and demand savings calculations listed in the following sections will allow the savings to be calculated based on the unit size and equivalent full load hours listed in the Illinois Technical Resource Manual (TRM).

###### Electric Energy Savings

ΔkWh = (kBtu/hr) / EERbefore \* EFLH \* %Savings

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 6.11%[[627]](#footnote-635)

EFLHcooling = IL TRM v6 Equivalent Full Load Hours (EFLH) for cooling are provided in the following table

| **Building Type** | **Cooling EFLH** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Assembly | 725 | 796 | 937 | 1,183 | 932 |
| Assisted Living | 1,475 | 1,457 | 1,773 | 2,110 | 1,811 |
| College | 475 | 481 | 662 | 746 | 806 |
| Conditioned Storage (Warehouse) | 357 | 338 | 422 | 647 | 533 |
| Convenience Store | 1,088 | 1,067 | 1,368 | 1,541 | 1,371 |
| Garage | 934 | 974 | 1,226 | 1,582 | 1,383 |
| Grocery | 1,033 | 1,000 | 1,236 | 1,499 | 1,286 |
| Manufacturing Facility | 1,010 | 1,055 | 1,209 | 1,453 | 1,273 |
| Office - Low Rise | 949 | 1,010 | 1,182 | 1,452 | 1,281 |
| Religious Building | 861 | 817 | 967 | 1,159 | 1,067 |
| Restaurant | 1,074 | 1,134 | 1,279 | 1,627 | 1,325 |
| Retail - Department Store | 949 | 889 | 1,124 | 1,367 | 1,157 |
| Retail - Strip Mall | 950 | 919 | 1,149 | 1,351 | 1,215 |

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives packaged RTU sealing:

ΔkWh = (5\*12) / 12 \* 949 \* 6.11%

= 289.9 kWh

###### Summer Coincident Peak Demand Savings

ΔkWssp = (kBtu/hr) / EERbefore \* %Savings \* CFssp

ΔkWpjm = (kBtu/hr) / EERbefore \* %Savings \* CFpjm

Where:

kBtu/hr = Capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 6.11%

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[628]](#footnote-636)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[629]](#footnote-637)

For example, a 12 EER 5-ton rooftop air conditioner using the Summer System Peak Coincidence Factor receives RTU sealing:

ΔkW = (5\*12) / 12 \* 6.11% \* 91.3%

= 0.279 kW

###### 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-HVC-PRTU-V01-190101

###### Review Deadline: 1/1/2023

### Efficient Thermal Oxidizers

###### Description

Thermal Oxidizers are used to destroy volatile organic compounds (VOCs) from process exhausts, before emitting the treated air to the environment. VOC emissions are precursors to the formation of ground-level ozone pollution, and its control is mandated by the U.S. EPA. Some VOC constituents are individually toxic and require efficient destruction. Some waste streams have high enough concentrations to present an explosion hazard. Other waste streams merely present nuisance odors that need to be mitigated.

A facility may be required to utilize a Thermal Oxidizer by a state regulatory agency air quality permit. Some permits may require a VOC destruction efficiency that must be demonstrated with periodic emissions testing. Other permits merely require maintaining an oxidizer chamber temperature. A facility may also choose to utilize a Thermal Oxidizer for other purposes (nuisance odors), without a regulatory requirement.

The Efficient Thermal Oxidizer measure seeks to evaluate natural gas savings from utilizing more efficient means for VOC destruction with the use of a recuperative or regenerative thermal oxidizer. The heat recovery (either Recuperative or Regenerative) is used to pre-heat the inlet process air stream. This primary heat recovery is used within the thermal oxidizer process and the only heat recovery that is covered in this measure protocol. Natural gas savings will result from reduced burner firing. There is a “secondary” form of heat recovery that recovers heat from the combustion exhaust stack for other purposes like space heating, DHW heating, etc.

###### Definition of Efficient Equipment

Two Thermal Oxidizer technologies can be considered as efficient equipment: Recuperative and Regenerative.

Recuperative Thermal Oxidizer

In a Recuperative Thermal Oxidizer, the exhaust air stream is sent through a heat exchanger to indirectly pre-heat the inlet air stream coming from the process. The heat exchanger efficiency[[630]](#footnote-638) for a recuperator is typically 50-70%. The chamber temperature is typically 1400 oF to 1500 oF.

Regenerative Thermal Oxidizer

A Regenerative Thermal Oxidizer utilizes a two-chamber ceramic bed as its heat exchanger system. The exhaust air passes through one bed, imparting its heat onto the ceramic media, while the intake air passes through the other bed, capturing the waste heat from the previous cycle. The flow reverses every few minutes so that the intake bed becomes the exhausted bed and vice versa. The heat exchanger efficiency of a regenerative system is much higher than a recuperative system. These efficiencies[[631]](#footnote-639) can reach 85% to 97%. However, the ceramic media needs to be periodically cleaned or replaced. The chamber temperatures in Regenerative Thermal Oxidizers are typically 1,500 oF to 1,600 oF (depending on VOC requirements).

###### Definition of Baseline Equipment

Depending on the facility process, there may be two baseline selection options: incinerator or recuperator.

The baseline Thermal Oxidizer with no heat recovery is referred to as an Incinerator. This baseline is recommended for selection if it currently exists on site or in new construction when there is a specific process that cannot practically utilize a recuperator due to VOCs coating or clogging the heat exchanger. This system employs a burner to provide direct fire to a process exhaust air stream. Typical operative temperatures are 1400 oF to 2200 oF. The advantage of an afterburner is a quick startup and shutdown time that is ready on demand. The equipment cost is lower than the efficient equipment, but the fuel consumption is much higher.

In all other cases, (existing equipment is recuperative or new construction/ expansion of manufacturing process), a recuperative thermal oxidizer is recommended as the appropriate baseline.

###### Deemed Lifetime of Efficient Equipment

The expected useful life of any thermal oxidizer system is assumed to 20 years.[[632]](#footnote-640)

###### Deemed Measure Cost

###### The cost[[633]](#footnote-641) of any thermal oxidizer is dependent on various variables such as air flow capacity, destruction efficiency, heat exchanger efficiency, etc. Shown below is an example of a system for 20,000 CFM.

Recuperative Thermal Oxidizer costs, based on their heat recovery efficiency, is detailed in the table below.

|  |  |
| --- | --- |
| **Heat Recovery Efficiency** | **Equipment Cost** |
| 0% | $106,042 |
| 35% | $174,193 |
| 50% | $203,801 |
| 70% | $253,801 |
| Average | $184,317 |

Regenerative Thermal Oxidizer, at 95% heat recovery, have a deemed cost of $546,000.

Incinerator cost is treated as 0% heat recovery in the Recuperative Cost summary table above, and has a deemed cost of $106,042.

###### Loadshape

N/A

###### Coincidence Factor

N/A

Algorithm

###### Calculation of Energy Savings

Energy savings from thermally efficient equipment are entirely natural gas related. There are no electricity savings nor peak demand savings, as the blower fans and valve actuators are assumed to operate the same in all conditions.

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

ΔTherms = ((Baseline QT Air Pollution Control Device - Proposed QT Air Pollution Control Device) x Hours) / LHV

Where:

LHV = Latent Heat of Vaporization

= If the post is regenerative thermal oxidizer, LHV = 0.953.

= If the post is recuperative thermal oxidizer, LHV = 1.

Regenerative or Recuperative: A baseline or proposed Regenerative or Recuperative Air Pollution Control Device can each be modeled in the following heat balance equation[[634]](#footnote-642):

QT (BTU/hr) = QI + QCC + QRL – QVOC

Incinerator: A baseline incinerator Air Pollution Control Device can be modeled as the following heat balance equation:

QT (BTU/hr) = QI + QCC + QRL

Where:

QT = Total Energy Input

QI = Energy used to raise the temperature of process air (FI) in BTU/hr

QCC = Heat used to raise the temperature of combustion air (FCC)

QRL = Radiation heat loss from RTO (BTU/hr)

QVOC = Heat release provided by VOC combustion

Hours = Annual hours per year that Oxidizer is used

Where:

QI = FI X 1.08 x (TO – TI)

TO = Average stack outlet temperature (°F) (actual trended average or use efficiency equation below to solve for TO under assumed conditions)

TO = TC - (N X (TC - TI) X FI / (FI + FCC)

TC = Combustion chamber temperature (°F), trended or design value provided by the manufacturer

N = Thermal Efficiency of Heat Exchanger

|  |  |
| --- | --- |
| **Thermal Oxidizer** | **Efficiency** |
| Regenerative | 97% |
| Recuperative | 70% |
| Incinerator | 0% |

TI = Inlet air temperature (°F), this is the temperature of the air coming from the process

FI = Process air (CFM), actual loading or use maximum design value

1.08 = Conversion Factor

= 60 (min/hr) x 0.07489 (lb/ft3, density air at standard conditions) x 0.2404 Btu/°F-lb, (specific heat of air), where 0.2404 is average heat capacity of intake air

Where:

QCC = FCC X 1.08 X (TO – TA)

FCC = Additional combustion air CFM at provided FI value

= If unknown, assume 3% of design value[[635]](#footnote-643)

TO = Average outlet temperature (°F) (same as above)

TA = Combustion intake air temperature (°F)

= Indoor: Actual, or assume 70 °F year-round

= Outdoor: Actual annual average found near the facility, or assume TMY3 annual averages:

|  |  |
| --- | --- |
| **Region / Area** | **Average Outdoor Air Temperature** |
| Chicago O'Hare | 50.0 °F |
| Chicago Midway | 52.5 °F |
| Rockford Airport | 47.6 °F |

Where:

QRL = SA x BTU/hr radiant loss

SA = Surface Area (provided by the manufacturer or rough measurements taken)

BTU/hr radiant loss = Assume 240 BTU/hr if installed outdoors, otherwise, 0 BTU/hr for indoor installation since the waste heat provides space heating and offset gas-fired space heating equipment

Where:

QVOC = VOC X HC X (% Dest / 100)

VOC = Average lbs/hr from process to oxidizer

HC = Btu/lb, weighted average for the heat of combustion of VOCS

= Site-specific, lookup table

% Destruction = Destruction efficiency of VOCs provided by the manufacturer, or use:

Hours = Annual hours of operation of the air pollution control device, assume customer production schedule or hours of occupancy

LHV = Lower heating value of natural gas

= 983 BTU/CF[[636]](#footnote-644)

HHV = High heating value of natural gas

= 1,031 BTU/CF[[637]](#footnote-645)

0.953 = LHV / HHV conversion factor

To calculate the natural gas savings by upgrading from an incinerator to an Efficient Thermal Oxidizer system, the new temperatures must be considered. The addition of heat recovery (either Recuperative or Regenerative) will increase the inlet temperature, TI, above that found in the facility.

The calculation should consider changes in the inlet temperature. First, the key temperature required for 99.99% destruction efficiency of various VOC compounds must be determined. The U.S. EPA’s Innovative Strategies and Economics Group produced some guidance on the key temperatures[[638]](#footnote-646) for the following compounds:

|  |  |
| --- | --- |
| **VOC Compound** | **Key Destruction Temperature (°F)** |
| Acrylonitrile | 1,344 |
| Allyl chloride | 1,276 |
| Benzene | 1,350 |
| Chlorobenzene | 1,407 |
| 1,2 – dichloromethane | 1,368 |
| Methyl chloride | 1,596 |
| Toluene | 1,341 |
| Vinyl chloride | 1,369 |

For VOC compounds not listed above, the Key Destruction Temperature should be determined through product literature, equipment vendors, Material Data Safety Sheets (MSDS), or some other source.

When employing heat recovery, either Recuperative or Regenerative, the increased outlet temperature is limited to the heat exchanger efficiency. This efficiency, or in other words how much heat can be recovered, is limited to the auto-ignition temperatures of the VOCs in the air stream. Regenerative Thermal Oxidizers offer the advantage of recovering more heat as the combustion can occur within the heat exchanger, whereas with Recuperative Thermal Oxidizers, the heat exchanger efficiency is much lower to prevent premature combustion in the stack of the recuperator.

While the VOCs in the waste air stream have some heating value that contributes to reaching the required chamber temperature, such contributions do not have as high of an impact in the overall energy consumption calculation when compared to the heat exchanger efficiency.

###### Water and Other Non-Energy Impact Descriptions and Calculation

Thermal oxidizer operations will have no impact on water or other resources. There may be some safety issues with potential burning hazards from deploying this equipment at high temperatures. There may also be some potential issues with installing outdoor natural gas piping to the location of the Thermal Oxidizers. In terms of physical sizing, regenerative thermal oxidizers are much larger, thus requiring larger physical space at the site of installation.

###### Deemed O&M Cost Adjustment Calculation

The ceramic media in the regenerative thermal oxidizer requires regular servicing and may need to be considered as a regular part of facility O&M.

###### Measure Code: CI-HVC-ETOX-V01-190101

###### Review Deadline: 1/1/2023

### Commercial Ground Source Heat Pump

###### Description

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

1. New Construction:
   1. The installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new C&I building.
   2. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.
2. Time of Sale:
   1. The planned installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section C below.
   2. Note the baseline in this case is an equivalent replacement system to that which exists currently in the building. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   3. DHW savings are calculated based upon the fuel and efficiency of the existing unit.
3. Early Replacement/Retrofit:
   1. The early removal of functioning electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   2. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   3. DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   4. Early Replacement determination will be based on meeting the following conditions:
      * The existing unit is operational when replaced, or
      * The existing unit requires minor repairs to be operational, defined as costing less than[[639]](#footnote-647):

|  |  |
| --- | --- |
| **Existing System** | **Maximum repair cost** |
| Air Source Heat Pump | $263/ton |
| Chiller | $308/ton |
| Boiler (Steam) | $3.87/ kBtu |
| Boiler (Hot Water) | $4.25/ kBtu |
| Furnace | $2.49/ kBtu |
| Ground Source Heat Pump | $2,185/ton |

* + - All other conditions will be considered Time of Sale.

The Baseline efficiency of the existing unit replaced:

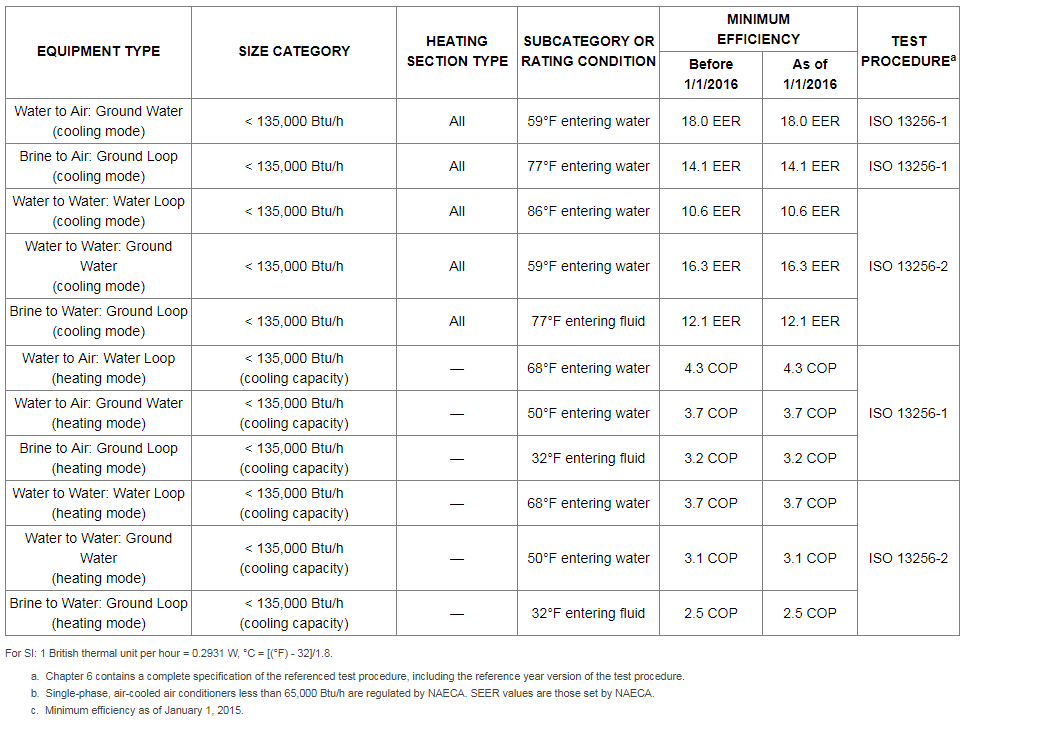
* + - Use actual existing efficiency whenever possible.
    - If the efficiency of the existing unit is unknown, use assumptions based on the federal minimum standards provided in tables below.
    - If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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. For best practices of Ground Source Heat Pump installations, see the Technical Advisory Committee Sharepoint resources.[[640]](#footnote-648)

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum IECC 2015 efficiency level standards effective at the time of installation as detailed below:

**IECC 2015 Minimum Requirements GSHP ENERGY STAR Requirements (Effective January 1, 2012[[641]](#footnote-649))**



###### Definition of Baseline Equipment

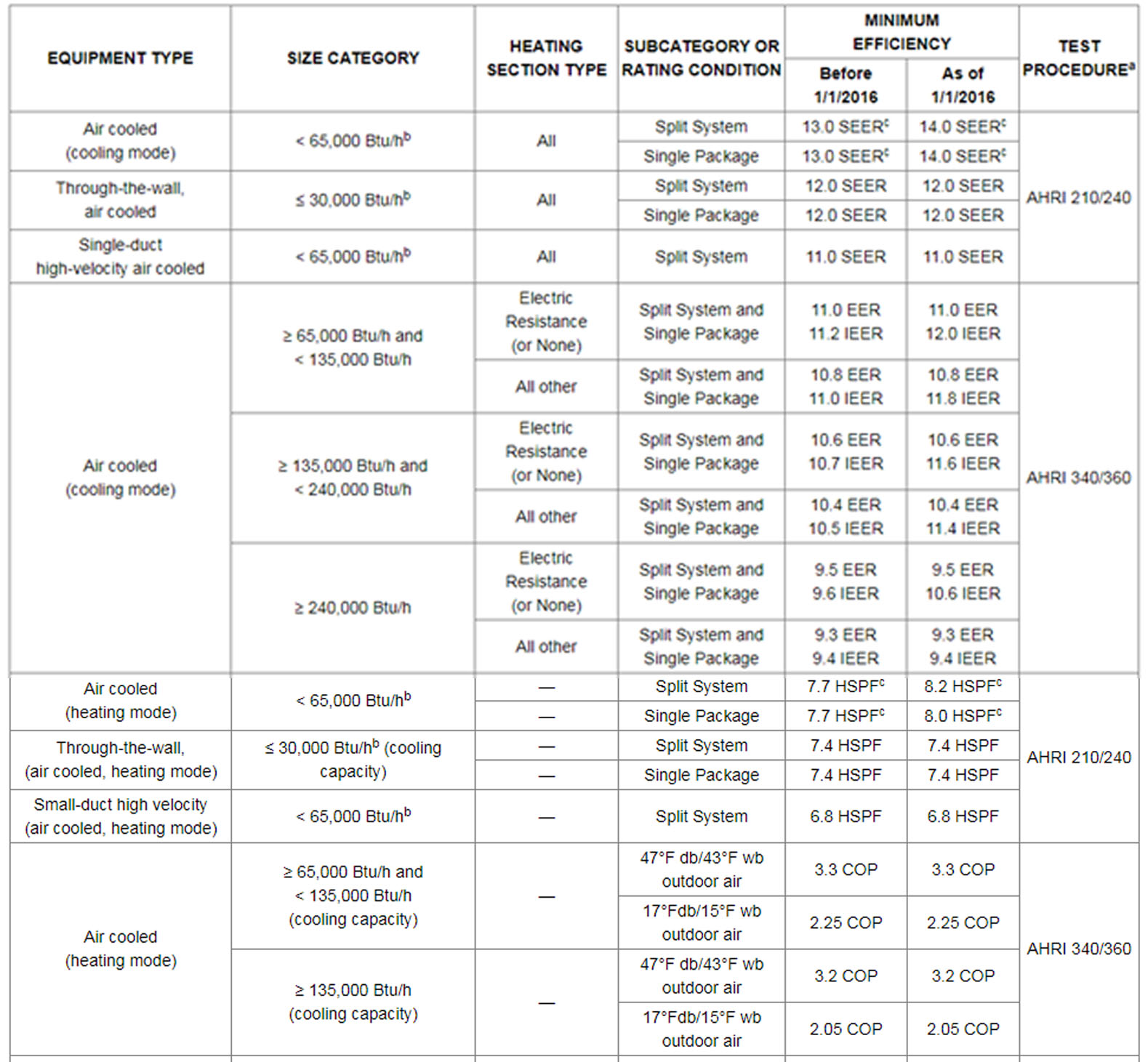
For these products, the baseline equipment includes Air Conditioning, Space Heating and Domestic Hot Water Heating.

New Construction:

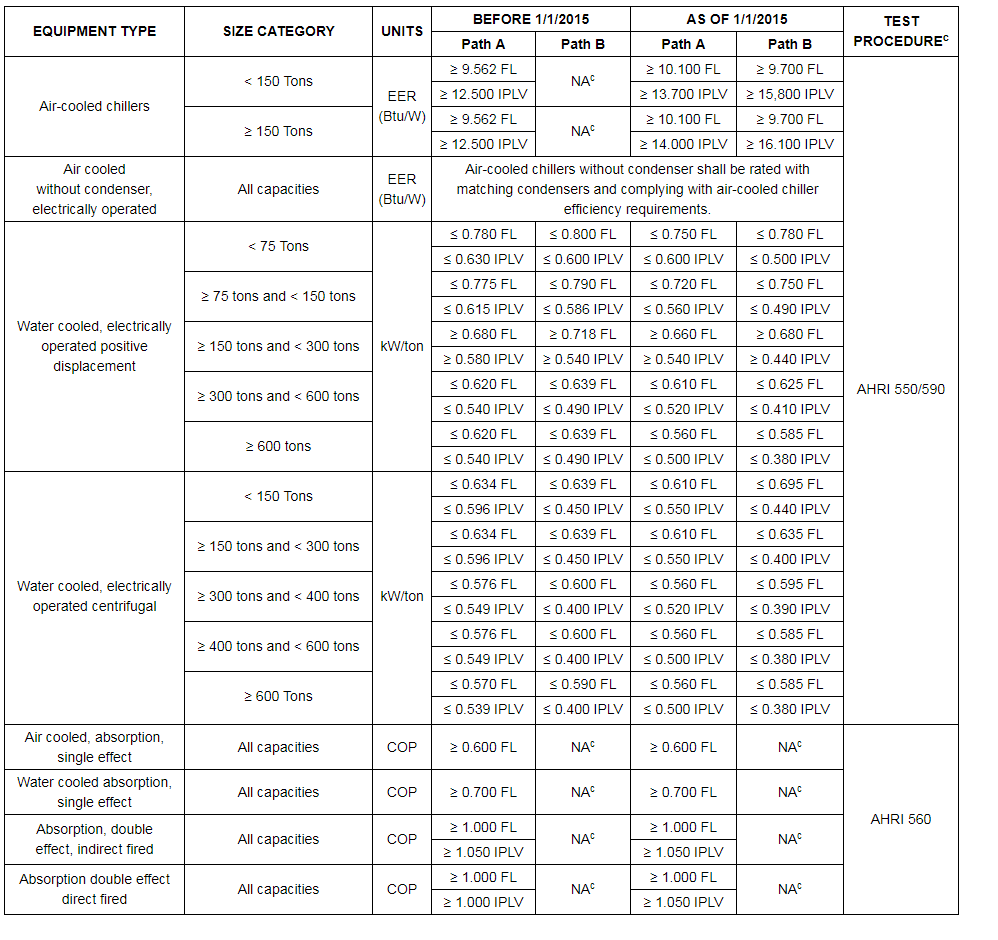
To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level as outlined inTable 2; and a Federal Standard electric hot water heater efficiency level as outlined inTable 6.

To calculate savings with a chiller/unitary cooling systems and boiler/furnace baseline, the baseline equipment is assumed to meet the minimum standard efficiencies as outlined in the Table 3 for chillers/unitary cooling systems , and Table 4 for boilers or Table 5 for furnaces. If a desuperheater is installed, the domestic hot water heater minimum standard efficiency is calculated as per Table 6 below.

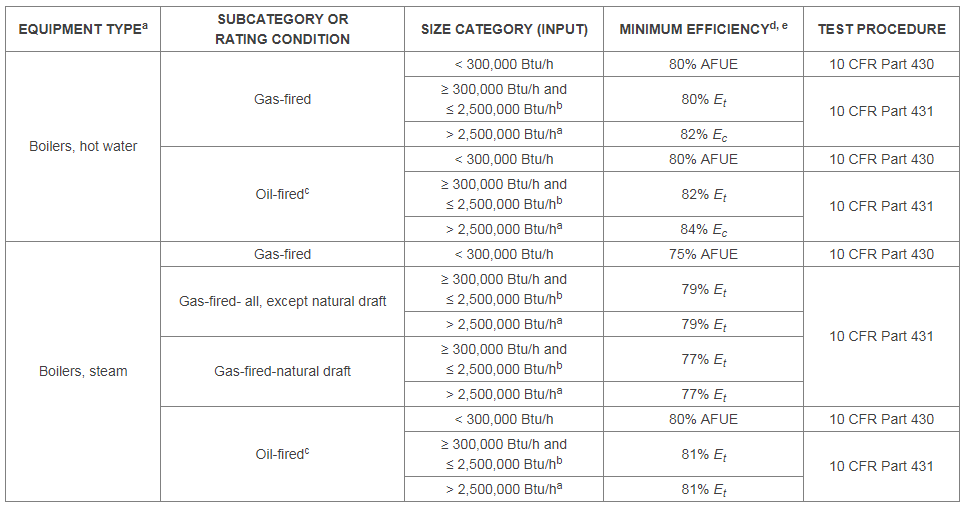
**Table2: IECC 2015 ASHP Minimum Efficiency Requirements:**



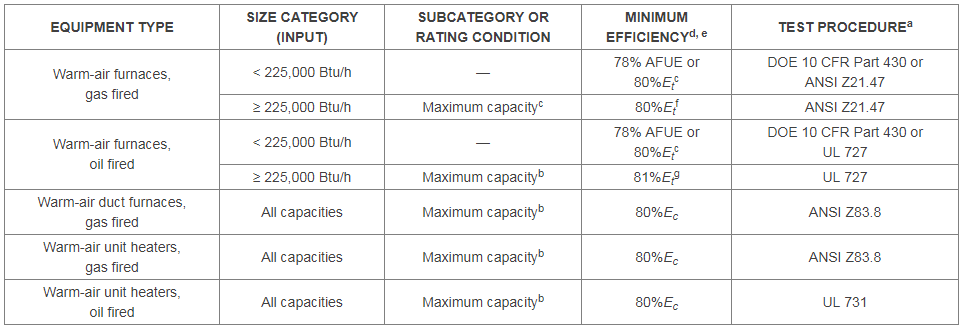
**Table 3: IECC 2015 Electric Chillers, Air-Cooled and Water-Cooled minimum efficiencies**



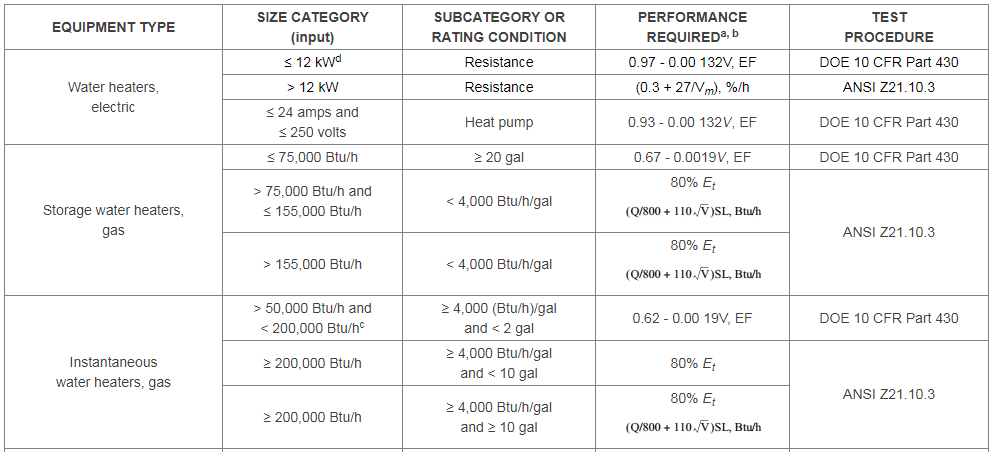
**Table 4: IECC 2015 Boiler minimum efficiency requirements**



**Table 5: IECC 2015 Warm-air Furnace minimum efficiency standards**



**Table 6: IECC 2015 Water Heaters mininmum performance**



Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the minimum standard efficiencies provided above.

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit, and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above).

###### Deemed Lifetime of Efficient Equipment

The expected measure life of the ground source heat pump is assumed to be 25 years[[642]](#footnote-650).

The expected measure life of the ground loop field is assumed to be 50 years[[643]](#footnote-651).

For early replacement, the remaining life of existing equipment is assumed to be 8 years[[644]](#footnote-652).

###### Deemed Measure Cost

New Construction and Time of Sale: Incremental costs of the Ground Source Heat Pump should be used. This would be the actual installed cost of the Ground Source Heat Pump including system commissioning costs (default of $10,923 per ton[[645]](#footnote-653)), minus the assumed installation cost of the baseline equipment ($1,316 per ton for ASHP[[646]](#footnote-654) or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler[[647]](#footnote-655) and $1,539 per ton[[648]](#footnote-656) for new baseline chiller replacement).

Early Replacement: The actual installed cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,316 per ton for a new baseline Air Source Heat Pump, or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler and $1,539 per ton for new baseline chiller replacement. This future cost should be discounted to present value using the nominal societal discount rate.

###### Loadshape

Loadshape C04 – Commercial Electric Heating (if replacing building with no existing cooling)

Loadshape C05 - Commercial Electric Heating and Cooling Note for the purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape C04 - Commercial Electric Heating and Loadshape C03 – Commercial Cooling respectively) can be applied.

###### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.  Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[649]](#footnote-657)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[650]](#footnote-658)

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings] +[Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERbase – 1/EERGSHP))/1000

Heating Savings = ElecHeat \*((CapacityHeat \* EFLHHeat \* (1/HSPFbase – 1/(COPGSHP \* 3.412)))/1000)

DHW Savings = ElecDHW \* (%DHW \* ((1/EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1/3412))

Motor Energy Impacts =

If closed loop geothermal field, Motor Energy = 0

If open loop geothermal field:

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

If open loop or closed loop with high expectant pumping energy for geothermal system:

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings] + [Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERbase – 1/EERGSHP))/1000

Heating Savings from base ASHP to GSHP = (CapacityHeat \* EFLHHeat \* (1/HSPFASHP – 1/(COPGSHP \* 3.412)))/1000

DHW Savings = ElecDHW \* (%DHW \* ((1/EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))

Motor Energy Impacts =

If closed loop geothermal field, Motor Energy = 0

If open loop geothermal field:

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

If open loop or closed loop with high expectant pumping energy for geothermal system:

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)Early replacement (non-fuel switch only)[[651]](#footnote-659):

Early replacement (non-fuel switch only)[[652]](#footnote-660):

ΔkWH for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings] + [DHW savings] + [Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERExist – 1/EERGSHP))/1000

Heating Savings = ElecHeat \*((CapacityHeat \* EFLHHeat \* (1/HSPFExist – 1/(COPGSHP \* 3.412)))/1000)

DHW Savings = ElecDHW \* (%DHW \* ((1/ EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1/3412))

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

ΔkWH for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings ] + [DHW savings] + [Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERbase – 1/EERGSHP))/1000

Heating Savings = ElecHeat \*((CapacityHeat \* EFLHHeat \* (1/HSPFBase – 1/(COPGSHP \* 3.412)))/1000)

DHW Savings = ElecDHW \* (%DHW \* ((1/ EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings] + [Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERExist – 1/EERGSHP))/1000

Heating Savings from base ASHP to GSHP = (CapacityHeat \* EFLHHeat \* (1/HSPFASHP – 1/(COPGSHP \* 3.412)))/1000

DHW Savings = ElecDHW \* (%DHW \* ((1/ EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings] + [Motor Energy Impacts]

Cooling Savings = (Capacitycool \* EFLHCool \* (1/EERbase – 1/EERGSHP))/1000

Heating Savings from base ASHP to GSHP = (CapacityHeat \* EFLHHeat \* (1/HSPFASHP – 1/(COPGSHP \* 3.412)))/1000

DHW Savings = ElecDHW \* (%DHW \* ((1/ EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))

Motor Energy Impacts = (((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)

Where:

Capacitycool = Cooling Capacity of Ground Source Heat Pump (Btu/hr)

= Actual installed

EFLHcool = Cooling Equivalent Full Load Hours

Dependent on building type, provided in section 4.4 HVAC End Use

EERExist = Energy Efficiency Ratio of existing cooling unit (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

EERexist = (-0.02 \* SEERexist2) + (1.12 \* SEERexist) [[653]](#footnote-661)

EERbase = EER of baseline replacement cooling system

= Use minimum standard efficiencies as specified in Table 2 in *Definition of Baseline Equipment*

EERGSHP = Part Load EER efficiency of efficient GSHP unit[[654]](#footnote-662)

= Actual installed

ElecHeat[[655]](#footnote-663) = 1 if existing heating system is electric

= 0 if existing system is non electric

CapacityHeat = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual installed

EFLHHeat = Heating Equivalent Full Load Hours

Dependent on building type, provided in section 4.4 HVAC End Use

HSPFExist = Heating System Performance Factor of existing electric heating system (kBtu/kWh)

= Actual

HSPFbase =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

|  |  |
| --- | --- |
| **Existing Heating System** | **HSPF\_base** |
| Air Source Heat Pump | Refer to Table 2 |
| Electric Resistance | 3.41[[656]](#footnote-664) |

HSPFASHP = Heating System Performance Factor of new replacement ASHP (kBtu/kWh) (for fuel switch)

= Refer to Table 2 in *Definition of Baseline Equipment*

COPGSHP = Part Load Coefficient of Performance of efficient GSHP[[657]](#footnote-665)

= Actual installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF)

ElecDHW = 1 if building has electric DHW

= 0 if building has non electric DHW

%DHW = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed assume 44%[[658]](#footnote-666)

= 0% if no desuperheater installed

EFelecbase = Energy Factor of baseline electric DHW

= Actual. If unknown or for new construction assume federal standard as defined in Table 6 in *Definition of Baseline Equipment*

HotWaterUseGallon = 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[[659]](#footnote-667)

| **Building Type[[660]](#footnote-668)** | **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 |

1. Consumption per unit area by building type

= (Area/1000) \* Consumption/1,000 sq.ft.

Where:

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

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[[661]](#footnote-669)

| **Building Type[[662]](#footnote-670)** | **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 = Density of water

= 8.33 pounds per gallon

Tout  = Tank temperature

= 125°F

Tin = Incoming water temperature from well or municiplal system

= 54°F[[663]](#footnote-671)

1 = Heat Capacity of water (1 Btu/lb\*°F)

3.412 = Conversion from Btu to kWh

BHPCoolingMotorExist = System Brake Horsepower for all motors that drive pumps and fans to cool the building (eg. Circulation pump motor, Air Handling Unit fan motor, Unit Ventilator fan motor).

(Nominal motor HP \* Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined412.  Custom load factor may be applied if known.

BHPHeatingMotorExist= System Brake Horsepower for all motors that drive pumps and fans to heat the building (eg. Circulation pump motor, Air Handling Unit fan motor, Unit Ventilator fan motor, Recirculation pump motor).

(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.  Custom load factor may be applied if known.

BHPGSHPMotor = System Brake Horsepower for all motors that drive loop field liquid circulation pumps as well as motors that drive air handling unit fans.

Any pumps and motors that are included in the packaged heat pump do not need to be included in the BHPGSHPMotor variable.

(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.  Custom load factor may be applied if known.

BHPDHW = System Brake Horsepower for domestic hot water circulation pump

(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. Custom load factor may be applied if known.

TOUbase = Baseline Motor Time of Use Factor varies by VFD application. Units are kW/kW

= 1 if there are no VFD controls

= 1- Energy Savings Factor (ESF) if there are VFD controls. Refer to following table

| **Application** | **ESF** | **TOU** |
| --- | --- | --- |
| Hot Water Pump | 0.569[[664]](#footnote-672) | 0.431 |
| Chilled Water Pump | 0.551[[665]](#footnote-673) | 0.449 |
| Cooling Tower Fan | 0.169[[666]](#footnote-674) | 0.831 |

TOUeff = Efficient Time of Use Factor for GSHP loop pump varies by controls application. Units are kW/kW

= 1 if there are no GSHP ground loop pump controls specified

= Custom calculated based on ground loop pump HP and MEP engineer’s ground loop controls specifications in the MEP design drawings. If detailed sequence of operations from the controls contractor are available, they may provide additional detail about the ground loop pump hours and speed that should be accounted for in the ground loop pump time of use multiplier.

0.7457 = Conversion factor from horsepower to kW.

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

HoursDHW = 8760

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** | **Model Source** |
| Assembly | 4888 | 2150 | eQuest |
| Assisted Living | 4711 | 4373 | eQuest |
| College | 3990 | 1605 | eQuest |
| Convenience Store | 4136 | 2084 | eQuest |
| Elementary School | 5105 | 3276 | eQuest |
| Garage | 4849 | 2102 | eQuest |
| Grocery | 4200 | 2096 | eQuest |
| Healthcare Clinic | 5481 | 1987 | eQuest |
| High School | 5480 | 3141 | eQuest |
| Hospital - VAV econ | 3718 | 2788 | eQuest |
| Hospital - CAV econ | 7170 | 2881 | eQuest |
| Hospital - CAV no econ | 7139 | 8760 | eQuest |
| Hospital - FCU | 5844 | 8729 | eQuest |
| Manufacturing Facility | 3821 | 2805 | eQuest |
| MF - High Rise | 4522 | 4237 | eQuest |
| MF - Mid Rise | 5749 | 2899 | eQuest |
| Hotel/Motel - Guest | 4480 | 4479 | eQuest |
| Hotel/Motel - Common | 3292 | 8712 | eQuest |
| Movie Theater | 5063 | 2120 | eQuest |
| Office - High Rise - VAV econ | 4094 | 2038 | eQuest |
| Office - High Rise - CAV econ | 5361 | 4849 | eQuest |
| Office - High Rise - CAV no econ | 5331 | 5682 | eQuest |
| Office - High Rise - FCU | 3758 | 3069 | eQuest |
| Office - Low Rise | 3834 | 2481 | eQuest |
| Office - Mid Rise | 6155 | 3036 | OpenStudio |
| Religious Building | 5199 | 2830 | eQuest |
| Restaurant | 4579 | 3350 | eQuest |
| Retail - Department Store | 4249 | 2528 | eQuest |
| Retail - Strip Mall | 4475 | 2266 | eQuest |
| Warehouse | 4606 | 770 | eQuest |
| Unknown | 4649 | 2718 | m/a |

Illustrative Examples

New Construction using ASHP baseline:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4, with desuperheater installed, and with a 100 gallon electric water heater in an Assisted living building in Chicago:

ΔkWh = [120,000 \* 1,457 \* (1/11 – 1/20) / 1000] + [1,646\* 120,000 \* (1/11 – 1/(4.4\*3.412)) / 1000] + [1 \* 0.44 \* ((1/0.9568 \* (100\*672) \* 8.33 \* (125-54) \* 1)/3412)]

= 7,153 + 4,800 +5,357

= 17,309 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 and with da esuperheater installed in in an Assisted living building in Chicago with a 100 gallon electric water heater, replacing an existing working Air Source Heat Pump with efficiency ratings of 8.2 EER and 7.7 HSPF. The existing system has a 0.5 HP DHW circulation pump, and the GSHP system has a 1 HP ground loop pump:

ΔkWH for remaining life of existing unit (1st 8 years):

= [120,000 \* 1,457 \* (1/8.2 – 1/20) / 1000] + [1,646\* 120,000 \* (1/7.7 – 1/(4.4\*3.412)) / 1000] + [1 \* 0.44 \* ((1/0.9568 \* (100\*672) \* 8.33 \* (125-54) \* 1)/3412)] + [(((0)-(1 \* 1)) \* (0.7457/0.93) \*4,373)+(((0)-(1 \* 1) \* (0.7457/0.93) \* 4,711)+(1 \* 0.5 \* (0.7457/0.93) \* 8,760)]

= 12,580 + 12,495 +5357 – 3,772

= 26,660 kWh

ΔkWH for remaining measure life (next 17 years):

= [120,000 \* 1,457 \* (1/11 – 1/20) / 1000] + [1,646\* 120,000 \* (1/11 – 1/(4.4\*3.412)) / 1000] + [1 \* 0.44 \* ((1/0.9568 \* (100\*672) \* 8.33 \* (125-54) \* 1)/3412)] + [(((0)-(1\*1)) \* (0.7457/0.93) \*4,373)+(((0)-(1 \* 1) \* (0.7457/0.93) \* 4,711)+(1 \* 0.5 \* (0.7457/0.93) \* 8,760)]

= 7,153 + 4,800 +5,357 – 3,772

= 13,537 kWh

###### Summer Coincident Peak Demand Savings

New Construction and Time of Sale:

ΔkW = (CapacityCool \* (1/EERbase - 1/EERGSHP))/1000 \* CF

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

= (CapacityCool \* (1/EERexist - 1/EERGSHP))/1000 \* CF

ΔkW for remaining measure life (next 17 years):

= (CapacityCool \* (1/EERbase - 1/EERGSHP))/1000 \* CF

Where:

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 91.3%%[[667]](#footnote-675)

CFPJM = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 47.8%[[668]](#footnote-676)

New Construction or Time of Sale:

For example, a 10 ton closed loop unit with Full Load EER rating of 20:

ΔkWSSP = (120,000 \* (1/11 – 1/20))/1000 \* 0.913

= 4.482kW

ΔkWPJM = (36,000 \* (1/11 – 1/20))/1000 \* 0.478

= 2.347kW

Early Replacement:

For example, a 10 ton closed loop unit with Full Load 20 EER replaces an existing working Air Source Heat Pump with 8.2 EER:

ΔkWSSP for remaining life of existing unit (1st 8 years):

= (120,000 \* (1/8.2 – 1/20))/1000 \* 0.913

= 7.883 kW

ΔkWSSP for remaining measure life (next 17 years):

= (120,000 \* (1/11– 1/20))/1000 \* 0.913

= 4.482kW

ΔkWPJM for remaining life of existing unit (1st 8 years):

= (120,000 \* (1/8.2 – 1/20))/1000 \* 0.478

= 4.127 kW

ΔkWPJM for remaining measure life (next 17 years):

= (120,000 \* (1/11 – 1/20))/1000 \* 0.478

= 2.347kW

###### Natural Gas Savings

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh

= (1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffbase) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/(COPGSHP \* 3.412))/1000)

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/EFGasBase \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 )/100,000

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

= (1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffbase) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/HSPFASHP)/1000)

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)

Early replacement for buildings with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of GSHP source kWh

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/ GasEffExist) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/(COPGSHP \* 3.412))/1000)]

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/ GasEffbase) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/(COPGSHP \* 3.412))/1000)] +

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of base ASHP source kWh

= (1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffExist) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/HSPFASHP)/1000)

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

= (1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffBase) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/HSPFASHP)/1000)

DHW Savings = (1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)

Where:

Gas\_Heating\_Load = Estimate of annual heating load

= Capacityheat \* EFLHheat / 100,000

GasEffbase = Minimum federal standard baseline efficiency of boiler or furnace

= Refer to *Definition of Baseline Equipment* section Table 4 for boiler efficiency and Table 5 for furnace efficiency

GasEffExist = Existing efficiency of boiler or furnace

= Actual

kWhtoTherm = Converts source kWh to Therms

= Hgrid / 100,000

Hgrid = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest) [[669]](#footnote-677). Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses

Capacityheat = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual installed

EFLHheat = Heating Equivalent Full Load Hours

Dependent on building type, provided in section 4.4 HVAC End Use

EFGasBase = Energy factor of Baseline natural gas DHW heater

= Actual. IF unknown or New Construction assume federal standard as defined in Table 6 in *Definitions of Baseline Equipment*

All other variabes provided above.

Illustrative Examples *[for illustrative purposes a Hgrid value of 10,000 Btu/kWh is used]*

New construction using gas boiler and air-cooled chiller, *supported by Gas utility only*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater is installed in place of a natural gas boiler and air-cooled chiller:

ΔkWH = 0

ΔTherms = [Replaced baseline gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1-0)\* ((1,975/80%)-(10,000/100,000 \*1,646 \*120,000 \*1/(4.4 \*3.412))/1,000)] + [(1 - 0) \* 0.44 \* (1/80% \* (100\*672) \* 8.33 \* (125- 54) \* 1 )/100,000]

= 1,153 +219

= 1,372 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER, and desuperheater installed with natural gas existing DHW heater. The existing system has a 1 HP hot water pump and 1 HP chilled water pump, both operating on VFDs, and the GSHP system has a 1 HP ground loop pump:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings] + [Motor Energy Impacts]

= [(Capacitycool \* EFLHCool \* (1/EERExist – 1/EERGSHP))/1000] + [(CapacityHeat \* EFLHHeat \* (1/HSPFASHP – 1/(COPGSHP \* 3.412)))/1000] + [ElecDHW \* (%DHW \* ((1/EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))]+ [(((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)]

= [(120,000 \* 1,457 \* (1/9.5 - 1/20))/1,000] + [(120,000 \* 1,646 \* (1/11 - 1/(4.4 \* 3.412)))/1,000] + [0 \* (0.44 \* ((1/0.9568) \* (100\*672) \* 8.33 \* (125 - 54) \* 1 /3412))] + [(((1\*0.449)-(1\*1))\*(0.7457/0.93)\*4,373)+(((1\*0.431)-(1\*1)\*(0.7457/0.93)\*4,711)+(0)]

= 9,662 + 4,800 + 0 – 4,081

= 10,381 kWh

Continued on next page.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings] + [Motor Energy Impacts]

= [(Capacitycool \* EFLHCool \* (1/EERbase – 1/EERGSHP))/1000] + [(CapacityHeat \* EFLHHeat \* (1/HSPFASHP – 1/(COPGSHP \* 3.412)))/1000] + [ElecDHW \* (%DHW \* ((1/EFelecbase) \* HotWaterUseGallon \* γWater \* (Tout – Tin) \* 1 /3412))] [(((BHPCoolingMotorExist \* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursCooling) + (((BHPHeatingMotorExist ­\* TOUbase) – (BHPGSHPMotor \* TOUeff)) \* 0.7457 /EFFi \* HoursHeating)+ (ElecDHW \* BHPDHW \*0.7457 /EFFi \* HoursDHW)]

= [120,000 \* 1,457 \* (1/11 – 1/20) / 1000] + [1,646\* 120,000 \* (1/11 – 1/(4.4\*3.412)) / 1000] + [0 \* 0.44 \* ((1/0.9568 \* (100\*672) \* 8.33 \* (125-54) \* 1)/3412)] + [(((1\*0.449)-(1\*1))\*(0.7457/0.93)\*4,373)+(((1\*0.431)-(1\*1)\*(0.7457/0.93)\*4,711)+(0)]

= 7,153 + 4,800 +0 – 4,081

= 7,872 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced existing gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffExist) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1 - 0)\*((1975/75%) - (10000/100000 \* 1646 \* 120,000 \* 1/11)/1000)]+ [(1 - 0) \*( 0.44 \* (1/ 80% \*(100\*672) \* 8.33 \* (125- 54) \* 1) / 100000)]

= 838 + 219

= 1,057 therms

ΔTherms for remaining measure life (next 17 years):

= [Replaced baseline gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/GasEffBase) – (kWhtoTherm \* EFLHheat \* Capacityheat \* 1/HSPFASHP)/1000)] + [(1 – ElecDHW) \* (%DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0)\* ((1,975/80%)-(10,000/100,000 \*1,646 \*120,000 \*1/11)/1,000)] + [(1 - 0) \* 0.44 \* (1/80% \* (100\*672) \* 8.33 \* (125- 54) \* 1 )/100,000]

= 673 + 219

= 892 therms

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Cost Effectiveness Screening and Load Reduction Forecasting when Fuel Switching

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B; changes in site energy use at the customer’s meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the “Electric Energy Savings” and “Natural Gas Savings” sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[[670]](#footnote-678)] + [DHW Savings if existing natural gas DHW]

= [(1 – ElecHeat) \* ((Gas\_Heating\_Load/ GasEffbase)] + [(1 – ElecDHW) \* %DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

ΔkWh = - [GSHP heating consumption] + [Cooling savings[[671]](#footnote-679)] + [DHW savings if existing electric DHW]

= - [(EFLHheat \* CapacityHeat \* (1/ COPGSHP  \* 3.412))/1000] + [(EFLHcool \* CapacityCool \* (1/EERbase - 1/EERGSHP))/1000] + [ElecDHW \* %DHW \* ((1/EFELEC \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 10 ton unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms = [(1 – ElecHeat) \* ((Gas\_Heating\_Load/ GasEffbase)] + [(1 – ElecDHW) \* %DHW \* (1/ EFGasBase \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 100,000)]

= [(1-0) \* (1975/0.8)] + [((1 - 0) \* 0.44 \* (1/0.8 \* (100\*672) \* 8.33 \* (125- 54) \* 1 )/100000)]

= 2,469 + 219

= 2,688 therms

ΔkWh = - [(EFLHheat \* CapacityHeat \* (1/ COPGSHP  \* 3.412))/1000] + [(EFLHcool \* CapacityCool \* (1/EERbase - 1/EERGSHP))/1000] + [ElecDHW \* %DHW \* ((1/EFELEC \* HotWaterUseGallon \* γWater \* (TOUT – Tin) \* 1.0) / 3412)]

= - [(1646 \* 120000 \* (1/ 4.4 \* 3.412))/1000] + [( 1457\* 120000 \* (1/11 - 1/20))/1000] + [0 \* (0.44 \* ((1/0.9568) \* (100\*672) \* 8.33 \* (125 - 54) \* 1 /3412))]

= -153,168 + 7153 + 0

= -146,015 kWh

###### Measure Code: CI-HVC-GSHP-V01-190101

###### Review Deadline: 1/1/2021

## Lighting End Use

The commercial lighting measures use a standard set of variables for hours or use, waste heat factors, coincident factors and HVAC interaction effects. This table has been developed based on information provided by the various stakeholders. For ease of review, the table is included here and referenced in each measure.

The building characteristics can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”. Note a modeling subcommittee is in the process of transferring and calibrating models from eQuest to OpenStudio. The model source is provided in the table.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

| **Building/Space Type** | **Fixture Annual Operating Hours**[[672]](#footnote-680) | **Screw based bulb Annual Operating hours**[[673]](#footnote-681) | **Waste Heat Cooling Energy WHFe**[[674]](#footnote-682) | **Waste Heat Cooling Demand****WHFd** | **Coinci-dence Factor**  **CF**[[675]](#footnote-683) | **Waste Heat Gas Heating**  **IFTherms**[[676]](#footnote-684) | **Waste Heat Electric Resistance Heating** **IFkWh**[[677]](#footnote-685) | **Waste Heat Electric Heat Pump Heating IFkWh** | **Model Source** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Assisted Living | 7,862 | 5,950 | 1.14 | 1.30 | 0.66 | 0.035 | 0.823 | 0.358 | eQuest |
| Childcare/Pre-School | 2,860 | 2,860 | 1.17 | 1.29 | 0.72 | 0.018 | 0.420 | 0.183 | eQuest |
| College | 3,395 | 2,588 | 1.06 | 1.39 | 0.63 | 0.020 | 0.462 | 0.201 | eQuest |
| Convenience Store | 4,672 | 3,650 | 1.09 | 1.26 | 0.76 | 0.035 | 0.828 | 0.360 | eQuest |
| Elementary School | 3,038 | 2,118 | 1.17 | 1.29 | 0.72 | 0.018 | 0.420 | 0.183 | eQuest |
| Garage | 3,401 | 3,540 | 1.00 | 1.00 | 0.92 | 0.000 | 0.000 | 0.000 | eQuest |
| Garage, 24/7 lighting | 8,766 | 8,766 | 1.00 | 1.00 | 1.00 | 0.000 | 0.000 | 0.000 | eQuest |
| Grocery | 4,650 | 3,650 | 1.05 | 1.22 | 0.73 | 0.022 | 0.511 | 0.222 | eQuest |
| Healthcare Clinic | 3,890 | 4,207 | 1.40 | 1.85 | 0.65 | 0.006 | 0.144 | 0.063 | eQuest |
| High School | 3,038 | 2,327 | 1.18 | 1.39 | 0.72 | 0.028 | 0.656 | 0.285 | eQuest |
| Hospital - CAV no econ | 7,616 | 4,207 | 1.11 | 1.29 | 0.76 | 0.022 | 0.527 | 0.229 | eQuest |
| Hospital - CAV econ | 7,616 | 4,207 | 1.06 | 1.27 | 0.75 | 0.023 | 0.533 | 0.232 | eQuest |
| Hospital - VAV econ | 7,616 | 4,207 | 1.37 | 1.79 | 0.70 | 0.010 | 0.241 | 0.105 | eQuest |
| Hospital - FCU | 7,616 | 4,207 | 1.38 | 1.29 | 0.73 | 0.001 | 0.033 | 0.015 | eQuest |
| Manufacturing Facility | 4,618 | 2,629 | 1.02 | 1.04 | 0.81 | 0.012 | 0.270 | 0.117 | eQuest |
| MF - High Rise - Common | 6,138 | 5,950 | 1.14 | 1.32 | 0.64 | 0.025 | 0.596 | 0.259 | eQuest |
| MF - Mid Rise - Common | 5,216 | 5,950 | 1.24 | 1.55 | 0.82 | 0.032 | 0.741 | 0.322 | OpenStudio |
| Hotel/Motel - Guest | 2,390 | 777 | 1.18 | 1.36 | 0.28 | 0.020 | 0.463 | 0.201 | eQuest |
| Hotel/Motel - Common | 6,138 | 4,542 | 1.20 | 1.24 | 0.73 | 0.032 | 0.748 | 0.325 | eQuest |
| Movie Theater | 3,506 | 5,475 | 1.11 | 1.38 | 0.53 | 0.029 | 0.673 | 0.293 | eQuest |
| Office - High Rise - CAV no econ | 2,886 | 3,088 | 1.00 | 1.07 | 0.57 | 0.037 | 0.874 | 0.380 | eQuest |
| Office - High Rise - CAV econ | 2,886 | 3,088 | 1.00 | 1.07 | 0.57 | 0.039 | 0.905 | 0.394 | eQuest |
| Office - High Rise - VAV econ | 2,886 | 3,088 | 1.27 | 1.65 | 0.53 | 0.022 | 0.510 | 0.222 | eQuest |
| Office - High Rise - FCU | 2,886 | 3,088 | 1.35 | 1.56 | 0.59 | 0.015 | 0.346 | 0.150 | eQuest |
| Office - Low Rise | 2,698 | 3,088 | 1.11 | 1.31 | 0.52 | 0.016 | 0.371 | 0.161 | eQuest |
| Office - Mid Rise | 3,266 | 3,088 | 1.06 | 1.34 | 0.60 | 0.006 | 0.139 | 0.060 | OpenStudio |
| Religious Building | 2,085 | 1,664 | 1.12 | 1.37 | 0.48 | 0.015 | 0.356 | 0.155 | eQuest |
| Restaurant | 5,571 | 4,784 | 1.17 | 1.31 | 0.68 | 0.021 | 0.491 | 0.213 | eQuest |
| Retail - Department Store | 4,099 | 2,935 | 1.06 | 1.06 | 0.94 | 0.015 | 0.346 | 0.150 | OpenStudio |
| Retail - Strip Mall | 4,093 | 2,935 | 1.12 | 1.29 | 0.71 | 0.019 | 0.450 | 0.196 | eQuest |
| Warehouse | 3,135 | 4,293 | 1.02 | 1.17 | 0.85 | 0.016 | 0.378 | 0.164 | OpenStudio |
| Unknown | 3,379 | 3,612 | 1.09 | 1.36 | 0.58 | 0.022 | 0.522 | 0.227 | n/a |
| Exterior – dusk to dawn[[678]](#footnote-686) | 4,303 | 4,303 | 1.00 | 1.00 | 0.00 | 0.000 | 0.000 | 0.000 | n/a |
| Exterior – dusk to business close | See calculation below | | 1.00 | 1.00 | 0.00 | 0.000 | 0.000 | 0.000 | n/a |
| Low-Use Small Business | 2,954 | 2,954 | 1.31 | 1.53 | 0.66 | 0.023 | 0.524 | 0.262 | n/a |
| Uncooled Building | Varies | varies | 1.00 | 1.00 | 0.66 | 0.014 | 0.320 | 0.160 | n/a |
| Refrigerated Cases | 5,802 | n/a | 1.29 | 1.29 | 1.00 | 0.000 | 0.000 | 0.000 | n/a |
| Freezer Cases | 5,802 | n/a | 1.50 | 1.5 | 1.00 | 0.000 | 0.000 | 0.000 | n/a |

**Exterior Lighting Hours – dusk to business close**

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

Where:

                6.19        = Average hours per day between dusk and midnight[[679]](#footnote-687)

                Days      = Days of business operation

= Actual

                %Adj     = Percent adjustment dependent on hour closing[[680]](#footnote-688)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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

### Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

###### Note: This measure is effective until 12/31/2018. It is left in the manual for reference purposes and for calculation of carry over savings.

###### Description

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (<https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd>). The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a commercial location. If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[[681]](#footnote-689), and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[[682]](#footnote-690).

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[[683]](#footnote-691)) 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.

###### Deemed Measure Cost

The incremental capital cost assumption for all bulbs under 2600 lumens is $1.20[[684]](#footnote-692).

For bulbs over 2600 lumens the assumed incremental capital cost is $5.

###### Loadshape

|  |
| --- |
| Loadshape C06 - Commercial Indoor Lighting |
| Loadshape C07 - Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 - Hospital Indoor Lighting |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh =((WattsBase-WattsEE)/1000) \* ISR \* Hours \* WHFe

Where:

WattsBase = Actual (if retrofit measure) or based on lumens of CFL bulb and program year installed:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent  Post-EISA 2007  (WattsBase) |
| --- | --- | --- |
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 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%[[685]](#footnote-693) 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%[[686]](#footnote-694) | 14.5% | 12.3% | 98.0%[[687]](#footnote-695) |

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[[688]](#footnote-696). 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

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[689]](#footnote-697) = (((WattsBase-WattsEE)/1000) \* ISR \* Hours \* -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in a heat pump heated office and sign off form provided:

ΔkWhheatpenalty = (((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.

ΔkWH1st year installs = ((43 - 14) / 1000) \* 0.755 \* 3612 \* 1.06

= 83.8 kWh

ΔkWH2nd 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.

ΔkWH3rd year installs = ((43 - 14) / 1000) \* 0.103 \* 3612 \* 1.06

= 11.4 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ((WattsBase-WattsEE)/1000) \* ISR \* WHFd \* CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

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[[690]](#footnote-698) = (((WattsBase-WattsEE)/1000) \* ISR \* Hours \*- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by 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)[[691]](#footnote-699)** | **Replacement Cost**[[692]](#footnote-700) |
| --- | --- |
| = 1000 / Hours | $1.25 |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

###### Measure Code: CI-LTG-CCFL-V08-190101

###### Review Deadline: 1/1/2020

### 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[[693]](#footnote-701).

###### 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[[694]](#footnote-702) |
| 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 |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh =((WattsBase-WattsEE)/1000) \* ISR \* Hours \* WHFe

Where:

WattsBase = Assume wattage reduction of lamp removed

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Wattage of lamp removed**[[695]](#footnote-703) | | **Weighted average** |
|  | **T8** | **T12** | **80% T12, 20% T8** |
| 8-ft T8 | 38.6 | 60.3 | 56.0 |
| 4-ft T8 | 19.4 | 33.7 | 30.8 |
| 3-ft T8 | 14.6 | 40.0 | 34.9 |
| 2-ft T8 | 9.8 | 28.0 | 24.4 |

WattsEE = 0

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment permanently removed and disposed of.

Hours = Average hours of use per year are provided in Reference Table in Section 4.5. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in an office building:

ΔkWh =((19.4 - 0)/1000) \* 1.0 \* 4439 \* 1.25

= 107.6 kWh

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[696]](#footnote-704) = (((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:

ΔkWhheatpenalty =((19.4 - 0)/1000) \* 1.0 \* 4439 \* -0.151

=-13.0 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ((WattsBase-WattsEE)/1000) \* ISR \* WHFd \* CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔkW =((19.4 - 0)/1000) \* 1.0 \* 1.3 \* 0.66

= 0.017 kW

###### Natural Gas Energy Savings

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

ΔTherms[[697]](#footnote-705) = (((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

### High Performance and Reduced Wattage T8 Fixtures and Lamps

###### Description

This measure applies to “High Performance T8” (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the “Reduced Wattage T8 lamps” or RWT8 lamps that result in re-lamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 100% Commercial and 0% Residential should be used[[698]](#footnote-706).

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. |

###### 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[[699]](#footnote-707) and qualifying RWT8 products[[700]](#footnote-708).

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.  As of v7.0, T-12s are no longer considered a viable baseline for refrofits due to Federal Standards enacted in July 14, 2012. |

###### Deemed Lifetime of Efficient Equipment

The deemed lifetime of efficient equipment varies based on the program and is defined below:

| **Time of Sale (TOS)** | **Retrofit (RF) and Direct Install (DI)** |
| --- | --- |
| Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 12 years[[701]](#footnote-709).  Fixture retrofits which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below.  RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 12 years.[[702]](#footnote-710) | Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 15 years.  As per explanation above, for existing T12 fixtures, a mid life baseline shift should be applied in 2019 as described in table C-1.  Note, since the fixture lifetime is deemed at 12 years, the replacement cost of both the lamp and ballast should be incorporated in to the O&M calculation. |

###### Deemed Measure Cost

The deemed measure cost is found in the reference table at the end of this characterization.

###### Loadshape

|  |
| --- |
| Loadshape C06 - Commercial Indoor Lighting |
| Loadshape C07 - Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 - Hospital Indoor Lighting |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((Wattsbase-WattsEE)/1000) \* Hours \* WHFe \* ISR

Where:

Wattsbase = 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 |

WattsEE = 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.

WHFe = 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%[[703]](#footnote-711) 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** |
| --- | --- | --- | --- |
| 93.4%[[704]](#footnote-712) | 2.5% | 2.1% | 98.0%[[705]](#footnote-713) |

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[706]](#footnote-714) = (((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 =( (Wattsbase-WattsEE)/1000) \* WHFd\*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 of 0.66.

Other factors as defined above

###### Natural Gas Savings

ΔTherms[[707]](#footnote-715) = (((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.

###### 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[[708]](#footnote-716)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **EE Measure Description** | **Nominal Watts** | **WattsEE** | **Baseline Description** | **Nominal Watt** | **WattsBASE** | **Incremental Cost** | **WattsSAVE** |
| 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

A-2: Retrofit HPT8 New and Baseline Assumptions[[709]](#footnote-717)

| **EE Measure Description** | **Nominal Watts** | **Ballast Factor** | **Watts**EE | **Baseline Description** | **Nominal Watts** | **Watts**BASE | **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 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 |
|  |  |  |  |  |  |  |  |  |
| 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 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

| **EE Measure Description** | **Nominal Watts** | **WattsEE** | **EE Lamp Cost** | **Baseline Description** | **Base Lamp Cost** | **Nominal Watts** | **WattsBASE** | **WattsSAVE** | **Measure Cost** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RW T8 - F28T8 Lamp | 28 | 24.64 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 3.52 | $2.00 |
| RWT8 F2T8 Extra Life Lamp | 28 | 24.64 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 3.52 | $2.00 |
| RWT8 - F32/25W T8 Lamp | 25 | 22.00 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 6.16 | $2.00 |
| RWT8 - F32/25W T8 Lamp Extra Life | 25 | 22.00 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 6.16 | $2.00 |
| RWT8 F17T8 Lamp - 2 ft | 16 | 14.08 | $4.80 | F17 T8 Standard Lamp - 2ft | $2.80 | 17 | 14.96 | 0.88 | $2.00 |
| RWT8 F25T8 Lamp - 3 ft | 23 | 20.24 | $5.10 | F25 T8 Standard Lamp - 3ft | $3.10 | 25 | 22.00 | 1.76 | $2.00 |
| RWT8 F30T8 Lamp - 6' Utube | 30 | 26.40 | $11.31 | F32 T8 Standard Utube | $9.31 | 32 | 28.16 | 1.76 | $2.00 |
| RWT8 F29T8 Lamp - Utube | 29 | 25.52 | $11.31 | F32 T8 Standard Utube | $9.31 | 32 | 28.16 | 2.64 | $2.00 |
| RWT8 F96T8 Lamp - 8 ft | 65 | 57.20 | $9.00 | F96 T8 Standard Lamp - 8 ft | $7.00 | 70 | 61.60 | 4.40 | $2.00 |

A– 3: RWT8 New and Baseline Assumptions

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

B-1: Time of Sale T8 Component Costs and Lifetime[[710]](#footnote-718)

| **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 F32T8 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 F32T8 w/ Elec Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| 3-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp Standard F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| 4-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 4-Lamp Standard F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
|  |  |  |  | $32.50 |  |  |  |  |  |  |  |  |  |
| 2-lamp High-Performance HPT8 Troffer | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |

B-2: T8 Retrofit Component Costs and Lifetime[[711]](#footnote-719)

| **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 T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 1-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 2-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 2-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 3-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 4-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 4-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 2-lamp High-Performance HPT8 Troffer | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |

B-3: Reduced Wattage T8 Component Costs and Lifetime[[712]](#footnote-720)

| **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 |



###### Measure Code: CI-LTG-T8FX-V07-190101

###### Review Deadline: 1/1/2022

### LED Bulbs and Fixtures

###### Description

This characterization provides savings assumptions for a variety of LED lamps including Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16), and fixtures including refrigerated case, recessed and outdoor/garage fixtures.

If the implementation strategy does not allow for the installation location to be known, for Residential targeted programs (e.g. an upstream retail program), a deemed split of 97% Residential and 3% Commercial assumptions should be used[[713]](#footnote-722), and for Commercial targeted programs a deemed split of 98% Commercial and 2% Residential should be used[[714]](#footnote-723).

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

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

###### Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 becomes effective on 1/2/2017 (<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 |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((Wattsbase-WattsEE)/1000) \* Hours \*WHFe\*ISR

Where:

Wattsbase = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.

WattsEE = 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:[[715]](#footnote-724)

**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[[716]](#footnote-725) (WattsEE)** | **Baseline 2014-2019 (WattsBase)** | **Delta Watts 2014-2019 (WattsEE)** | **Baseline Post EISA 2020 requirement[[717]](#footnote-726)  (WattsBase)** | **Delta Watts Post 2020 (WattsEE)** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|
|
| 5280 | 6209 | 5745 | 72.9 | 300.0 | 227.1 | 300.0 | 227.1 |
| 3301 | 5279 | 4290 | 54.5 | 200.0 | 145.5 | 200.0 | 145.5 |
| 2601 | 3300 | 2951 | 37.5 | 150.0 | 112.5 | 65.6 | 28.1 |
| 1490 | 2600 | 2045 | 26.0 | 72.0 | 46.0 | 45.4 | 19.5 |
| 1050 | 1489 | 1270 | 16.1 | 53.0 | 36.9 | 28.2 | 12.1 |
| 750 | 1049 | 900 | 11.4 | 43.0 | 31.6 | 20.0 | 8.6 |
| 310 | 749 | 530 | 6.7 | 29.0 | 22.3 | 11.8 | 5.0 |
| 250 | 309 | 280 | 3.5 | 25.0 | 21.5 | 25.0 | 21.5 |

**Decorative Lamps - ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps**

| **Bulb Type** | | **Minimum Lumens** | **Maximum Lumens** | | **Lumens used to calculate LED Wattage (midpoint)** | | **LED Wattage (WattsEE)** | **Baseline 2014-2019 (WattsBase)** | **Delta Watts 2014-2019 (WattsEE)** | **Baseline Post EISA 2020 Requirement (WattsBase)[[718]](#footnote-727)** | **Delta Watts Post 2020 (WattsEE)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **3-Way[[719]](#footnote-728)** | | 250 | 449 | | 350 | | 4.4 | 25 | 20.6 | 7.8 | 3.3 |
| 450 | 799 | | 625 | | 7.9 | 40 | 32.1 | 13.9 | 6.0 |
| 800 | 1,099 | | 950 | | 12.1 | 60 | 47.9 | 21.1 | 9.0 |
| 1,100 | 1,599 | | 1350 | | 17.1 | 75 | 57.9 | 30.0 | 12.9 |
| 1,600 | 1,999 | | 1800 | | 22.8 | 100 | 77.2 | 40.0 | 17.1 |
| 2,000 | 2,549 | | 2275 | | 28.9 | 125 | 96.1 | 50.5 | 21.7 |
| 2,550 | 2,999 | | 2775 | | 35.2 | 150 | 114.8 | 61.7 | 26.4 |
| **Globe (medium and intermediate bases less than 750 lumens)** | | 90 | 179 | | 135 | | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| 180 | 249 | | 215 | | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| 250 | 349 | | 300 | | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| 350 | 749 | | 550 | | 8.5 | 40 | 31.5 | 12.2 | 3.8 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | | 70 | 89 | | 80 | | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| 90 | 149 | | 120 | | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| 150 | 299 | | 225 | | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| 300 | 749 | | 525 | | 8.1 | 40 | 31.9 | 11.7 | 3.6 |
| **Globe (candelabra bases less than 1050 lumens)** | | 90 | 179 | | 135 | | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| 180 | 249 | | 215 | | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| 250 | 349 | | 300 | | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| 350 | 499 | | 425 | | 6.5 | 40 | 33.5 | 9.4 | 2.9 |
| 500 | 1,049 | | 775 | | 11.9 | 60 | 48.1 | 17.2 | 5.3 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | | 70 | 89 | | 80 | | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| 90 | 149 | | 120 | | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| 150 | 299 | | 225 | | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| 300 | 499 | | 400 | | 6.1 | 40 | 33.9 | 8.9 | 2.7 |
| 500 | 1,049 | | 775 | | 11.9 | 60 | 48.1 | 17.2 | 5.3 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types:

| **Bulb Type** | **Minimum Lumens** | **Maximum Lumens** | **Lumens used to calculate LED Wattage (midpoint)** | **LED Wattage (WattsEE)** | **Baseline 2014-2019 (WattsBase)** | **Delta Watts 2014-2019 (WattsEE)** | **Baseline Post EISA 2020 Requirement (WattsBase)[[720]](#footnote-729)** | **Delta Watts Post 2020 (WattsEE)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **R, ER, BR with medium screw bases w/ diameter >2.25" (\*see exceptions below)** | 420 | 472 | 446 | 6.6 | 40 | 33.4 | 9.9 | 3.4 |
| 473 | 524 | 499 | 7.3 | 45 | 37.7 | 11.1 | 3.8 |
| 525 | 714 | 620 | 9.1 | 50 | 40.9 | 13.8 | 4.7 |
| 715 | 937 | 826 | 12.1 | 65 | 52.9 | 18.4 | 6.2 |
| 938 | 1259 | 1099 | 16.2 | 75 | 58.8 | 24.4 | 8.3 |
| 1260 | 1399 | 1330 | 19.6 | 90 | 70.4 | 29.6 | 10.0 |
| 1400 | 1739 | 1570 | 23.1 | 100 | 76.9 | 34.9 | 11.8 |
| 1740 | 2174 | 1957 | 28.8 | 120 | 91.2 | 43.5 | 14.7 |
| 2175 | 2624 | 2400 | 35.3 | 150 | 114.7 | 53.3 | 18.0 |
| 2625 | 2999 | 2812 | 41.3 | 175 | 133.7 | 62.5 | 21.1 |
| 3000 | 4500 | 3750 | 55.1 | 200 | 144.9 | 83.3 | 28.2 |
| **\*R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| 650 | 1199 | 925 | 13.6 | 65 | 51.4 | 20.6 | 7.0 |
| **\*ER30, BR30, BR40, or ER40** | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| **\*BR30, BR40, or ER40** | 650 | 1419 | 1035 | 15.2 | 65 | 49.8 | 23.0 | 7.8 |
| **\*R20** | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| 450 | 719 | 585 | 8.6 | 45 | 36.4 | 13.0 | 4.4 |
| **\*All reflector lamps below lumen ranges specified above** | 200 | 299 | 250 | 3.7 | 20 | 16.3 | 5.6 | 1.9 |
| 300 | [[721]](#footnote-730)399 | 350 | 5.1 | 30 | 24.9 | 7.8 | 2.6 |

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[[722]](#footnote-731) 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.[[723]](#footnote-732)

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** | **Minimum Lumens** | **Maximum Lumens** | **Lumens used to calculate LED Wattage (midpoint)** | **LED Wattage (WattsEE)** | **Baseline 2014-2019 (WattsBase)** | **Delta Watts 2014-2019 (WattsEE)** | **Baseline Post EISA 2020 Requirement (WattsBase)[[724]](#footnote-733)** | **Delta Watts Post 2020 (WattsEE)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 530 | 6.7 | 29 | 22.3 | 11.8 | 5.0 |
| 750 | 1049 | 900 | 11.4 | 43 | 31.6 | 20.0 | 8.6 |
| 1050 | 1489 | 1270 | 16.1 | 53 | 36.9 | 28.2 | 12.1 |
| 1490 | 2600 | 2045 | 26.0 | 72 | 46.0 | 45.4 | 19.5 |

Hours = Average hours of use per year are provided in the Reference Table in Section 4.5,Screw based bulb annual operating hours, for each building type. If unknown, use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

ISR = In Service Rate -the percentage of units rebated that actually get installed.

=100%[[725]](#footnote-734) if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

| **Weighted Average 1st year In Service Rate (ISR)** | **2nd year Installations** | **3rd year Installations** | **Final Lifetime In Service Rate** |
| --- | --- | --- | --- |
| 82.5%[[726]](#footnote-735) | 8.4% | 7.1% | 98.0%[[727]](#footnote-736) |

**Mid Life Baseline Adjustment**

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <310 and 3300+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

| **Minimum Lumens** | **Maximum Lumens** | **LED Wattage (WattsEE)** | **Delta Watts 2014-2019 (WattsEE)** | **Delta Watts Post 2020 (WattsEE)** | **Mid Life adjustment (made from 01/2021) to first year savings** |
| --- | --- | --- | --- | --- | --- |
| 2601 | 3300 | 37.5 | 112.5 | 28.1 | 25.0% |
| 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |
| 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |

Since the backstop provision now applies to specialty and directional lamps, the annual savings claim for these bulbs must also be reduced within the life of the measure.

|  | **Bulb Type** | **Lower Lumen Range** | **Upper Lumen Range** | **LED Wattage (WattsEE)** | **Delta Watts 2014-2019 (WattsEE)** | **Delta Watts Post 2020 (WattsEE)** | **Mid Life adjustment (made from 01/2021) to first year savings** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Decorative EISA 2014 Exempt, 2020 Non-Exempt | **3-Way** | 250 | 449 | 4.4 | 20.6 | 3.3 | 16.2% |
| 450 | 799 | 7.9 | 32.1 | 6.0 | 18.6% |
| 800 | 1,099 | 12.1 | 47.9 | 9.0 | 18.9% |
| 1,100 | 1,599 | 17.1 | 57.9 | 12.9 | 22.2% |
| 1,600 | 1,999 | 22.8 | 77.2 | 17.1 | 22.2% |
| 2,000 | 2,549 | 28.9 | 96.1 | 21.7 | 22.5% |
| 2,550 | 2,999 | 35.2 | 114.8 | 26.4 | 23.0% |
| **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| 350 | 749 | 8.5 | 31.5 | 3.8 | 11.9% |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| 300 | 749 | 8.1 | 31.9 | 3.6 | 11.2% |
| **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| 350 | 499 | 6.5 | 33.5 | 2.9 | 8.7% |
| 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| 300 | 499 | 6.1 | 33.9 | 2.7 | 8.1% |
| 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| Directional EISA 2014 Exempt, 2020 Non-Exempt | **R, ER, BR with medium screw bases w/ diameter >2.25" (\*see exceptions below)** | 420 | 472 | 6.6 | 33.4 | 3.4 | 10.0% |
| 473 | 524 | 7.3 | 37.7 | 3.8 | 10.0% |
| 525 | 714 | 9.1 | 40.9 | 4.7 | 11.4% |
| 715 | 937 | 12.1 | 52.9 | 6.2 | 11.8% |
| 938 | 1259 | 16.2 | 58.8 | 8.3 | 14.0% |
| 1260 | 1399 | 19.6 | 70.4 | 10.0 | 14.2% |
| 1400 | 1739 | 23.1 | 76.9 | 11.8 | 15.3% |
| 1740 | 2174 | 28.8 | 91.2 | 14.7 | 16.1% |
| 2175 | 2624 | 35.3 | 114.7 | 18.0 | 15.7% |
| 2625 | 2999 | 41.3 | 133.7 | 21.1 | 15.8% |
| 3000 | 4500 | 55.1 | 144.9 | 28.2 | 19.5% |
| **\*R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| 650 | 1199 | 13.6 | 51.4 | 7.0 | 13.5% |
| **\*ER30, BR30, BR40, or ER40** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| **\*BR30, BR40, or ER40** | 650 | 1419 | 15.2 | 49.8 | 7.8 | 15.6% |
| **\*R20** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| 450 | 719 | 8.6 | 36.4 | 4.4 | 12.1% |
| **\*All reflector lamps below lumen ranges specified above** | 200 | 299 | 3.7 | 16.3 | 1.9 | 11.5% |
| 300 | 399 | 5.1 | 24.9 | 2.6 | 10.6% |
| EISA Non-Exempt | **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |
| 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[728]](#footnote-737) = (((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:

ΔkWhheatpenalty = ((29-6.7)/1000)\*1.0\*3088\* -0.151

= - 10.4 kWh

###### Deferred Installs

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

###### Summer Coincident Peak Demand Savings

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 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:

ΔkW = ((29-6.7)/1000)\* 1.0\*1.3\*0.66

= 0.019 kW

###### Natural Gas Energy Savings

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

ΔTherms = (((WattsBase-WattsEE)/1000) \* ISR \* Hours \* - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔTherms = ((29-6.7)/1000)\*1.0\*3088\* -0.016

= - 1.10 therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

For fixture measures, the individual component lifetimes and costs are provided in the reference table section below[[729]](#footnote-738).

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb (assumed to be 15,000/3,612 =4.2 years for commercial and 15,000/5,950 = 2.5 years for multi-family common area installations) is calculated[[730]](#footnote-739). The key assumptions used in this calculation are documented below[[731]](#footnote-740):

| **Lamp Type** | **Installation Year** | **Std Inc** | **EISA Compliant Halogen** | **CFL** |
| --- | --- | --- | --- | --- |
| Omnidirectional | 2019 | $0.43 | $1.25 | N/A |
| 2020 | $0.43 | $1.25 | N/A |
| 2021 & after | $0.43 | N/A | $2.45 |
| Decorative | 2019 | $1.74 | N/A | N/A |
| 2020 | $1.74 | N/A | N/A |
| 2021 & after | $1.74 | N/A | $2.50 |
| Directional | 2019 | $3.53 | N/A | N/A |
| 2020 | $3.53 | N/A | N/A |
| 2021 & after | $3.53 | N/A | $4.50 |



The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

**Omnidirectional Lamps**

| **Location** | **Lumen Level** | **NPV of replacement costs for period** | | | **Levelized annual replacement cost savings** | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **2019** | **2020** | **2021** | **2019** | **2020** | **2021** |
| Commercial | Lumens <310 or >3300 (EISA exempt) | $6.02 | $6.02 | $6.02 | $1.47 | $1.47 | $1.47 |
| Lumens ≥ 310 and ≤ 23300 (EISA compliant) | $9.64 | $6.04 | $1.23 | $2.35 | $1.47 | $0.30 |
| Multi Family Common Areas | Lumens <310 or >3300 (non-EISA compliant) | $5.92 | $5.92 | $5.92 | $2.37 | $2.37 | $2.37 |
| Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $14.25 | $8.32 | $1.18 | $5.70 | $3.33 | $0.47 |

**Decorative Lamps**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Location** | **NPV of replacement costs for period** | | | **Levelized annual replacement cost savings** | | |
| **2019** | **2020** | **2021** | **2019** | **2020** | **2021** |
| Commercial | $12.71 | $7.37 | $1.26 | $3.10 | $1.80 | $0.31 |
| Multi Family Common Areas | $19.57 | $10.78 | $1.20 | $7.82 | $4.31 | $0.48 |

**Directional Lamps**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Location** | **NPV of replacement costs for period** | | | **Levelized annual replacement cost savings** | | |
| **2019** | **2020** | **2021** | **2019** | **2020** | **2021** |
| Commercial | $25.33 | $14.31 | $2.27 | $6.17 | $3.49 | $0.55 |
| Multi Family Common Areas | $39.53 | $21.37 | $2.16 | $15.81 | $8.54 | $0.86 |

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[[732]](#footnote-741) 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[[733]](#footnote-742):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bulb Type** | **Year** | **LED** | **Incandescent** | **Incremental Cost** |
| **Omnidirectional** | 2017 | $3.21 | $1.25 | $1.96 |
| 2018 | $3.21 | $1.96 |
| 2019 | $3.11 | $1.86 |
| **Directional** | 2017 | $6.24 | $3.53 | $2.71 |
| 2018-2019 | $5.18 | $1.65 |
| **Decorative and Globe** | 2017 | $3.50 | $1.60 | $1.90 |
| 2018-2019 | $3.40 | $1.74 | $1.66 |

**LED Fixture Wattage and Incremental Cost Assumptions**[[734]](#footnote-743)

| **LED Category** | **EE Measure Description** | **WattsEE** | **Baseline Description** | **WattsBASE** | **Incremental Cost** | **Mid Life Savings Adjustment (2019)** |
| --- | --- | --- | --- | --- | --- | --- |
| 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 | T8 LED Replacement Lamp (TLED), < 1200 lumens | 8.9 | F17T8 Standard Lamp - 2 foot | 15.0 | $13 | N/A |
| T8 LED Replacement Lamp (TLED), 1200-2400 lumens | 15.8 | F32T8 Standard Lamp - 4 foot | 28.2 | $15 | N/A |
| T8 LED Replacement Lamp (TLED), > 2400 lumens | 22.9 | F32T8/HO Standard Lamp - 4 foot | 41.8 | $13 | N/A |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 25.4 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | $53 | 97% |
| LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 36.7 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | $69 | 92% |
| LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 33.3 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | $55 | 96% |
| LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 44.8 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | $76 | 90% |
| LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 57.2 | 4-Lamp 32w T8 (BF < 0.88) | 112.6 | $104 | 91% |
| LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 21.8 | 1-Lamp 32w T8 (BF <0.91) | 29.1 | $22 | 96% |
| LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 33.7 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | $75 | 96% |
| LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 43.3 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | $83 | 91% |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, <= 3000 lumens | 19.5 | 1-Lamp 32w T8 (BF <0.91) | 29.1 | $10 | 97% |
| LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 32.1 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | $52 | 96% |
| LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 43.5 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | $78 | 91% |
| LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 56.3 | T5HO 2L-F54T5HO - 4' | 120.0 | $131 | N/A |
| LED Surface & Suspended Linear Fixture, > 7500 lumens | 82.8 | T5HO 3L-F54T5HO - 4' | 180.0 | $173 | N/A |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, <= 10,000 lumens | 61.6 | 3-Lamp T8HO Low-Bay | 157.0 | $44 | N/A |
| LED High-Bay Fixtures, 10,001-15,000 lumens | 99.5 | 4-Lamp T8HO High-Bay | 196.0 | $137 | N/A |
| LED High-Bay Fixtures, 15,001-20,000 lumens | 140.2 | 6-Lamp T8HO High-Bay | 294.0 | $202 | N/A |
| LED High-Bay Fixtures, > 20,000 lumens | 193.8 | 8-Lamp T8HO High-Bay | 392.0 | $264 | N/A |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, <= 2,000 lumens | 12.9 | 25% 73 Watt EISA Inc, 75% 1L T8 | 42.0 | $18 | N/A |
| LED Ag Interior Fixtures, 2,001-4,000 lumens | 29.7 | 25% 146 Watt EISA Inc, 75% 2L T8 | 81.0 | $48 | N/A |
| LED Ag Interior Fixtures, 4,001-6,000 lumens | 45.1 | 25% 217 Watt EISA Inc, 75% 3L T8 | 121.0 | $57 | N/A |
| LED Ag Interior Fixtures, 6,001-8,000 lumens | 59.7 | 25% 292 Watt EISA Inc, 75% 4L T8 | 159.0 | $88 | N/A |
| LED Ag Interior Fixtures, 8,001-12,000 lumens | 84.9 | 200W Pulse Start Metal Halide | 227.3 | $168 | N/A |
| LED Ag Interior Fixtures, 12,001-16,000 lumens | 113.9 | 320W Pulse Start Metal Halide | 363.6 | $151 | N/A |
| LED Ag Interior Fixtures, 16,001-20,000 lumens | 143.7 | 350W Pulse Start Metal Halide | 397.7 | $205 | N/A |
| LED Ag Interior Fixtures, > 20,000 lumens | 193.8 | (2) 320W Pulse Start Metal Halide | 727.3 | $356 | N/A |
| LED Exterior Fixtures | LED Exterior Fixtures, <= 5,000 lumens | 34.1 | 100W Metal Halide | 113.6 | $80 | N/A |
| LED Exterior Fixtures, 5,001-10,000 lumens | 67.2 | 175W Pulse Start Metal Halide | 198.9 | $248 | N/A |
| LED Exterior Fixtures, 10,001-15,000 lumens | 108.8 | 250W Pulse Start Metal Halide | 284.1 | $566 | N/A |
| LED Exterior Fixtures, > 15,000 lumens | 183.9 | 400W Pulse Start Metal Halide | 454.5 | $946 | N/A |

**LED Fixture Component Costs & Lifetime[[735]](#footnote-744)**

|  |  | **EE Measure** | | | | **Baseline** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **LED Category** | **EE Measure Description** | **Lamp Life (hrs)** | **Total Lamp Replacement Cost** | **LED Driver Life (hrs)** | **Total LED Driver Replacement Cost** | **Lamp Life (hrs)** | **Total Lamp Replacement Cost** | **Ballast Life (hrs)** | **Total Ballast Replacement Cost** |
| LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 50,000 | $30.75 | 70,000 | $47.50 | 2,500 | $8.86 | 40,000 | $14.40 |
| LED Interior Directional | LED Track Lighting | 50,000 | $39.00 | 70,000 | $47.50 | 2,500 | $12.71 | 40,000 | $11.00 |
| LED Wall-Wash Fixtures | 50,000 | $39.00 | 70,000 | $47.50 | 2,500 | $9.17 | 40,000 | $27.00 |
| LED Display Case | LED Display Case Light Fixture | 50,000 | $9.75/ft | 70,000 | $11.88/ft | 2,500 | $6.70 | 40,000 | $5.63 |
| LED Undercabinet Shelf-Mounted Task Light Fixtures | 50,000 | $9.75/ft | 70,000 | $11.88/ft | 2,500 | $6.70 | 40,000 | $5.63 |
| LED Refrigerated Case Light, Horizontal or Vertical | 50,000 | $8.63/ft | 70,000 | $9.50/ft | 15,000 | $1.13 | 40,000 | $8.00 |
| LED Freezer Case Light, Horizontal or Vertical | 50,000 | $7.88/ft | 70,000 | $7.92/ft | 12,000 | $0.94 | 40,000 | $6.67 |
| LED Linear Replacement Lamps | T8 LED Replacement Lamp (TLED), < 1200 lumens | 50,000 | $5.76 | 70,000 | $13.67 | 30,000 | $6.17 | 40,000 | $11.96 |
| T8 LED Replacement Lamp (TLED), 1200-2400 lumens | 50,000 | $8.57 | 70,000 | $13.67 | 24,000 | $6.17 | 40,000 | $11.96 |
| T8 LED Replacement Lamp (TLED), > 2400 lumens | 50,000 | $8.57 | 70,000 | $13.67 | 18,000 | $6.17 | 40,000 | $11.96 |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 50,000 | $78.07 | 70,000 | $40.00 | 24,000 | $26.33 | 40,000 | $35.00 |
| LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 50,000 | $89.23 | 70,000 | $40.00 | 24,000 | $39.50 | 40,000 | $35.00 |
| LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 50,000 | $96.10 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 50,000 | $114.37 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 50,000 | $137.43 | 70,000 | $40.00 | 24,000 | $24.67 | 40,000 | $35.00 |
| LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 50,000 | $65.43 | 70,000 | $40.00 | 24,000 | $6.17 | 40,000 | $35.00 |
| LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 50,000 | $100.44 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 50,000 | $108.28 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, <= 3000 lumens | 50,000 | $62.21 | 70,000 | $40.00 | 24,000 | $6.17 | 40,000 | $35.00 |
| LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 50,000 | $93.22 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 50,000 | $114.06 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 50,000 | $152.32 | 70,000 | $40.00 | 30,000 | $26.33 | 40,000 | $60.00 |
| LED Surface & Suspended Linear Fixture, > 7500 lumens | 50,000 | $183.78 | 70,000 | $40.00 | 30,000 | $39.50 | 40,000 | $60.00 |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, <= 10,000 lumens | 50,000 | $90.03 | 70,000 | $62.50 | 18,000 | $64.50 | 40,000 | $92.50 |
| LED High-Bay Fixtures, 10,001-15,000 lumens | 50,000 | $122.59 | 70,000 | $62.50 | 18,000 | $86.00 | 40,000 | $92.50 |
| LED High-Bay Fixtures, 15,001-20,000 lumens | 50,000 | $157.22 | 70,000 | $62.50 | 18,000 | $129.00 | 40,000 | $117.50 |
| LED High-Bay Fixtures, > 20,000 lumens | 50,000 | $228.52 | 70,000 | $62.50 | 18,000 | $172.00 | 40,000 | $142.50 |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, <= 2,000 lumens | 50,000 | $41.20 | 70,000 | $40.00 | 1,000 | $1.23 | 40,000 | $26.25 |
| LED Ag Interior Fixtures, 2,001-4,000 lumens | 50,000 | $65.97 | 70,000 | $40.00 | 1,000 | $1.43 | 40,000 | $26.25 |
| LED Ag Interior Fixtures, 4,001-6,000 lumens | 50,000 | $80.08 | 70,000 | $40.00 | 1,000 | $1.62 | 40,000 | $26.25 |
| LED Ag Interior Fixtures, 6,001-8,000 lumens | 50,000 | $105.54 | 70,000 | $40.00 | 1,000 | $1.81 | 40,000 | $26.25 |
| LED Ag Interior Fixtures, 8,001-12,000 lumens | 50,000 | $179.81 | 70,000 | $62.50 | 15,000 | $63.00 | 40,000 | $112.50 |
| LED Ag Interior Fixtures, 12,001-16,000 lumens | 50,000 | $190.86 | 70,000 | $62.50 | 15,000 | $68.00 | 40,000 | $122.50 |
| LED Ag Interior Fixtures, 16,001-20,000 lumens | 50,000 | $237.71 | 70,000 | $62.50 | 15,000 | $73.00 | 40,000 | $132.50 |
| LED Ag Interior Fixtures, > 20,000 lumens | 50,000 | $331.73 | 70,000 | $62.50 | 15,000 | $136.00 | 40,000 | $202.50 |
| LED Exterior Fixtures | LED Exterior Fixtures, <= 5,000 lumens | 50,000 | $73.80 | 70,000 | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 |
| LED Exterior Fixtures, 5,001-10,000 lumens | 50,000 | $124.89 | 70,000 | $62.50 | 15,000 | $63.00 | 40,000 | $112.50 |
| LED Exterior Fixtures, 10,001-15,000 lumens | 50,000 | $214.95 | 70,000 | $62.50 | 15,000 | $68.00 | 40,000 | $122.50 |
| LED Exterior Fixtures, > 15,000 lumens | 50,000 | $321.06 | 70,000 | $62.50 | 15,000 | $73.00 | 40,000 | $132.50 |

###### Measure Code: CI-LTG-LEDB-V08-190101

###### Review Deadline: 1/1/2022

### Commercial LED Exit Signs

###### Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Commercial building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

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

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

###### Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

###### Definition of Baseline Equipment

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

###### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[[736]](#footnote-745).

###### Deemed Measure Cost

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of at $32.50[[737]](#footnote-746)

###### Loadshape

Loadshape C53 - Flat

###### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 100%[[738]](#footnote-748).

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((WattsBase - WattsEE) / 1000) \* HOURS \* WHFe

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

| **Baseline Type** | **WattsBase** |
| --- | --- |
| Incandescent | 35W[[739]](#footnote-749) |
| CFL (dual sided) | 14W[[740]](#footnote-750) |
| CFL (single sided) | 7W |
| Unknown | 7W |



WattsEE = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W[[741]](#footnote-754)

HOURS = Annual operating hours

= 8766

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔkWH = (35 – 2)/1000 \* 8766 \* 1.25

= 362 kWh

For example, replacing single sided fluorescent fixture in a hospital

ΔkWH = (7– 2)/1000 \* 8766 \* 1.35

= 59.2 kWh

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[742]](#footnote-756) = (((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

ΔkWhheatpenalty = (35 – 2)/1000 \* 8766 \* -0.151

= -43.7 kWh

For example, replacing single sided fluorescent fixture in a heat pump heated hospital

ΔkWhheatpenalty = (7 – 2)/1000 \* 8766 \* -0.104

= -4.6 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = ((WattsBase - WattsEE) / 1000) \* 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

= 1.0

For example, replacing incandescent fixture in an office

ΔkW = (35 – 2)/1000 \* 1.3 \* 1.0

= 0.043 kW

For example, replacing single sided fluorescent fixture in a hospital

ΔkW = (7 – 2)/1000 \* 1.69 \* 1.0

= 0.0085 kW

###### Natural Gas Savings

Heating Penalty if natural gas heated building (or if heating fuel is unknown):

Δtherms = (((WattsBase-WattsEE)/1000) \* Hours \*- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔTherms = (35 – 2)/1000 \* 8766 \* -0.016

= -4.63 Therms

For example, replacing single sided fluorescent fixture in a hospital

ΔTherms = (7 – 2)/1000 \* 8766 \* -0.011

= - 0.48 Therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

|  | **Baseline Measures** | |
| --- | --- | --- |
| Component | Cost | Life (yrs) |
| Lamp | $12.45[[743]](#footnote-757) | 1.37 years[[744]](#footnote-758) |

###### Measure Code: CI-LTG-LEDE-V03-190601

###### Review Deadline: 1/1/2024

### 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.[[745]](#footnote-761) 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[[746]](#footnote-762)

The summer peak coincidence factor (CF) for this measure is dependent on lamp type as below:

| Lamp Type | CF |
| --- | --- |
| Red Round, always changing or flashing | 0.55 |
| Red Arrows | 0.90 |
| 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

ΔkWh = (Wbase - Weff) x 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:

ΔkWh = ((69 - 7) x 4818) / 1000

= 299 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (Wbase– Weff) x 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:

ΔkW = ((69 – 7) x 0.55) / 1000

= 0.0341 kW

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Reference Tables

Traffic Signals Technology Equivalencies[[747]](#footnote-763)

| **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[[748]](#footnote-764) | 8” Red | LED | Incandescent | 4380 | 7 | 69 | 272 |
| Flashing Signal | 12” Red | LED | Incandescent | 4380 | 6 | 150 | 631 |
| Flashing Signal | 8” Yellow | LED | Incandescent | 4380 | 10 | 69 | 258 |
| Flashing Signal | 12” Yellow | LED | Incandescent | 4380 | 13 | 150 | 600 |
| Round Signals | 8” Yellow | LED | Incandescent | 175 | 10 | 69 | 10 |
| Round Signals | 12” Yellow | LED | Incandescent | 175 | 13 | 150 | 24 |
| Round Signals | 8” Green | LED | Incandescent | 3767 | 9 | 69 | 266 |
| Round Signals | 12” Green | LED | Incandescent | 3767 | 12 | 150 | 520 |
| Turn Arrows | 8” Yellow | LED | Incandescent | 701 | 7 | 116 | 76 |
| Turn Arrows | 12” Yellow | LED | Incandescent | 701 | 9 | 116 | 75 |
| Turn Arrows | 8” Green | LED | Incandescent | 701 | 7 | 116 | 76 |
| Turn Arrows | 12” Green | LED | Incandescent | 701 | 7 | 116 | 76 |
| Pedestrian Sign | 12” Hand/Man | LED | Incandescent | 8766 | 8 | 116 | 946 |

Reference specifications for above traffic signal wattages are from the following manufacturers:

1. 8” Incandescent traffic signal bulb: General Electric Traffic Signal Model 17325-69A21/TS
2. 12” Incandescent traffic signal bulb: General Electric Signal Model 35327-150PAR46/TS
3. Incandescent Arrows & Hand/Man Pedestrian Signs: General Electric Traffic Signal Model 19010-116A21/TS
4. 8” and 12” LED traffic signals: Leotek Models TSL-ES08 and TSL-ES12
5. 8” LED Yellow Arrow: General Electric Model DR4-YTA2-01A
6. 8” LED Green Arrow: General Electric Model DR4-GCA2-01A
7. 12” LED Yellow Arrow: Dialight Model 431-3334-001X
8. 12: LED Green Arrow: Dialight Model 432-2324-001X
9. LED Hand/Man Pedestrian Sign: Dialight 430-6450-001X

###### Measure Code: CI-LTG-LEDT-V01-120601

###### Review Deadline: 1/1/2019

### 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[[749]](#footnote-765). 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

ΔkWh = (WSFbase-WSFeffic )/1000\* SF\* Hours \* WHFe

Summer Coincident Peak kW Savings

ΔkW = (WSFbase-WSFeffic )/1000\* SF\* CF \* WHFd

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[[750]](#footnote-766)

###### 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 |
| 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

ΔkWh = (WSFbase-WSFeffic )/1000\* SF\* Hours \* WHFe

Where:

WSFbase = 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.[[751]](#footnote-767)

WSFeffic = 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.

WHFe  = 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 WHFe is 1.

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[752]](#footnote-768) = (WSFbase-WSFeffic )/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 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 = (WSFbase-WSFeffic )/1000\* SF\* CF \* WHFd

Where:

WHFd = 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

ΔTherms = (WSFbase-WSFeffic )/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

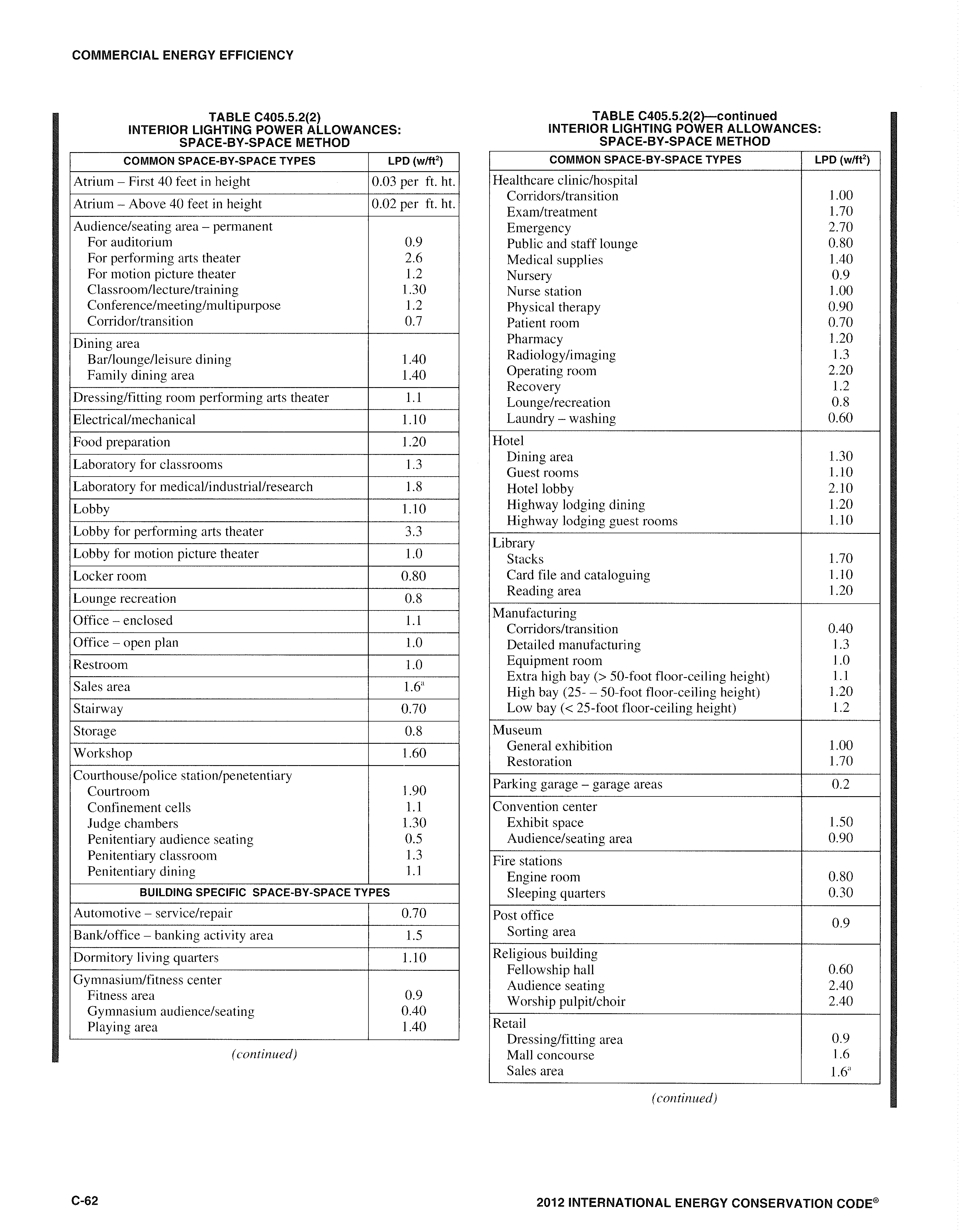
N/A

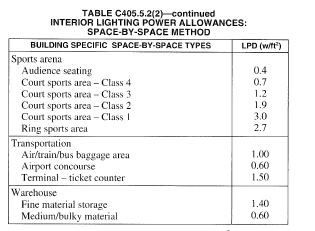
###### Reference Tables

Lighting Power Density Values from IECC 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

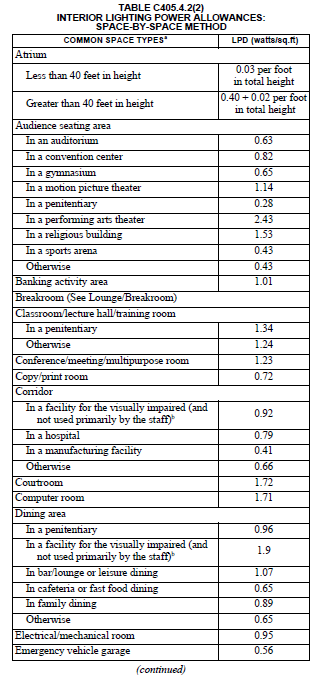
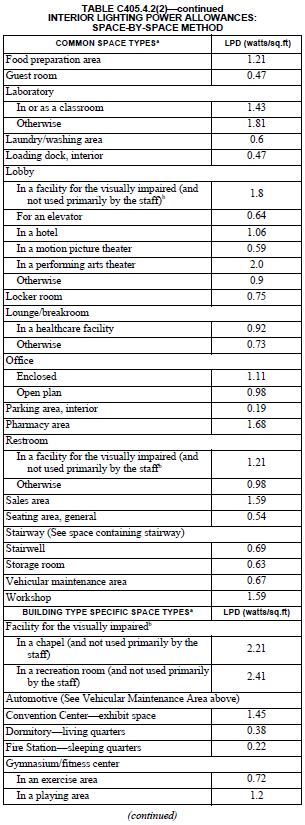
| **Building Area Type [[753]](#footnote-769)** | **IECC 2012**  **Lighting Power Density (w/ft2)** | **IECC 2015**  **Lighting Power Density (w/ft2)** |
| --- | --- | --- |
| Automotive Facility | 0.9 | 0.80 |
| Convention Center | 1.2 | 1.01 |
| Court House | 1.2 | 1.01 |
| Dining: Bar Lounge/Leisure | 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 |
| 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[[754]](#footnote-770) | 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 |

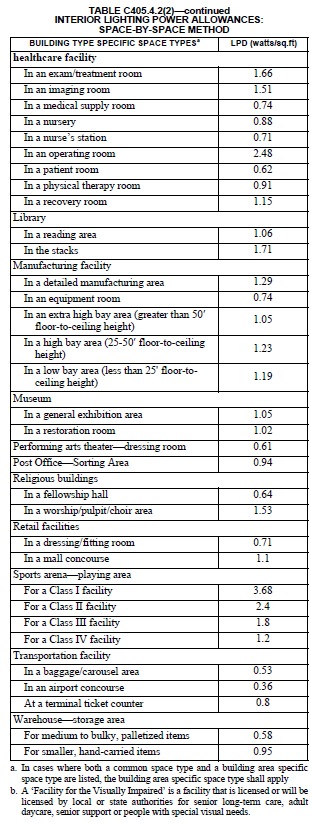
Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:





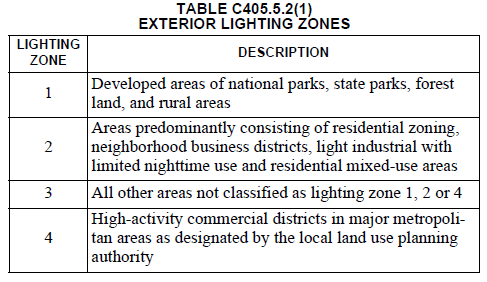
Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:



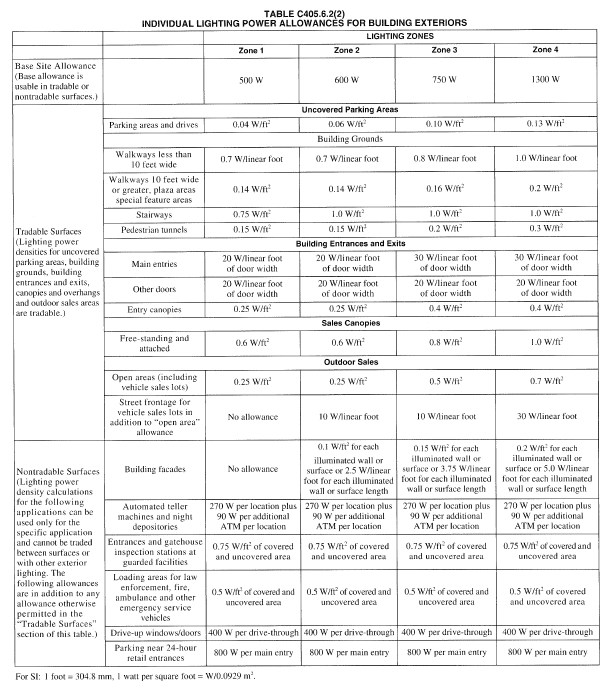
The exterior lighting design will be based on the building location and the applicable “Lighting Zone” as defined in

IECC 2015 Table C405.5.2(1) which follows. This table is identical to IECC 2012 Table C405.62(1).

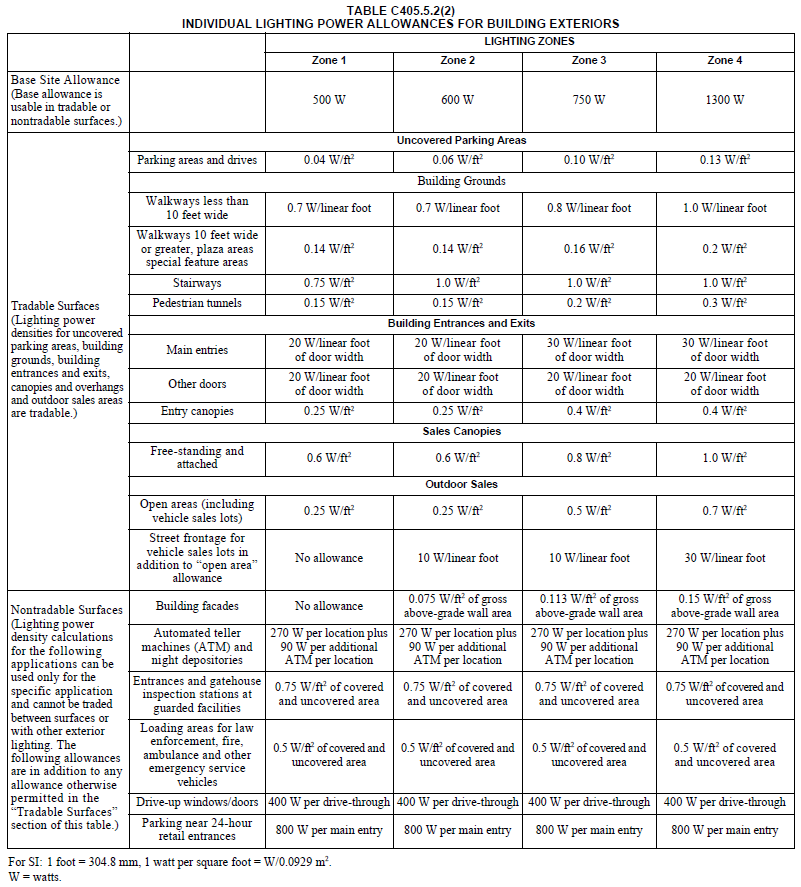


The lighting power density savings will be based on reductions below the allowable design levels as specified in IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).

Allowable Design Levels from IECC 2012



Allowable Design Levels from IECC 2015



###### Measure Code: CI-LTG-LPDE-V03-160601

###### Review Deadline: 1/1/2020

### Miscellaneous Commercial/Industrial Lighting

###### Description

This measure is designed to calculate savings from energy efficient lighting upgrades that are not captured in other measures within the TRM. If a lighting project fits the measure description in sections 4.5.1-4.5.4, then those criteria, definitions, and calculations should be used.

Unlike other lighting measures this one applies only to RF applications (because there is no defined baseline for TOS or NC applications).

###### Definition of Efficient Equipment

A lighting fixture that replaces an existing fixture to provide the same or greater lumen output at a lower kW consumption.

###### Definition of Baseline Equipment

The definition of baseline equipment is the existing lighting fixture.

###### Deemed Lifetime of Efficient Equipment

The lifetime of the efficient equipment fixture is the rated fixture life divided by hours of use. If unknown the default lifetime, regardless of program type is 12 years[[755]](#footnote-771).

###### 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.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((Wattsbase-WattsEE)/1000) \* Hours \* WHFe \* ISR

Where:

Wattsbase = 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

WattsEE = 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.

WHFe = 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%[[756]](#footnote-772) 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%[[757]](#footnote-773) | 12.1% | 10.3% | 98.0%[[758]](#footnote-774) |

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[759]](#footnote-775) = (((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.

###### 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

ΔkW = ((Wattsbase-WattsEE)/1000) \* WHFd \* 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[[760]](#footnote-776) = (((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.

###### Measure Code: CI-LTG-MSCI-V03-190101

###### Review Deadline: 1/1/2021

### 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[[761]](#footnote-777).

###### 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[[762]](#footnote-778).

###### Loadshape

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| --- |
| Loadshape C06 - Commercial Indoor Lighting |
| Loadshape C07 - Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 - Hospital Indoor Lighting |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = KWControlled\* Hours \* ESF \* WHFe

Where:

KWControlled = 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[[763]](#footnote-779):

| **Building Type** | **Energy Savings Factor (ESF)** |
| --- | --- |
| Private Office | 21.6% |
| Open Office | 16.0% |
| Retail | 14.8% |
| Classrooms | 8.3% |
| Unknown, average | 15% |

WHFe = 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:

ΔkWhheatpenalty[[764]](#footnote-780) = KWControlled\* Hours \* ESF \* -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

###### Summer Coincident Peak Demand Savings

ΔkW = KWcontrolled  \* ESF \* 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 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[[765]](#footnote-781).

###### Natural Gas Energy Savings

Δtherms = KWControlled\* Hours \* ESF \* - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 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

### Lighting Controls

###### Description

This measure relates to the installation of new occupancy or daylighting sensors on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling, fixture mounted or integrated controls. Passive infrared, ultrasonic detectors and fixture-mounted sensors or sensors with a combination thereof are eligible. Lighting controls required by state energy codes are not eligible. This must be a new installation and may not replace an existing lighting occupancy sensor control.

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

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the existing system is assumed to be manually controlled or an uncontrolled lighting system which is being controlled by one of the lighting controls systems listed above. This measure is intended for controlling interior lighting only.

A subset of occupancy sensors are those that are programmed as “vacancy” sensors. To qualify as a vacancy sensor, the control must be configured such that manual input is required to turn on the controlled lighting and the control automatically turns the lighting off. Additional savings are achieved compared to standard occupancy sensors because lighting does not automatically turn on and occupants may decide to not turn it on. Note that vacancy sensors are not a viable option for many applications where standard occupancy sensors should be used instead.

###### Definition of Baseline Equipment

The baseline is assumed to be a lighting system uncontrolled by occupancy.

###### Deemed Lifetime of Efficient Equipment

The expected measure life for all lighting controls is assumed to be 8 years[[766]](#footnote-782).

###### Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

| Lighting Control Type | Incremental Cost**[[767]](#footnote-783)** |
| --- | --- |
| Wall Switch Occupancy Sensor | $55.00 |
| Fixture-Mounted Occupancy Sensor | $67.00 |
| Remote or Wall-Mounted Occupancy Sensor | $125.00 |
| Fixture-Mounted Daylight Sensor | $ 50.00 |
| Remote or Wall-Mounted Daylight Sensor | $65.00 |
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | $40.00 |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | $40.00 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | $50.00 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | $50.00 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | $ 100.00 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | $ 100.00 |
| Exterior Occupancy Sensor | $82.00 |



###### Loadshape

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| --- |
| 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

ΔkWh = KWControlled\* Hours \* ESF \* WHFe

Where:

KwControlled = 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[[768]](#footnote-786)** | **Wattage Unit** | **Default kW Controlled** |
| --- | --- | --- |
| Wall Switch Occupancy Sensor | per control | 0.084 |
| Fixture-Mounted Occupancy Sensor | per fixture | 0.081 |
| Remote or Wall-Mounted Occupancy Sensor | per control | 0.338 |
| Fixture-Mounted Daylight Sensor | per fixture | 0.095 |
| or Wall-Mounted Daylight Sensor | per control | 0.239 |
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | per fixture | 0.031 |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | per fixture | 0.118 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | per control | 0.031 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | per control | 0.118 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | per control | 0.031 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | per control | 0.118 |
| Exterior Occupancy Sensor | per fixture | 0.086 |



Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown buidling type, use the Miscellaneous value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system).

|  |  |
| --- | --- |
| **Lighting Control Type** | **Energy Savings Factor[[769]](#footnote-789)** |
| Wall Switch Occupancy Sensor | 24% |
| Fixture-Mounted Occupancy Sensor | 24% |
| Remote or Wall-Mounted Occupancy Sensor | 24% |
| Fixture-Mounted Daylight Sensor | 28% |
| Remote or Wall-Mounted Daylight Sensor | 28% |
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | 24% |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | 24% |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | 38% |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | 38% |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | 38% |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | 38% |
| Exterior Occupancy Sensor | 41% |

WHFe = 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:

ΔkWhheatpenalty[[770]](#footnote-792) = KWControlled\* Hours \* ESF \* -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

###### Summer Coincident Peak Demand Savings

ΔkW = KWcontrolled  \* WHFd \* (CFbaseline – CFos)

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 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.[[771]](#footnote-793)

###### Natural Gas Energy Savings

Δtherms = KWControlled\* Hours \* ESF \* - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-LTG-OSLC-V05-190101

###### Review Deadline: 1/1/2021

### 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[[772]](#footnote-794).

###### 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 $5002.

###### Loadshape

|  |
| --- |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)[[773]](#footnote-795) |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on location.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = kWf\* HOURS \* WHFe

Where:

kWf *=* Connected load of the fixture the solar tube replaces

| **Size of Tube** | **Average Lumen output for Chicago Illinois (minimum)[[774]](#footnote-796)** | **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 [[775]](#footnote-797)

WHFe = 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:

ΔkWhheatpenalty[[776]](#footnote-798) = kWf\* 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

∆kW*=* ∆kWf \* 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[[777]](#footnote-799) = ∆kWf \* 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.

###### 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

### 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[[778]](#footnote-800).

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. |

###### 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.  As of v7.0, T-12s are no longer considered a viable baseline for refrofits due to Federal Standards enacted in July 14, 2012. |

###### Deemed Lifetime of Efficient Equipment

The lifetime of the efficient equipment fixture should be the rated life of the fixture divided by hours of use. If unknown default is, regardless of program type is 12 years[[779]](#footnote-801).

###### Loadshape

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| --- |
| 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 |

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh =( (Wattsbase-WattsEE)/1000) \* Hours \*WHFe\*ISR

Where:

Wattsbase = 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.

WattsEE = 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.

WHFe = 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%[[780]](#footnote-802) 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%[[781]](#footnote-803) | 0% | 0% | 98.0%[[782]](#footnote-804) |

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[783]](#footnote-805) = (((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 =((Wattsbase-WattsEE)/1000) \* WHFd\*CF\*ISR

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value.

###### Natural Gas Energy Savings

ΔTherms[[784]](#footnote-806) = (((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.

A-1: Time of Sale: T5 New and Baseline Assumptions[[785]](#footnote-807)



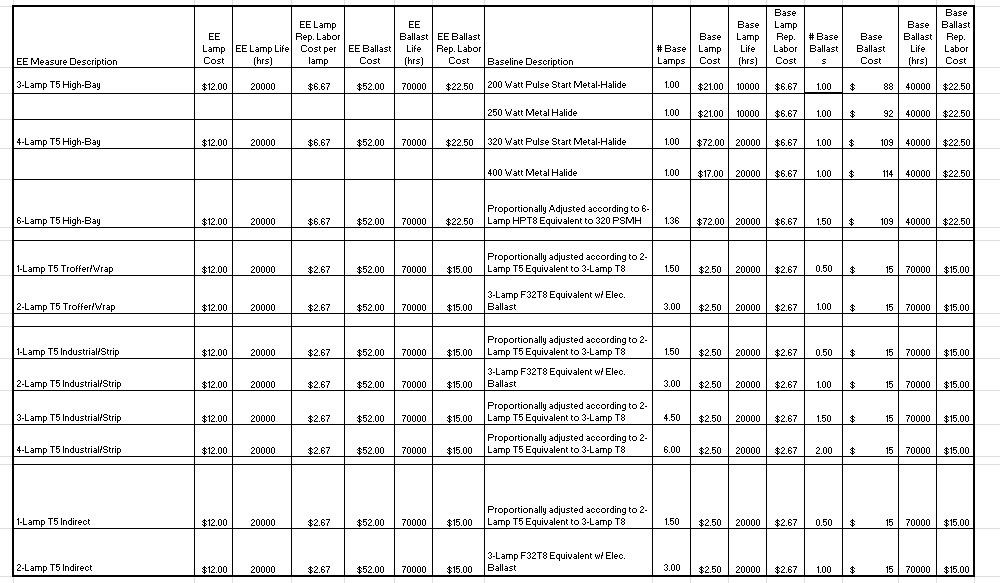
A-2: Retrofit T5 New and Baseline Assumptions[[786]](#footnote-808)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EE Measure Description** | **EE Cost** | **WattsEE** |  | **Baseline Description** | **WattsBASE** |
| 3-Lamp T5 High-Bay | $200.00 | 180 |  | 200 Watt Pulse Start Metal-Halide | 232 |
| 4-Lamp T5 High-Bay | $225.00 | 234 |  | 250 Watt Metal-Halide | 295 |
| 6-Lamp T5 High-Bay | $250.00 | 358 |  | 320 Watt Pulse Start Metal-Halide | 350 |
|  |  |  |  | 400 Watt Metal-Halide | 455 |
| 1-Lamp T5 Troffer/Wrap | $100.00 | 32 |  | 400 Watt Pulse Start Metal-Halide | 476 |
| 2-Lamp T5 Troffer/Wrap | $100.00 | 64 |  |  |  |
|  |  |  |  | 1-Lamp F32T8 | 32 |
|  |  |  |  | 2-Lamp F32T8 | 59 |
|  |  |  |  | 3-Lamp F32T8 | 88 |
|  |  |  |  | 4-Lamp F32T8 | 114 |

B-1: Time of Sale T5 Component Costs and Lifetime[[787]](#footnote-809)



B-2: T5 Retrofit Component Costs and Lifetime[[788]](#footnote-810)





###### Measure Code: CI-LTG-T5FX-V06-190101

###### Review Deadline: 1/1/2021

### 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[[789]](#footnote-811).

###### Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the assumed measure cost is $274[[790]](#footnote-812).

###### Loadshape

|  |
| --- |
| Loadshape C06 - Commercial Indoor Lighting |
| Loadshape C07 - Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 - Hospital Indoor Lighting |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = (KWBaseline - (KWControlled \*(1 –ESF))) \* Hours \* WHFe

Where:

KWBaseline = 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 KWBaseline will equal KWControlled .

KWControlled = 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 KWControlled 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%[[791]](#footnote-813) | 50% | 39.3% |
| 33% | 52.6% |
| 10% | 70.7% |
| 5% | 74.6% |
| Corridors | 50.0%[[792]](#footnote-814) | 50% | 25.0% |
| 33% | 33.5% |
| 10% | 45.0% |
| 5% | 47.5% |
| Other 24/7 Space Type | 50.0%[[793]](#footnote-815) | 50% | 25.0% |
| 33% | 33.5% |
| 10% | 45.0% |
| 5% | 47.5% |

WHFe = 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:

ΔkWhheatpenalty[[794]](#footnote-816) = (KWBaseline - (KWControlled \*(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

ΔkW = (KWBaseline - (KWControlled \* (1 –ESF))) \* WHFd \* (CFbaseline - CFos)

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 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.[[795]](#footnote-817)

###### Natural Gas Heating Penalty

If natural gas heating:

Δtherms = (KWBaseline - (KWControlled \*(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

### Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

**Note: This measure is effective until 12/31/2018. It is left in the manual for reference purposes and for calculation of carry over savings.**

###### Description

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb in a commercial location.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (<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[[796]](#footnote-818), and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[[797]](#footnote-819).

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[[798]](#footnote-820)) 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[[799]](#footnote-821).

For the Retrofit measures, the full cost of $8.50 should be used plus $5 labor[[800]](#footnote-822) for a total of $13.50. However actual program delivery costs should be utilized if available.

###### Loadshape

|  |
| --- |
| Loadshape C06 - Commercial Indoor Lighting |
| Loadshape C07 - Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 - Hospital Indoor Lighting |
| Loadshape C09 - Office Indoor Lighting |
| Loadshape C10 - Restaurant Indoor Lighting |
| Loadshape C11 - Retail Indoor Lighting |
| Loadshape C12 - Warehouse Indoor Lighting |
| Loadshape C13 - K-12 School Indoor Lighting |
| Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights) |
| Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights) |
| Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights) |
| Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights) |
| Loadshape C18 - Industrial Indoor Lighting |
| Loadshape C19 - Industrial Outdoor Lighting |
| Loadshape C20 - Commercial Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

###### Calculation of Savings

###### Electric Energy Savings

∆kWh = ((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[[801]](#footnote-823); use 60W if unknown[[802]](#footnote-824)

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 |
| **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[[803]](#footnote-825).

For Directional R, BR, and ER lamp types[[804]](#footnote-826):

|  |  |  |  |
| --- | --- | --- | --- |
| **Bulb Type** | **Lower Lumen Range** | **Upper Lumen Range** | **WattsBase** |
| **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 | [[805]](#footnote-827)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.[[806]](#footnote-828) 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.[[807]](#footnote-829)

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[[808]](#footnote-830)

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[[809]](#footnote-831) 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 |
| 71.2%[[810]](#footnote-832) | 14.5% | 12.3% | 98.0%[[811]](#footnote-833) |

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[[812]](#footnote-834). If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

###### Deferred Installs

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

###### EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

ΔkWh = (((45 - 14)/1000) \* 1.0 \* 3088 \* 1.25

= 119.7 kWh

###### Heating Penalty

If electrically heated building:

ΔkWhheatpenalty[[813]](#footnote-835) = (((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.

ΔkWhheatpenalty = (((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[[814]](#footnote-836) = (((WattsBase-WattsEE)/1000) \* ISR \* Hours \*- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

###### EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in a gas heated office and sign off form provided.

ΔTherms = (((45 - 14)/1000) \* 1.0 \* 3088 \* -0.016

= - 1.5 Therms

###### 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[[815]](#footnote-837). It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

###### Measure Code: CI-LTG-SCFL-V04-190101

###### Review Deadline: 1/1/2020

### 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. [[816]](#footnote-838)

###### 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 |

###### 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:

ΔkWh = (Wattsbase – Wattsee) / 1,000 \* Hours \* WHFe

Where:

Wattsbase = Wattage of neon sign with magnetic high voltage transformer

= Actual; if unknown use 46.0W[[817]](#footnote-839)

Wattsee = Wattage of LED sign with low voltage transformer

= Actual; if unknown use 14.9W[[818]](#footnote-840)

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:

ΔkWhheatpenalty[[819]](#footnote-841) = ((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

ΔkW = ((Wattsbase – Wattsee)/ 1000) \* CF \* WHFd

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

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**[[820]](#footnote-842) | **Energy Savings (kWh)** | **ΔkWhheatpenalty**  **(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[[821]](#footnote-843) = ((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** | **ΔThermsheatpenalty**  **(if gas heat)** |
| Convenience Store | -5.1 |
| Grocery | -3.2 |
| Healthcare Clinic | -0.7 |
| Hotel/Motel - Common | -6.1 |
| Movie Theater | -3.2 |
| Restaurant | -3.6 |
| Retail - Department Store | -3.7 |
| Miscellaneous | -2.3 |

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-LTG-OPEN-V01-180101

###### Review Deadline: 1/1/2022

### LED Streetlighting

###### Description

Existing streetlights are retrofitted to be illuminated with light emitting diodes (LED) instead of less efficient lamps. Incentive applies for the replacement or retrofit of existing streetlights with new LED lamps.

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

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

###### Definition of Efficient Equipment

The efficient equipment is the installed streetlight illuminated by LEDs*.*

###### Definition of Baseline Equipment

The baseline equipment is the existing streetlight.

###### Deemed Lifetime of Efficient Equipment

The assumed EUL of an LED streetlight is 12 years.[[822]](#footnote-844)

###### Deemed Measure Cost

The actual measure installation cost should be used (including material and labor).

###### Loadshape

Loadshape C20 - Commercial Outdoor Lighting

###### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0[[823]](#footnote-845).

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh = (Wbase - Weff) \* HOURS / 1000

Where:

Wbase =the connected load of the baseline equipment

= actual baseline equipment wattage

Weff=the connected load of the efficient equipment

= actual efficient equipment wattage

EFLH = annual operating hours of the lamp

= 4,303 hours[[824]](#footnote-846)

1000 = conversion factor (W/kW)

EXAMPLE

For example, an existing 469 watts streetlight is replaced by an LED light of 161 watts:

ΔkWh = ((469 - 161) \* 4,303) / 1000

= 1,325.3 kWh

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

N/A

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

###### Measure Code: CI-LTG-STRT-V01-190101

###### Review Deadline: 1/1/2022

## Refrigeration End Use

### 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.[[825]](#footnote-847)

###### Deemed Measure Cost

The deemed measure cost is $156.82 for a walk-in cooler or freezer.[[826]](#footnote-848)

###### 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[[827]](#footnote-849).

|  |  |
| --- | --- |
| **Annual Savings** | **kWh** |
| Walk in Cooler | 943 |
| Walk in Freezer | 2307 |

###### 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-V02-190101

###### Review Deadline: 1/1/2023

### 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 [[828]](#footnote-850).

###### Deemed Measure Cost

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes[[829]](#footnote-851):

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[[830]](#footnote-852).

**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[[831]](#footnote-853)** |
| 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)[[832]](#footnote-854)** |
| 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

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-RFG-BEVM-V03-190101

###### Review Deadline: 1/1/2022

### Door Heater Controls for Cooler or Freezer

###### Description

By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize significant energy savings. There are two commercially available control strategies that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

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

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

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing humidity or conductivity control.

###### Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door with no controls installed.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years [[833]](#footnote-855).

###### 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[[834]](#footnote-856).

###### Loadshape

Loadshape C51 - Door Heater Control

###### Coincidence Factor[[835]](#footnote-857)

The summer peak coincidence factor for this measure is assumed to be 0%[[836]](#footnote-858).

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWH = kWbase \* NUMdoors \* ESF \* BF \* 8766

Where:

kWbase[[837]](#footnote-859) = 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[[838]](#footnote-860) = 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[[839]](#footnote-861) = 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[[840]](#footnote-862)** | **Typical Uses** | **BF** |
| Low | -35 to 0 | Freezers for times such as frozen pizza, ice cream, etc. | 1.36 |
| Medium | 0 – 20 | Coolers for items such as meat, milk, dairy, etc | 1.22 |
| High | 20 – 45 | Coolers for items such as floral, produce and meat preperation rooms | 1.15 |

8766 = annual hours of operation

###### Summer Coincident Peak Demand Savings

N/A

###### NATURAL GAS ENERGY SAVINGS

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-RFG-DHCT-V02-190101

###### Review Deadline: 1/1/2022

### 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[[841]](#footnote-863)

###### Deemed Measure Cost

The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer. [[842]](#footnote-864)

###### Loadshape

Loadshape C53 - Flat

###### Coincidence Factor

The peak kW coincidence factor is 100%.

**Algorithm**

###### Calculation of Savings

###### 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 | 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

∆kW*=* ∆kWh/ Hours \* CF \* motors

Where:

∆kWh = 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

### 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[[843]](#footnote-865)

###### Deemed Measure Cost

The incremental cost of this measure is $500[[844]](#footnote-866)

###### 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[[845]](#footnote-867)

| **Vending Machine Capacity (cans)** | **kWh Savings Per Machine w/o software** | **kWh Savings Per Machine w/ software** |
| --- | --- | --- |
| <500 | 1,099 | 1,659 |
| 500 - 599 | 1,754 | 2,231 |
| 600 - 699 | 1,242 | 1,751 |
| 700 - 799 | 1,741 | 2,283 |
| 800+ | 713 | 1,288 |
| Average | 1,310 | 1,842 |

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-RFG-ESVE-V03-190101

###### Review Deadline: 1/1/2022

### Evaporator Fan Control for Electrically Commutated Motors

###### Description

This measure is for the installation of controls for Electronically Commutated Motors in existing medium temperature walk-in coolers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow.

This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers.

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

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

###### Definition of Efficient Equipment

The measure must control a minimum of 1/20 HP where fans operate continuously at full speed. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

* The compressor runs more than 4380 hours annually
* The evaporator fan does not run at full speed all the time
* The evaporator fan motor runs on poly-phase power
* Evaporator does not use off-cycle or time-off defrost.

###### Definition of Baseline Equipment

In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by Electrically Commutated Motors

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 13 years[[846]](#footnote-868)

###### Deemed Measure Cost

The measure cost is assumed to be $291[[847]](#footnote-869)

###### Loadshape

Loadshape C46 - Evaporator Fan Control

###### Coincidence Factor

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

**Algorithm**

###### Calculation of Savings

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association[[848]](#footnote-870) 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

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-RFG-EVPF-V04-190101

###### Review Deadline: 1/1/2024

### 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.[[849]](#footnote-871)

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[[850]](#footnote-872) 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[[851]](#footnote-873).

###### Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening [[852]](#footnote-874)

###### Loadshape

Loadshape C22 - Commercial Refrigeration

###### Coincidence Factor

The summer peak coincidence factor for this measure is 100%[[853]](#footnote-875).

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings[[854]](#footnote-876)

ΔkWh = ∆kWh/sq ft \* A

Where:

∆kWh/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[[855]](#footnote-877)

|  |  |  |
| --- | --- | --- |
| **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[[856]](#footnote-878)

| **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 |

###### 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

### 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[[857]](#footnote-879).

###### Deemed Measure Cost

The installation cost for an economizer is $2,558.[[858]](#footnote-880)

###### Loadshape

Loadshape C22 - Commercial Refrigeration

###### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0%[[859]](#footnote-881).

**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]

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) [[860]](#footnote-882)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Hermetic / Semi-Hermetic** | **Scroll** | **Discus** |
| kWh/HP | 1,256 | 1,108 | 1,051 |

Hours = Number of annual hours that economizer operates [[861]](#footnote-883).

|  |  |
| --- | --- |
| **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% [[862]](#footnote-884)

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW[[863]](#footnote-885)

kWCirc = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW[[864]](#footnote-886)

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%[[865]](#footnote-887)

BF = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)[[866]](#footnote-888)

kWEcon = Connected load kW of the economizer fan

= If known, actual installed. Otherwise assume 0.227 kW.[[867]](#footnote-889)

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

### 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.[[868]](#footnote-890)

###### Deemed Measure Cost

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.[[869]](#footnote-891)

###### Loadshape

Loadshape 22: Commercial Refrigeration

###### Coincidence Factor

N/A – savings occur at night only.

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

∆kWh = ES \* L

Where:

ES = the energy savings (∆kWh/ft) found in table below:

| **Display Case Description** | **Case Temperature Range (°F)** | **Annual Electricity Use**  **kWh/ft[[870]](#footnote-892)** | **ES**  **∆kWh/ft reduction**  **(= 9% reduction of electricity use**[[871]](#footnote-893),[[872]](#footnote-894)**)** |
| --- | --- | --- | --- |
| 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

###### Measure Code: CI-RFG-NCOV-V01-150601

###### Review Deadline: 1/1/2024

### High Speed Rollup Doors

###### Description

This measure entails the installation of High Speed Doors in refrigerated warehouses. High speed doors can save energy by lowering infiltration through a reduction in time that cooled spaces are exposed to ambient outdoor conditions. This in turn can lower the demand on refrigeration systems.

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

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

###### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a High Speed Door installed on the loading dock doorway of a refrigerated space. The high speed door is assumed to act as a primary door. It should be noted that for high-traffic applications (about 45 door passages per hour, using the defaults for this measure) a custom analysis is necessary to ensure that high-speed rollup doors will provide savings, because strip curtains may outperform the high speed door, if no other open-door protection device is installed.

###### Definition of Baseline Equipment

The baseline equipment is existing strip curtains on doorways to a loading dock. During times of traffic, primary doors are left open, leaving just the strip curtains as open-doorway protection.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[[873]](#footnote-895)

###### Deemed Measure Cost

The incremental measure cost is $150/sq.ft.[[874]](#footnote-896)

###### 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.

Where:

0.00008333 = conversion from Btu/h to tons

*q* = sensible and latent refrigeration load for fully established flow, Btu/h

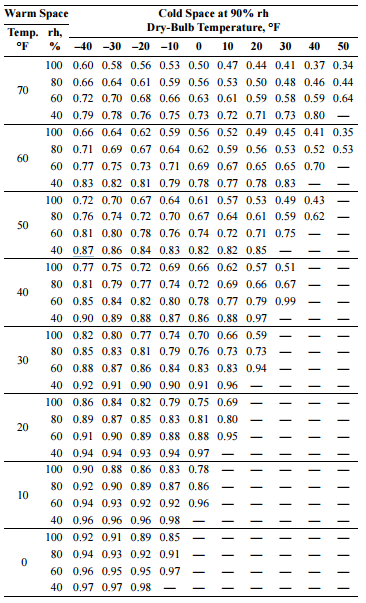
W = width of doorway, in feet. Custom input.

H = height of doorway, in feet. Custom input.

= 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 50⁰ F[[875]](#footnote-897), cooler temperature 35⁰F and freezer temperature -10⁰F[[876]](#footnote-898), resulting in values of 0.06 for a cooler and 0.5 for a freezer.



Rs = 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%[[877]](#footnote-899), resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.



Df = 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[[878]](#footnote-900).

η = Efficiency of refrigeration system (kW/ton). Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton[[879]](#footnote-901) for freezers.

DtB = 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.

P = Number of passages through doorway per hour.

ΘpB = Door open to close time in seconds.

ΘoB = Time door remains open in minutes.

Θd = Period of time considered in hours, 1 hr.

DtE = decimal portion of time doorway is open in the efficient condition.

P = Number of passages through doorway per hour. Custom input, assume 5.9[[880]](#footnote-902) if unknown.

ΘpE = Door open to close time in seconds. Custom input, assume 7.5 seconds[[881]](#footnote-903) if unknown.

ΘoE = Time door remains open in minutes. Custom input, assume 3 minutes[[882]](#footnote-904) if unknown.

Θd = Period of time considered in hours, 1 hr.

DtM = decimal portion of time high speed door motor is operational.

Variables defined above.

EB = effectiveness of baseline open-doorway protective device (strip curtains). Equal to 0.85[[883]](#footnote-905).

EE = 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[[884]](#footnote-906) if unknown.

t = hours per year when primary doors to the cooled space are open.

= Custom input, assume 2,959 hrs/yr[[885]](#footnote-907) 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

###### 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[[886]](#footnote-908).

###### Measure Code: CI-RFG-HSRD-V02-190101

###### Review Deadline: 1/1/2022

### Q-Sync Motors for Reach-in Coolers/Freezers

###### Description

This measure is applicable to replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole and electronically commutated (EC) evaporator fan motors in refrigerated display cases.

This measure achieves energy savings by installing a more efficient Q-sync motor in these scenarios. In addition to motor energy savings, the measure also results in less waste heat for the refrigeration equipment to reject and improves the power factor of the equipment.

This measure is limited to a typical refrigerated display case with the evaporator fan power of 12 watt. Besides the motor, the replacement evaporator fan will need to be replaced and provided by the manufacturer to provide matching airflow (because the fan’s speed has been modified).

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

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

###### Definition of Efficient Equipment

The replacement unit must be a Q-sync motor with a minimum of 73% motor efficiency.

###### Definition of Baseline Equipment

The baseline 1 for retrofit is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case.

The baseline 2 for retrofit is an EC motor with no fan control operating 8760 hours continuously in a refrigerated display case.

###### Deemed Lifetime of Efficient Equipment

The deemed measure life is assumed to be at least ten years[[887]](#footnote-909)

###### Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used[[888]](#footnote-910).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure** | **Material Unit (Each)** | **Material Cost / Unit** | **Labor Unit (Hours)** | **Labor Rate / Unit** | **Total Cost / Unit** |
| 12-watt Q-sync motor | 1 | $52 | 0.25 | $120 | $82 |

Notes: the unit cost is based on a large-scale retrofit project.

###### Loadshape

Loadshape C53 - Flat

###### Coincidence Factor

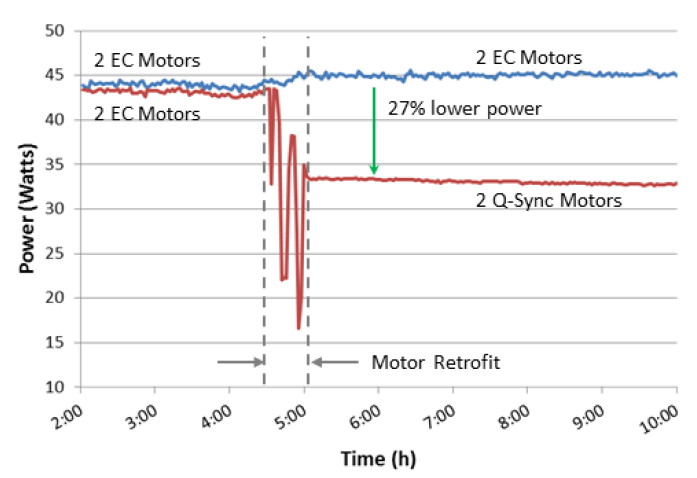
The peak kW coincidence factor is 100%

Algorithm

###### Calculation of Energy Savings

To determine the savings associated with the Q-sync motor measure we utilized the field study results provided by Oak Ridge National Laboratory[[889]](#footnote-911) and Alternative Energy Systems Consulting[[890]](#footnote-912).

In 2015, ORNL conducted a side-by-side comparison of Q-sync motors with EC motors in a 16 ft medium-temperature vertical multi-deck refrigerated display case at an Hy-Vee Supermarket in the Kansas City metropolitan area. A retrofit was done on the display case that contained four 12 W EC evaporator fan motors, two in each 8 ft section. Two existing EC motors in one of the 8 ft sections were replaced with two 12 W Q-Sync motors. The initial results show that Q-sync motors consumed approximately 16.4 watts per motor, and EC motors consumed approximately 22.6 watts per motor[[891]](#footnote-913).



In comparison, 2011 study by Navigant and PNNL demonstrated that a 12 w shade-pole motor ‘s actual power is 60.0 watts at design condition[[892]](#footnote-914).

The electrical energy savings for replacing a shaded-pole motor with a Q-sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours. For med-temperature cases, T is 8,760 hours. For low-temp freezer cases, T is 8,578 hours considering daily 30-minute defrost cycles during which fans are not powered[[893]](#footnote-915).

Motor energy savings (baseline 1, med-temp, per motor) = (60 w – 16.4 w) x 8760 hours = 381,936 Wh

Motor energy savings (baseline 1, low-temp, per motor) = (60 w – 16.4 w) x 8578 hours = 374,001 Wh

The electrical energy savings for replacing an EC motor with a Q-sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours (8760 hours):

Motor energy savings (baseline 2, med-temp, per motor) = (22.6 w – 16.4 w) x 8760 hours = 54,312 Wh

Motor energy savings (baseline 2, low-temp, per motor) = (22.6 w – 16.4 w) x 8578 hours = 53,184 Wh

The reduced motor power will also reduce refrigeration load. Assuming the power to drive the evaporator fan is converted to heat inside the display cases at 100% rate, the reduction in refrigeration system compressor power can be calculated using the following equation:

,

where COP is the Coefficient of Performance of refrigeration systems in the supermarket display cases. For med-temperature cases, the average COP is 2.5[[894]](#footnote-916). For low-temp freezer cases, the average COP is 1.3[[895]](#footnote-917).

The refrigeration energy savings can be calculated based on above numbers:

Refrigeration energy savings (baseline 1, med-temp, per motor) = 152,774 Wh

Refrigeration energy savings (baseline 1, low-temp, per motor) = 287,693 Wh

Refrigeration energy savings (baseline 2, med-temp, per motor) = 21,724 Wh

Refrigeration energy savings (baseline 2, low-temp, per motor) = 40,910 Wh

The overall energy savings are the sums of the motor energy savings and the refrigeration energy savings:

Overall energy savings (baseline 1, med-temp, per motor) = 534,710 Wh

Overall energy savings (baseline 1, low-temp, per motor) = 661,694 Wh

Overall energy savings (baseline 2, med-temp, per motor) = 76,036 Wh

Overall energy savings (baseline 2, low-temp, per motor) = 94,094 Wh

###### Electric Energy Savings

ΔkWh = Total savings per motor \* motors

Where overall energy savings per motor can be looked up from the following table:

|  |  |  |
| --- | --- | --- |
| **Evaporator Fan Motor Rating (of Q-sync motor)** | **Baseline** | **Annual kWh**  **Savings/motor** |
| 12w | shaded-pole motor, med-temp | 534.7 |
| 12w | shaded-pole motor, low-temp | 661.7 |
| 12w | EC motor, med-temp | 76.0 |
| 12w | EC motor, low-temp | 94.1 |

Motors = number of fan motor replaced

###### Summer Coincident Peak Demand Savings

ΔkWh = ΔkWh/Hours\*CF\*motors

Where:

ΔkWh = Gross customer annual kWh savings for the measure, as listed above

Hours = Full Load hours per year

= 8,760 (med-temp); 8,578 (low-temp)

CF = Summer Peak Coincident Factor

= 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor):

|  |  |  |
| --- | --- | --- |
| **Evaporator Fan Motor Rating (of Q-sync motor)** | **Baseline** | **kW**  **Savings/motor** |
| 12w | shaded-pole motor, med-temp | 0.061 |
| 12w | shaded-pole motor, low-temp | 0.077 |
| 12w | EC motor, med-temp | 0.009 |
| 12w | EC motor, low-temp | 0.011 |

###### Natural Gas Savings

N/A

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-RFG-QMF-V02-190101

###### Review Deadline: 1/1/2022

## Compressed Air

### VSD Air Compressor

###### Description

This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls or variable displacement control. Baseline compressors choke off the inlet air to modulate the compressor output, which is not efficient. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility’s load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp. Only one compressor per compressed air distribution system is eligible.

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

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

###### Definition of Efficient Equipment

The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

###### Definition of Baseline Equipment

The baseline equipment is either a modulating compressor with blow down ≤ 40 hp or an oil-free compressor with load/no load controls ≤ 40 hp.

###### Deemed Lifetime of Efficient Equipment

13 years[[896]](#footnote-918).

###### Deemed Measure Cost

IncrementalCost ($) *=* (127 x hpcompressor) + 1446

Where:

127 and 1446[[897]](#footnote-919) = compressor motor nominal hp to incremental cost conversion factor and offset

hpcompressor = compressor motor nominal

###### Deemed O&M Cost Adjustments

N/A

###### Loadshape

Loadshape C35 - Industrial Process

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh*=* 0.9 x hpcompressor x HOURS x (CFb – CFe)

Where:

ΔkWh= gross customer annual kWh savings for the measure

hpcompressor = compressor motor nominal hp

0.9[[898]](#footnote-920) = 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 |



CFb = baseline compressor factor[[899]](#footnote-921)

|  |  |
| --- | --- |
| **Baseline Compressor** | **Compressor Factor** |
| Modulating w/ Blowdown | 0.890 |
| Load/No Load w/ 1 Gallon/CFM | 0.909 |
| Load/No Load w/ 3 Gallon/CFM | 0.831 |
| Load/No Load w/ 5 Gallon/CFM | 0.806 |

CFe = efficient compressor [[900]](#footnote-922)

=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

###### Summer Coincident Peak Demand Savings

ΔkW*=* ΔkWh / HOURS \* CF

Where:

CF = Summer peak coincidence factor for this measure

|  |  |
| --- | --- |
| **Shift** | **Coincidence Factor** |
| Single shift (8/5) | 0.59 |
| 2-shift (16/5) | 0.95 |
| 3-shift (24/5) | 0.95 |
| 4-shift (24/7) | 0.95 |

EXAMPLE

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

ΔkW*=* 3290/1976\*0.59

= 0.98 kW

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-CPA-VSDA-V02-190101

###### Review Deadline: 1/1/2022

### Compressed Air Low Pressure Drop Filters

###### Description

Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in better efficiencies.

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

###### Definition of Efficient Equipment

The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psid when new and 3 psid at element change.

###### Definition of Baseline Equipment

The baseline condition is a standard coalescing filter with a pressure drop of 3 psid when new and 5 or more at element change

###### Deemed Lifetime of Efficient Equipment

10 years [[901]](#footnote-923).

###### Deemed Measure Cost

The incremental cost for this measure is estimated to be $1000 Incremental cost per filter[[902]](#footnote-924)

###### Loadshape

Loadshape C35 - Industrial Process

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

∆kWh = (kWtypical x ∆P x SF x Hours / HPtypical) x HPreal

Where:

kWtypical = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use Use actual compressor control type if known:

|  |  |
| --- | --- |
| Compressor kWtypical |  |
| **Control Type** | **kWtypical [[903]](#footnote-925)** |
| 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 %** | **kWtypical[[904]](#footnote-926)** |
| 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 |

∆P = Reduced filter loss (psi)

=2 psi[[905]](#footnote-927)

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[[906]](#footnote-928)

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 |

HPtypical = Nominal HP for typical compressor = 100 hp[[907]](#footnote-929)

HPreal = 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

ΔkW*=* ΔkWh / HOURS \* CF

Where:

CF = Summer peak coincidence factor for this measure

|  |  |
| --- | --- |
| **Shift** | **Coincidence Factor** |
| Single shift (8/5) | 0.59 |
| 2-shift (16/5) | 0.95 |
| 3-shift (24/5) | 0.95 |
| 4-shift (24/7) | 0.95 |

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-CPA-LPDF-V02-190101

###### Review Deadline: 1/1/2022

### 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 [[908]](#footnote-930)

###### Loadshape

Loadshape C35 - Industrial Process

###### Coincidence Factor

The coincidence factor equals 0.95

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

∆kWh = CFMreduced x kWCFM x Hours

Where:

CFMreduced = Reduced air consumption (CFM) per drain

= 3 CFM[[909]](#footnote-931)

kWCFM = System power reduction per reduced air demand (kw/CFM) depending on the type of compressor control:

System Power Reduction per Reduced Air Demand[[910]](#footnote-932)

| **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[[911]](#footnote-933)

###### Summer Coincident Peak Demand Savings

ΔkW*=* ΔkWh / HOURS \* CF

Where:

CF = Summer peak coincidence factor for this measure

= 0.95

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-CPA-NCLD-V02-190101

###### Review Deadline: 1/1/2020

### 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[[912]](#footnote-934)

###### Deemed Measure Cost

The estimated incremental measure costs are presented in the following table[[913]](#footnote-935)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Nozzle Diameter** | **1/8”** | **1/4"** | **5/16”** | **1/2"** |
| Average IMC | $42 | $57 | $87 | $121 |

###### Loadshape

Loadshape C35 - Industrial Process

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh = (SCFM \* SCFM%Reduced) \* kW/CFM \* %USE \* HOURS

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**[[914]](#footnote-936)**, **[[915]](#footnote-937)**.

|  |  |
| --- | --- |
| **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%[[916]](#footnote-938)

kW/CFM = System power reduction per air demand (kW/CFM) depending on the type of air compressor found in table below**[[917]](#footnote-939)**

|  |  |
| --- | --- |
| **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%[[918]](#footnote-940)

Hours = Compressed air system pressurized hours.

= Use actual hours if known, otherwise assume values in table below:

| **Shift** | **Hours** |
| --- | --- |
| Single Shift | 1976 |
| Two Shifts | 3952 |
| Three Shifts | 5928 |
| Four Shifts or Continual Operation | 8320 |
| Unknown / Weighted average[[919]](#footnote-941) | 5702 |

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/HOURS \* CF

Where:

ΔkWh = As calculated above

CF = summer peak coincidence factor

|  |  |
| --- | --- |
| **Shift** | **Coincidence Factor** |
| Single Shift | 0.59 |
| Two Shifts | 0.95 |
| Three Shifts | 0.95 |
| Four Shifts or Continual Operation | 0.95 |
| Unknown / Weighted average[[920]](#footnote-942) | 0.89 |

###### Natural Gas Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code CI-CPA-CNOZ-V02-190101

###### Review Deadline: 1/1/2023

### Efficient Refrigerated Compressed Air Dryer

###### Description

An air dryer is an essential component in a compressed air system that prevents condensate from being deposited in the compressed air supply lines of a facility. If the warm, saturated compressed air is supplied directly into the plant, excess condensate will form in the compressed air supply lines. Uncontrolled condensate can damage demand-side tools and process equipment. Secondly, in an oil-flooded rotary screw compressor, the residual oil from compression can be carried along the supply lines potentially damaging process equipment. Industries that use compressed air for processes make use of various types of dryers including refrigerated dryers (both cycling and non-cycling). For this measure, three types of refrigerated air dryers will be considered: thermal mass, variable speed and digital scroll. All of these technologies offer better part load performance compared to non-cycling refrigerated dryers, thereby offering energy savings during periods when the dryer is not operating at peak capacity.

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

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

###### Definition of Efficient Equipment

A new, high efficiency thermal mass dryer, variable speed dryer, or digital scroll dryer.

###### Definition of Baseline Equipment

A standard non-cycling refrigerated compressed air dryer of comparable capacity.

###### Deemed Lifetime of Efficient Equipment

The measure life is 13 years[[921]](#footnote-943).

###### Deemed Measure Cost

The incremental capital cost for this measure is $6 per CFM.[[922]](#footnote-944)

###### Loadshape

Loadshape C35 – Industrial Process

###### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh*=* Ps x (EC50baseline - EC50efficient) x HOURS x CFM

Where:

Ps  = Full flow specific power of the dryer

= 0.007 kW/CFM[[923]](#footnote-945) (for both baseline and efficient equipment)

EC50baseline = Energy consumption ratio of baseline dryer at 50%[[924]](#footnote-946) inlet load capacity as compared to fully loaded operating conditions.[[925]](#footnote-947)

= 0.843

ECF50efficient = 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[[926]](#footnote-948):

|  |  |
| --- | --- |
| **Dryer Type** | **EC50efficient** |
| 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****[[927]](#footnote-949)** | **Weighted Hours** |
| --- | --- | --- | --- |
| Single Shift  7 AM – 3 PM, weekdays, minus some holidays and scheduled down time | 1,976 | 16% | 316 |
| Two Shifts  7AM – 11 PM, weekdays, minus some holidays and scheduled down time | 3,952 | 23% | 909 |
| Three Shifts  24 hours per day, weekdays, minus some holidays and scheduled down time | 5,928 | 25% | 1,482 |
| Four Shifts or Continual Operation  24 hours per day, 7 days a week minus some holidays and scheduled down time | 8,320 | 36% | 2,995 |
|  |  | Total weighted average | 5,702 |

CFM = Cubic feet per minute, rated capacity of refrigerated dryer

= Assume 100% of actual rated capacity.

###### Summer Coincident Peak Demand Savings

ΔkW*=* ΔkWh / HOURS \* CF

Where:

CF = Summer peak coincidence factor, depending on shift. If unknown, use weighted average.

|  |  |
| --- | --- |
| **Shift** | **Coincidence Factor** |
| Single Shift | 0.59 |
| Two Shifts | 0.95 |
| Three Shifts | 0.95 |
| Four Shifts or Continual Operation | 0.95 |
| Unknown / Weighted average835 | 0.89 |



###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-CPA-CADR-V02-190101

###### Review Deadline: 1/1/2024

## Miscellaneous End Use

### Pump Optimization

###### Description

Pump improvements can be done to optimize the design and control of centrifugal water pumping systems, including water solutions with freeze protection up to 15% concentration by volume. Other fluid and gas pumps cannot use this measure calculation. The measurement of energy and demand savings for commercial and industrial applications will vary with the type of pumping technology, operating hours, efficiency, and existing and proposed controls. Depending on the specific application slowing the pump, trimming or replacing the impeller may be suitable options for improving pumping efficiency. Pumps up to 40 HP are allowed to use this energy savings calculation. Larger motors should use a custom calculation (which may result in larger savings that this measure would claim).

###### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is proven to be an optimized centrifugal pumping system meeting the applicable program efficiency requirements:

* Pump balancing valves no more than 15% throttled
* Balancing valves on at least one load 100% open.

###### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years[[928]](#footnote-950)

###### 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%[[929]](#footnote-951)

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = (HPmotor \* 0.746 \* LF / ηmotor) \* HOURS \* ESF

Where:

HPmotor = Installed nameplate motor horsepower

= Actual

0.746 = Conversion factor from horse-power to kW (kW/hp)

LF / ηmotor = Combined as a single factor since efficiency is a function of load

= 0.65 [[930]](#footnote-952)

Where:

LF = Load Factor; Ratio of the peak running load to the nameplate rating of the motor

ηmotor = Motor efficiency at pump operating conditions

HOURS = Annual operating hours of the pump

= Actual

ESF = Energy Savings Factor; assume a value of 15%[[931]](#footnote-953).

###### Summer Coincident Peak Demand Savings

ΔkW = (HPmotor \* 0.746 \*( LF / ηmotor)) \* (ESF) \* CF

Where:

CF = Summer Coincident Peak Factor for measure

###### Natural Gas Energy Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-MSC-PMPO-V02-190101

###### Review Deadline: 1/1/2022

### 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)..

R-Values: ASHRAE – 90.1 – 2010

|  | **IL TRM Zones 1, 2, & 3 [ASHRAE/IECC Climate Zone 5 (A, B, C)]** | | | |
| --- | --- | --- | --- | --- |
| **Nonresidential** | | **Semiheated** | |
| **Assembly Maximum** | **Insulation Min. R-Value** | **Assembly Maximum** | **Insulation Min. R-Value** |
| **Insulation Entirely Above Deck** | 0.048 | R-20 c.i. | U-0.119 | R-7.6 c.i. |
| **Metal Building (Roof)** | 0.055 | R-13.0 + R-13.0 | U-0.083 | R-13.0 |
| **Attic and Other** | 0.027 | R-38.0 | U-0.053 | R-19.0 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **IL TRM Zones 4 & 5 [ASHRAE/IECC Climate Zone 4 (A, B, C)]** | | | | Table Notes  c.i. = continuous insulation |
|  | **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 |

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)]** | | | | Table Notes  c.i. = continuous insulation  Ls = linear system, a continuous vapor barrier liner installed below the purlins and uninterrupted by framing members |
| **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 |

###### 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[[932]](#footnote-954), 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

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[933]](#footnote-955)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[934]](#footnote-956)

**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

∆kWh = ∆kWh\_cooling + ∆kWh\_heating

If central cooling, the electric energy saved in annual cooling due to the added insulation is

∆kWh\_cooling = ((1/R\_existing) - (1/R\_new)) \* Area \* EFLHcooling \* ΔTAVG,cooling / 1,000 / η\_cooling

Where:

R\_existing = Roof heat loss coefficient with existing insulation [(hr-⁰F-ft2)/Btu]

R\_new = Roof heat loss coefficienty with new insulation [(hr-⁰F-ft2)/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

EFLHcooling = Equivalent Full Load Hours for Cooling [hr] are provided in Section 4.4, HVAC end use

ΔTAVG,cooling = Average temperature difference [⁰F] during cooling season between outdoor air temperature and assumed 75⁰F indoor air temperature

| **Climate Zone**  **(City based upon)** | **OAAVG,cooling [°F][[935]](#footnote-957)** | **ΔTAVG,cooling [°F]** |
| --- | --- | --- |
| 1 (Rockford) | 81 | 6 |
| 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

∆kWh\_heating = [(1/R\_existing) - (1/R\_new)] \* Area \* EFLHheating \* ΔTAVG,heating / 3,412 / η\_heating

Where:

EFLHheating = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use

ΔTAVG,heating = Average temperature difference [⁰F] during heating season between outdoor air temperature and assumed 55⁰F heating base temperature

| **Climate Zone**  **(City based upon)** | **OAAVG,heating [°F][[936]](#footnote-958)** | **ΔTAVG,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.

∆kWh\_heating = ∆Therms \* Fe \* 29.3

Where:

∆Therms = 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

∆kW = (∆kWh\_cooling / EFLH\_cooling) \* CF

Where:

EFLHcooling = Equivalent full load hours of air conditioning are provided in Section 4.4, HVAC end use

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[937]](#footnote-959)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [[938]](#footnote-960)

###### Natural Gas Savings

If building uses a gas furnace, the savings resulting from the insulation is calculated with the following formula.

∆Therms = ((1/R\_existing) - (1/R\_new)) \* Area \* EFLHheating \* ΔTAVG,heating / 100,000 / η\_heat

Where:

R\_existing = Roof heat loss coefficient with existing insulation [(hr-⁰F-ft2)/Btu]

R\_new = Roof heat loss coefficienty with new insulation [(hr-⁰F-ft2)/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

EFLHheating = Equvalent Full Load Hours for Heating are provided in Section 4.4, HVAC end use

ΔTAVG,heating = Average temperature difference [⁰F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η\_heat = Efficiency of existing furnace. Assume 0.78 for planning purposes.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure code: CI-MSC-RINS-V02-160601

###### Review Deadline: 1/1/2021

### 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.[[939]](#footnote-961)

###### Deemed Measure Cost

The deemed measure cost is $29 per networked computer, including labor.[[940]](#footnote-962)

###### Loadshape

Loadshape C21: Commercial Office Equipment.

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh = Wsavings \* W

Where:

Wsavings = annual energy savings per workstation

= 200 kWh[[941]](#footnote-963) for desktops, 50 kWh for laptops[[942]](#footnote-964)

= If unknown assume 161 kWh (based on 74% desktop and 26% laptop[[943]](#footnote-965))

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 [[944]](#footnote-966)

###### Measure code: CI-MSC-CPMS-V01-150601

###### Review Deadline: 1/1/2020

### 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**[[945]](#footnote-967)**.

###### 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)**[[946]](#footnote-968)**.

###### 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

*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.*

ΔTherms = NCycles \* SF

Where:

NCycles = 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[[947]](#footnote-969) | 1,483 |
| Multi-family Dryers[[948]](#footnote-970) | 1,074 |
| On-Premise Laundromats[[949]](#footnote-971) | 3,607 |

SF = Savings factor

= 0.18 therms/cycle[[950]](#footnote-972)

If using default cycles the savings are as follows:

|  |  |
| --- | --- |
| **Application** | **ΔTherms** |
| Coin- Operated Laundromats[[951]](#footnote-973) | 267 |
| Multi-family Dryers[[952]](#footnote-974) | 193 |
| On-Premise Laundromats[[953]](#footnote-975) | 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

### 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[[954]](#footnote-976) 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[[955]](#footnote-977).

For early replacement measures it is assumed the existing unit would last another 2.3 years[[956]](#footnote-978)

###### Deemed Measure Cost[[957]](#footnote-979)

The incremental cost for time of sale is $9.70/lb capacity.

The full cost of the high speed washer for early replacement applications is $164.89/lb capacity. The deferred replacement cost of the baseline unit is $155.19/lb capacity. This future cost should be discounted to present value using the real discount rate:

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

N/A

###### Summer Coincident Peak Demand Savings

N/A

**Natural Gas Savings**

ΔTherms = (Ncycles \* Days \* Capacity \* RMC \* he / ηdryer /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[[958]](#footnote-980) |
| Multi-family | 3.4[[959]](#footnote-981) |
| Hotel/Motel/Hospital | 10.4[[960]](#footnote-982) |

Days = Days per year of commercial laundromat operation

= Actual, or if unknown, assume 360 days[[961]](#footnote-983)

Capacity = Clothes washer rated capacity (lb/cycle)[[962]](#footnote-984)

= Actual

RMC = Retained Moisture Content (%)[[963]](#footnote-985) reduction from replacing a low extraction speed washer

= Assume 25%[[964]](#footnote-986)

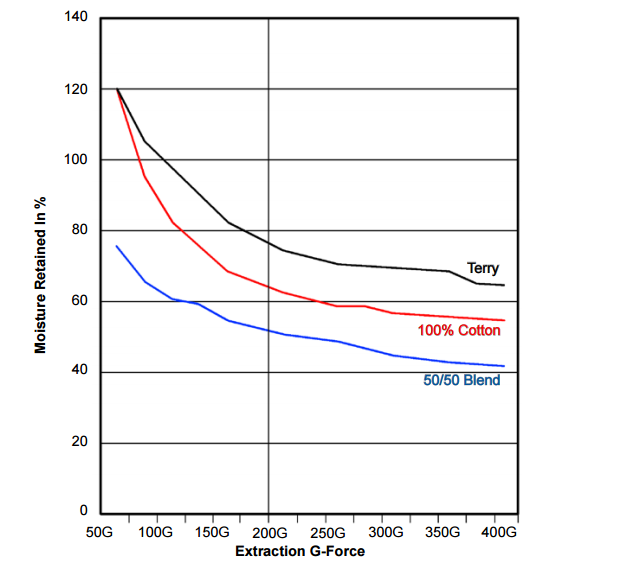


Figure 1

he = Heat required by a dryer to evaporate 1 lb of water

= Assume 1,200 Btu/lb[[965]](#footnote-987)

ηdryer = Efficiency of the clothes dryer

= Actual, or if unknown, assume 60%[[966]](#footnote-988)

100,000 = Converts Btus to therms

DryerUse = % of washer loads dried in the field

= Assume 91%[[967]](#footnote-989)

LF = Load Factor (%) to account for the pounds per washer load, as a percentage of rated capacity

= Assume 66%[[968]](#footnote-990)

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 \* he / ηdryer /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

### 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.[[969]](#footnote-991)

###### Deemed Measure Cost[[970]](#footnote-992)

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*[[971]](#footnote-993)*

ΔkWh = 8760/1000 \* (((WattsBase,Off \* %Time Off) + (Watts Base,Sleep \* %Time Sleep) + (Watts Base,Long \* %Time Long) + (Watts Base,Short \* %Time Short)) - ((Watts Eff,Off \* %TimeOff) + (Watts Eff,Sleep \* %Time Sleep) + (Watts Eff,Long \* %Time Long) + (Watts Eff,Short \* %Time Short)))

Where (see assumptions in table below):

8760/1000 = Converts W to kWh

Watts Base,Off = baseline equipment power in off mode

%Time Off = typical percent of time a desktop, integrated desktop or notebook is in off mode during the year

Watts Base,Sleep = baseline equipment power in sleep mode

%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[[972]](#footnote-994) | 45% | 5% | 15% | 35% |

| **Measure Watt Draw in Mode (Watts)** | **Off** | **Sleep** | **Long Idle** | **Short Idle** |
| --- | --- | --- | --- | --- |
| Baseline[[973]](#footnote-995) | 0.88 | 2.1 | 26.5 | 27.9 |
| ES 6.0 Desktops[[974]](#footnote-996) | 0.55 | 1.23 | 24.66 | 26.04 |
| ES 6.0 +20% Desktops[[975]](#footnote-997) | 0.52 | 1.63 | 21.33 | 22.58 |
| ES 6.0 Desktops w/ 80 PLUS Gold PSUs[[976]](#footnote-998) | 0.50 | 1.50 | 23.08 | 24.38 |
| ES 6.0 Desktops w/ 80 PLUS Platinum PSUs[[977]](#footnote-999) | 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”

###### Summer Coincident Peak Demand Savings[[978]](#footnote-1000)

ΔkW = (WattsBase - Watts Eff)/1000 \* CF

Where:

WattsBase = Assumed average baseline wattage during peak period (see table below)

WattsEff = 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

### 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.[[979]](#footnote-1001)

###### 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[[980]](#footnote-1002)

###### Coincidence Factor

N/A due to no savings attributable to standby losses between 1 and 5 PM.

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh[[981]](#footnote-1003) = ((kWwkday \* (hrswkday - hrswkday-open)) + (kWwkend \* (hrswkend - hrswkend-open))) \* weeks/year \* ISR

Where:

Wwkday = Standby power consumption of connected electronics on weekday off-hours. If unknown, assume 0.0315 kW.

kWwkend = Standby power consumption of connected electronics on weekend off-hours. If unknown, assume 0.00617 kW.

hrswkday = total hours during the work week (Monday 7:30 AM to Friday 5:30 PM)

= 106

hrswkend = total hours during the weekend (Friday 5:30 PM to Monday 7:30 AM)

= 62

hrswkday-open = hours the office is open during the work week. If unknown, assume 50 hours.

hrswkend-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[[982]](#footnote-1004)

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

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-MSC-APSC-V02-190101

###### Review Deadline: 1/1/2020

### 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[[983]](#footnote-1005).

**(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.***

**(2)** The efficiency of a liquid-immersed distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Liquid-immersed distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

|  |  |  |  |
| --- | --- | --- | --- |
| **Single-phase** | | **Three-phase** | |
| **kVA** | **Efficiency  (%)** | **kVA** | **Efficiency  (%)** |
| 10 | 98.70 | 15 | 98.65 |
| 15 | 98.82 | 30 | 98.83 |
| 25 | 98.95 | 45 | 98.92 |
| 37.5 | 99.05 | 75 | 99.03 |
| 50 | 99.11 | 112.5 | 99.11 |
| 75 | 99.19 | 150 | 99.16 |
| 100 | 99.25 | 225 | 99.23 |
| 167 | 99.33 | 300 | 99.27 |
| 250 | 99.39 | 500 | 99.35 |
| 333 | 99.43 | 750 | 99.40 |
| 500 | 99.49 | 1000 | 99.43 |
| 667 | 99.52 | 1500 | 99.48 |
| 833 | 99.55 | 2000 | 99.51 |
|  |  | 2500 | 99.53 |

**(c)** ***Medium-Voltage Dry-Type Distribution Transformers.***

**(2)** The efficiency of a medium- voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA and BIL rating in the table below. Medium-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

| **1** | | | | **Three-phase** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **kVA** | **BIL\*** | | | **kVA** | **BIL** | | |
| **20-45 kV** | **46-95 kV** | **≥96 kV** | **20-45 kV** | **46-95 kV** | **≥96 kV** |
| **Efficiency  (%)** | **Efficiency  (%)** | **Efficiency  (%)** | **Efficiency  (%)** | **Efficiency  (%)** | **Efficiency  (%)** |
| 15 | 98.10 | 97.86 |  | 15 | 97.50 | 97.18 |  |
| 25 | 98.33 | 98.12 |  | 30 | 97.90 | 97.63 |  |
| 37.5 | 98.49 | 98.30 |  | 45 | 98.10 | 97.86 |  |
| 50 | 98.60 | 98.42 |  | 75 | 98.33 | 98.13 |  |
| 75 | 98.73 | 98.57 | 98.53 | 112.5 | 98.52 | 98.36 |  |
| 100 | 98.82 | 98.67 | 98.63 | 150 | 98.65 | 98.51 |  |
| 167 | 98.96 | 98.83 | 98.80 | 225 | 98.82 | 98.69 | 98.57 |
| 250 | 99.07 | 98.95 | 98.91 | 300 | 98.93 | 98.81 | 98.69 |
| 333 | 99.14 | 99.03 | 98.99 | 500 | 99.09 | 98.99 | 98.89 |
| 500 | 99.22 | 99.12 | 99.09 | 750 | 99.21 | 99.12 | 99.02 |
| 667 | 99.27 | 99.18 | 99.15 | 1000 | 99.28 | 99.20 | 99.11 |
| 833 | 99.31 | 99.23 | 99.20 | 1500 | 99.37 | 99.30 | 99.21 |
|  |  |  |  | 2000 | 99.43 | 99.36 | 99.28 |
|  |  |  |  | 2500 | 99.47 | 99.41 | 99.33 |

###### Deemed Lifetime of Efficient Equipment

30 years[[984]](#footnote-1006)

###### 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

ΔkWh = Lossesbase – LossesEE

Where:

PowerRating = kVA rating of the transformer (in units of kVA)

EFFbase = baseline total efficiency rating of federal minimum standard transformer (refer to baseline tables above based on kVA, voltage, and type of transformer)

EFFEE = actual total efficiency rating of the transformer as calculated by the appropriate DOE test method[[985]](#footnote-1007)

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.[[986]](#footnote-1008)

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.[[987]](#footnote-1009)

###### Summer Coincident Peak Demand Savings

Variables as provided above.

###### Natural Gas Savings

N/A

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-MSC-TRNS-V01-180101

###### Review Deadline: 1/1/2021

### 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[[988]](#footnote-1010)

###### Deemed Measure Cost

The deemed incremental measure cost is $400[[989]](#footnote-1011)

###### 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. [[990]](#footnote-1012)

Algorithm

###### Electric Energy Savings

∆kWh = (CAP \* DOD) \* CHG \* (CRB/ PCB - CREE / PCEE)

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh[[991]](#footnote-1013)

DOD = Depth of Discharge

= Use actual depth of discharge, otherwise use a default value of 80%.[[992]](#footnote-1014)

CHG = Number of Charges per year

= Use actual number of annual charges, if unknown use values below based on the type of operations[[993]](#footnote-1015)

|  |  |
| --- | --- |
| **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 |

CRB = Baseline Charge Return Factor

= 1.2485[[994]](#footnote-1016)

PCB = Baseline Power Conversion Efficiency

= 0.84[[995]](#footnote-1017)

CREE = Efficient Charge Return Factor

= 1.107[[996]](#footnote-1018)

PCEE = Efficient Power Conversion Efficiency

= 0.89[[997]](#footnote-1019)

Default savings using defaults provided above are provided below:

| **Standard Operations** | **ΔkWh** |
| --- | --- |
| 1-shift (8 hrs/day – 5 days/week) | 3,531 |
| 2-shift (16 hrs/day – 5 days/week) | 7,061 |
| 3-shift (24 hrs/day – 5 days/week) | 10,592 |
| 4-shift (24 hrs/day – 7 days/week) | 14,829 |

###### Summer Coincident Peak Demand Savings

∆kW = (PFB/PCB - PFEE/PCEE) \* VoltsDC­ \* AmpsDC / 1000 \* CF

Where:

PFB = Power factor of baseline charger

= 0.9095[[998]](#footnote-1020)

PFEE = Power factor of high frequency charger

= 0.9370[[999]](#footnote-1021)

VoltsDC = 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.[[1000]](#footnote-1022)

AmpsDC = 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.[[1001]](#footnote-1023)

1,000 = watt to kilowatt conversion factor

CF = Summer Coincident Peak Factor for this measure

= 0.0 (for 1 and 2-shift operation)[[1002]](#footnote-1024)

= 1.0 (for 3 and 4-shift operation)[[1003]](#footnote-1025)

Other variables as provided above.

Default savings using defaults provided above are provided below:

|  |  |
| --- | --- |
| **Standard Operations** | **∆kW** |
| 1-shift (8 hrs/day – 5 days/week) | 0 |
| 2-shift (16 hrs/day – 5 days/week) | 0 |
| 3-shift (24 hrs/day – 5 days/week) | 0.1165 |
| 4-shift (24 hrs/day – 7 days/week) | 0.1165 |

###### Natural Gas Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-MSC-BACH-V01-180101

###### Review Deadline: 1/1/2021

### Commercial Clothes Dryer Moisture Sensor

###### Description

This measure applies to moisture sensing controllers installed on new or existing commercial natural gas clothes dryers controlled electronically. Moisture controllers detect when the load is dry, which will stop the cycle from consuming additional energy. Some new commercial dryers utilize moisture sensors, but the majority of older dryers, as well as many new models, still do not utilize moisture sensors. In a commercial dyer, when a load is drying, the heat will run completely on in the early stages. Then, it begins to cycle on and off more frequently as the load becomes drier. Traditional moisture sensors use a conductivity strip in the dryer drum. The wet load will contact the strip that completes the circuit. When the load is dry, the circuit is shorted that completes the drying cycle. Instead, this technology is a “plug and play” retrofit controller that uses patent-pending software to determine when the load is dry. When the load is dry, it overrides the existing controls to end the cycle, which shuts the drying cycle. This measure does not apply to mechanical timer dryers or to dryers with modulating valves installed.

Natural gas energy savings will be achieved by reduced drying times and correspondingly reduced natural gas consumption. Electric savings will also be achieved by reduced operating times.

This measure was developed to be applicable to following facility types:

* Hotel/Motel
* Miscellaneous - Fitness and Recreational Sports Centers
* Hospital
* Assisted Living Facilities
* Miscellaneous - Dry cleaning
* Multifamily

Moisture sensing controller retrofits could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries); however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.) capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

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

###### Definition of Efficient Equipment

A retrofit moisture controlling technology is added to new or existing commercial natural gas clothes dryers. Existing facilities must be able to confirm that they do not have moisture sensors (conductive strip type) or modulating gas valves installed on clothes dryers already before proceeding with the installation of this technology.

###### Definition of Baseline Equipment

The baseline equipment is a conventional natural gas clothes dryer without a moisture sensor or a modulating gas valve installed.

###### Deemed Lifetime of Efficient Equipment

The equipment effective useful life (EUL) is 14 years based on manufacturer claims, assumed to be equal to that of a commercial dryer.[[1004]](#footnote-1026)

###### Deemed Measure Cost

The full retrofit cost is assumed to be $600, including the material cost for the basic moisture control retrofit ($500) and the associated labor for installation ($100).[[1005]](#footnote-1027)

###### Loadshape

Loadshape C55; Commercial Clothes Washer

###### Coincidence Factor

The coincidence factor for this measure is dependent on the application:

|  |  |
| --- | --- |
| **Application** | **Coincidence Factor[[1006]](#footnote-1028)** |
| Multi-family Dryers | 0.15 |
| On-Premise Laundromats | 0.52 |

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

Electric energy savings are per retrofitted dryer.

ΔkWh = NCycles \* SF

Where:

NCycles  = Number of dryer cycles per year. Refer to the table below if this value is not directly available from the facility.

|  |  |
| --- | --- |
| **Application** | **Cycles per Dryer Per Year** |
| Multi-family Dryers[[1007]](#footnote-1029) | 1,074 |
| On-Premise Laundromats[[1008]](#footnote-1030) | 3,607 |

SF = Savings factor

= 0.16 kWh/cycle[[1009]](#footnote-1031)

If using default cycles the savings are as follows:

| **Application** | **ΔkWh per Dryer** |
| --- | --- |
| Multi-family Dryers | 171.8 |
| On-Premise Laundromats | 577.1 |

###### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/ Hours \* CF

Where:

Hours = Assumed Run hours of Clothes Dryer[[1010]](#footnote-1032)

|  |  |
| --- | --- |
| **Application** | **Hours** |
| Multi-family Dryers | 806 |
| On-Premise Laundromats | 2,705 |

CF = Summer Peak Coincidence Factor for measure.

|  |  |
| --- | --- |
| **Application** | **Coincidence Factor[[1011]](#footnote-1033)** |
| Multi-family Dryers | 0.15 |
| On-Premise Laundromats | 0.52 |

If using default cycles the savings are as follows:

|  |  |
| --- | --- |
| **Application** | **ΔkW per Dryer** |
| Multi-family Dryers | 0.0320 |
| On-Premise Laundromats | 0.1109 |

###### Natural Gas Savings

Natural gas savings are per retrofitted dryer.

ΔTherms = NCycles \* SF

Where:

SF = Savings factor

= 0.15 therms/cycle[[1012]](#footnote-1034)

If using default cycles the savings are as follows:

|  |  |
| --- | --- |
| **Application** | **ΔTherms per Dryer** |
| Multi-family Dryers | 161 |
| On-Premise Laundromats | 541 |

###### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-MSC-CDMS-V01-190101

###### Review Deadline: 1/1/2023

1. Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time. [↑](#footnote-ref-1)
2. Based on bulk pricing reported by EnSave, which administers the rebate in Vermont [↑](#footnote-ref-2)
3. Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015. Based on field study conducted by Efficiency Vermont on 352 sites in Vermont and Minnesota. [↑](#footnote-ref-3)
4. The number of days in the use season in which the temperature drops below 25°F in the state of Illinois. The data is sourced as an average from TMY3 weather data for five different weather zones within the state. [↑](#footnote-ref-4)
5. EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota. [↑](#footnote-ref-5)
6. Ibid. The hours per day saved is sourced as the difference between the baseline run hours per day without the timer, 10.66 hours, and the efficient run hours per day with the timer, 2.90 hours. [↑](#footnote-ref-6)
7. Ibid. Based on an average sized engine block heater, which typically ranges in connected load from 0.20 kW and 2 kW, as sourced from Efficiency Vermont program data. [↑](#footnote-ref-7)
8. Ibid. [↑](#footnote-ref-8)
9. Act on Energy Commercial Technical Reference Manual No. 2010-4 [↑](#footnote-ref-9)
10. Ibid. [↑](#footnote-ref-10)
11. Ibid. [↑](#footnote-ref-11)
12. Ibid. [↑](#footnote-ref-12)
13. Ibid. [↑](#footnote-ref-13)
14. Act on Energy Commercial Technical Reference Manual No. 2010-4 [↑](#footnote-ref-14)
15. Ibid. [↑](#footnote-ref-15)
16. Ibid. [↑](#footnote-ref-16)
17. Ibid. [↑](#footnote-ref-17)
18. Ibid. [↑](#footnote-ref-18)
19. Act on Energy Commercial Technical Reference Manual No. 2010-4 [↑](#footnote-ref-19)
20. Ibid. [↑](#footnote-ref-20)
21. Ibid. [↑](#footnote-ref-21)
22. Ibid. [↑](#footnote-ref-22)
23. Ibid. [↑](#footnote-ref-23)
24. ENERGY STAR Commercial Ovens Key Product Criteria

    http://www.energystar.gov/index.cfm?c=ovens.pr\_crit\_comm\_ovens [↑](#footnote-ref-24)
25. 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 [↑](#footnote-ref-25)
26. http://www.fishnick.com/saveenergy/tools/calculators/gcombicalc.php [↑](#footnote-ref-26)
27. 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 [↑](#footnote-ref-27)
28. 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 [↑](#footnote-ref-28)
29. 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 [↑](#footnote-ref-29)
30. 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 [↑](#footnote-ref-30)
31. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008. [↑](#footnote-ref-31)
32. Incremental costs are based on the Northwest Regional Technical Forum, ENERGY STAR Version 4.0 Analysis. For cost calculation details, see the CostData&Analysis tab within the file Commercial Refrigerators & Freezers\_Costs\_Nov 2017.xlsm.  [↑](#footnote-ref-32)
33. The CF for Commercial Refrigeration was calculated based upon the Ameren provided eShapes [↑](#footnote-ref-33)
34. [Federal](C:\\Users\\celia\\AppData\\Local\\Packages\\Microsoft.MicrosoftEdge_8wekyb3d8bbwe\\TempState\\Downloads\\Federal) standards for equipment manufactured on or after March 27, 2017: 10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers. [↑](#footnote-ref-34)
35. ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 4.0: https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version\_0.pdf [↑](#footnote-ref-35)
36. California DEER 2008 which is also used by both the Food Service Technology Center and ENERGY STAR®. [↑](#footnote-ref-36)
37. Source for incremental cost for efficient natural gas steamer is RSG Commercial Gas Steamer Workpaper, January 2012. [↑](#footnote-ref-37)
38. Source for efficient electric steamer incremental cost is $2,490 per 2009 PG&E Workpaper - PGECOFST104.1 - Commercial Steam Cooker - Electric and Gas as reference by KEMA in the ComEd C & I TRM. [↑](#footnote-ref-38)
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.Unknown is an average of other location types [↑](#footnote-ref-39)
40. Food Service Technology Center 2011 Savings Calculator [↑](#footnote-ref-40)
41. Food Service Technology Center 2011 Savings Calculator [↑](#footnote-ref-41)
42. Production capacity per Food Service Technology Center 2011 Savings Calculator of 23.3333 lb/hr per pan for electric baseline steam cookers and 21.6667 lb/hr per pan for natural gas baseline steam cookers. ENERGY STAR® savings calculator uses 23.3 lb/hr per pan for both electric and natural gas baseline steamers. [↑](#footnote-ref-42)
43. Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=COC. [↑](#footnote-ref-43)
44. Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies. [↑](#footnote-ref-44)
45. 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. [↑](#footnote-ref-45)
46. Unknown is average of other locations [↑](#footnote-ref-46)
47. Reference amount used by both Food Service Technology Center and ENERGY STAR® savings calculator [↑](#footnote-ref-47)
48. Reference information from the Food Service Technology Center siting that ENERGY STAR® steamers are not typically operated in constant steam mode, but rather are used in timed mode. Reference ENERGY STAR® 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. [↑](#footnote-ref-48)
49. Food Service Technology Center 2011 Savings Calculator [↑](#footnote-ref-49)
50. Production capacity per Food Service Technology Center 2011 Savings Calculator of 18.3333 lb/hr per pan for gas ENERGY STAR® steam cookers and 16.6667  lb/hr per pan for electric ENERGY STAR® steam cookers.  ENERGY STAR® savings calculator uses 16.7 lb/hr per pan for electric and 20 lb/hr for natural gas ENERGY STAR® steamers. [↑](#footnote-ref-50)
51. Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for Tier 1A and Tier 1B qualified electric and natural gas steamer heavy cooking load energy efficiencies and http://www.energystar.gov/ia/partners/product\_specs/program\_reqs/Commercial\_Steam\_Cookers\_Program\_Requirements.pdf?7010-36eb [↑](#footnote-ref-51)
52. Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=COC and Food [↑](#footnote-ref-52)
53. Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=COC and Food [↑](#footnote-ref-53)
54. 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](http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.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 [↑](#footnote-ref-54)
55. Reference Food Service Technology Center 2011 Savings Calculator values for Baseline Preheat Energy. [↑](#footnote-ref-55)
56. Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies. [↑](#footnote-ref-56)
57. Ibid. [↑](#footnote-ref-57)
58. Amount used by both Food Service Technology Center and ENERGY STAR® savings calculator [↑](#footnote-ref-58)
59. Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=COC. [↑](#footnote-ref-59)
60. Ibid. [↑](#footnote-ref-60)
61. Ibid. [↑](#footnote-ref-61)
62. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-62)
63. 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. [↑](#footnote-ref-63)
64. FSTC (2002). Commercial Cooking Appliance Technology Assessment. Chapter 8: Steamers. [↑](#footnote-ref-64)
65. Source Consortium for Energy Efficiency, Inc. September 2010 "Program Design Guidance for Steamers" for Tier 1A and Tier 1B water requirements. Ohio Technical Reference Manual 2010 for 10 gal/hr water consumption which can be used when Tier level is not known. [↑](#footnote-ref-65)
66. Source for 365.25 days/yr is ENERGY STAR® savings calculator which references Food Service Technology research on average use, 2009. [↑](#footnote-ref-66)
67. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-67)
68. Ibid. [↑](#footnote-ref-68)
69. The Resource Solutions Group Commercial Conveyor Oven – Gas workpaper from January 2012; Commercial Gas Conveyor Oven – Large Gas Savings (therms/unit). [↑](#footnote-ref-69)
70. Version 2.2. of the ENERGY STAR specification. [↑](#footnote-ref-70)
71. 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 [↑](#footnote-ref-71)
72. 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 [↑](#footnote-ref-72)
73. 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 [↑](#footnote-ref-73)
74. 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 [↑](#footnote-ref-74)
75. Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA research on available models using AutoQuotes, 2012” [↑](#footnote-ref-75)
76. 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 [↑](#footnote-ref-76)
77. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-79)
78. 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 [↑](#footnote-ref-80)
79. Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator ,which cites reference as “FSTC research on available models, 2009 [↑](#footnote-ref-82)
80. 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 [↑](#footnote-ref-83)
81. 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 [↑](#footnote-ref-84)
82. Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator [↑](#footnote-ref-85)
83. Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator [↑](#footnote-ref-87)
84. 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 [↑](#footnote-ref-88)
85. 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 [↑](#footnote-ref-89)
86. 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 [↑](#footnote-ref-90)
87. 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 [↑](#footnote-ref-91)
88. 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 [↑](#footnote-ref-92)
89. 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 [↑](#footnote-ref-93)
90. 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 [↑](#footnote-ref-94)
91. 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 [↑](#footnote-ref-95)
92. Based on DOE Technical Support Document, 2014 as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-96)
93. Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2016. [↑](#footnote-ref-97)
94. 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](http://www.deeresources.com)> 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. [↑](#footnote-ref-101)
95. Unit is assumed to be connected to power 24 hours per day, 365.25 days per year. [↑](#footnote-ref-102)
96. AHRI Certification Directory, Accessed on 7/7/10. <http://www.ahridirectory.org/ahridirectory/pages/home.aspx> [↑](#footnote-ref-103)
97. 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) [↑](#footnote-ref-104)
98. 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." [↑](#footnote-ref-105)
99. Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100). [↑](#footnote-ref-106)
100. 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 [↑](#footnote-ref-107)
101. 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. [↑](#footnote-ref-108)
102. 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. [↑](#footnote-ref-109)
103. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-110)
104. IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment [↑](#footnote-ref-111)
105. In order to calculate energy savings, water savings must first be calculated [↑](#footnote-ref-112)
106. 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. [↑](#footnote-ref-113)
107. 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) [↑](#footnote-ref-114)
108. 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. [↑](#footnote-ref-115)
109. 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. [↑](#footnote-ref-116)
110. 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. [↑](#footnote-ref-117)
111. Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment [↑](#footnote-ref-118)
112. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-119)
113. 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 [↑](#footnote-ref-120)
114. Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3 [↑](#footnote-ref-121)
115. Typical preheat time from FSTC Broiler Technology Assessment. [↑](#footnote-ref-122)
116. Duty cycle from FSTC Broiler Technology Assessment, Table 4.3 [↑](#footnote-ref-123)
117. Lifecycle determined from Food Service Technology Center Gas Oven Life-Cycle Cost Calculator. [↑](#footnote-ref-124)
118. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-125)
119. Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7.2 http://www.fishnick.com/equipment/techassessment/7\_ovens.pdf [↑](#footnote-ref-126)
120. 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. [↑](#footnote-ref-127)
121. Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2 [↑](#footnote-ref-128)
122. 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 [↑](#footnote-ref-129)
123. Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment. [↑](#footnote-ref-130)
124. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-131)
125. Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4\_broilers.pdf [↑](#footnote-ref-132)
126. 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% [↑](#footnote-ref-133)
127. Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3 [↑](#footnote-ref-134)
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 [↑](#footnote-ref-135)
129. Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment. [↑](#footnote-ref-136)
130. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-137)
131. 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% [↑](#footnote-ref-138)
132. Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessment/4\_broilers.pdf [↑](#footnote-ref-139)
133. Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3 [↑](#footnote-ref-140)
134. 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 [↑](#footnote-ref-141)
135. PG&E Workpaper: Commercial Kitchen Demand Ventilation Controls-Electric, 2004 - 2005 [↑](#footnote-ref-142)
136. Ibid. [↑](#footnote-ref-143)
137. Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See ‘Kitchen DCV.xls’ for details. [↑](#footnote-ref-144)
138. Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See ‘Kitchen DCV.xls’ for details. [↑](#footnote-ref-145)
139. Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See ‘Kitchen DCV.xls’ for details. [↑](#footnote-ref-146)
140. Average of units in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. [↑](#footnote-ref-147)
141. 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. [↑](#footnote-ref-148)
142. 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 [↑](#footnote-ref-149)
143. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-150)
144. Ibid. [↑](#footnote-ref-151)
145. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-152)
146. Lifecycle determined from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment [↑](#footnote-ref-153)
147. See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual. [↑](#footnote-ref-154)
148. 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. [↑](#footnote-ref-155)
149. Median rated energy input for rack ovens from FSTC Oven Technology Assessment, http://www.fishnick.com/equipment/techassessment/7\_ovens.pdf [↑](#footnote-ref-156)
150. Average baking efficiency of double rack oven from FSTC Gas Double Rack Oven Test Reports. [↑](#footnote-ref-157)
151. Duty cycle from FSTC Gas Double Rack Oven Test Reports on various double rack ovens. [↑](#footnote-ref-158)
152. 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. [↑](#footnote-ref-159)
153. Food Service Technology Center (FSTC). Default value from life cycle cost calculator. <http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php> [↑](#footnote-ref-160)
154. 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”. [↑](#footnote-ref-161)
155. Minnesota 2012 Technical Reference Manual, [Electric Food Service\_v03.2.xls](http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf), <http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech>. Unknown is an average of other location types [↑](#footnote-ref-162)
156. Minnesota 2012 Technical Reference Manual, [Electric Food Service\_v03.2.xls](http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html), http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech [↑](#footnote-ref-163)
157. Unknown is average of other locations [↑](#footnote-ref-164)
158. Food Service Technology Center (FSTC). Default value from life cycle cost calculator. <http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php> [↑](#footnote-ref-165)
159. Food Service Technology Center (2002). *Commercial Cooking Appliance Technology Assessment*. Prepared by Don Fisher. Chapter 7: Ovens [↑](#footnote-ref-166)
160. American Society for Testing and Materials. Industry standard for Commercial Ovens [↑](#footnote-ref-167)
161. Food Service Technology Center (FSTC). Default value from life cycle cost calculator. <http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php> [↑](#footnote-ref-168)
162. Food Service Technology Center (FSTC). Default values from life cycle cost calculator. <http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php> [↑](#footnote-ref-169)
163. 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. [↑](#footnote-ref-170)
164. Minnesota 2012 Technical Reference Manual, [Electric Food Service\_v03.2.xls](http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf), <http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech>. Unknown is an average of other location types [↑](#footnote-ref-171)
165. ≤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. [↑](#footnote-ref-172)
166. It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline. [↑](#footnote-ref-173)
167. DEER 08, EUL\_Summary\_10-1-08.xls. [↑](#footnote-ref-174)
168. 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. [↑](#footnote-ref-175)
169. Act on Energy Commercial Technical Reference Manual, Table 9.6.1-4 [↑](#footnote-ref-176)
170. Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads, [↑](#footnote-ref-177)
171. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL <http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html> [↑](#footnote-ref-178)
172. 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%. [↑](#footnote-ref-179)
173. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-180)
174. Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%. [↑](#footnote-ref-181)
175. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-182)
176. ≤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. [↑](#footnote-ref-183)
177. It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline. [↑](#footnote-ref-184)
178. Full load hours assumption based on Wh/Max W Ratio from Itron eShape data for Missouri, calibrated to Illinois loads, [↑](#footnote-ref-185)
179. Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads, [↑](#footnote-ref-186)
180. ≤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. [↑](#footnote-ref-187)
181. Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities. [↑](#footnote-ref-188)
182. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-189)
183. 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) [↑](#footnote-ref-190)
184. 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). [↑](#footnote-ref-191)
185. 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. [↑](#footnote-ref-192)
186. DeOreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission. [↑](#footnote-ref-193)
187. 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. [↑](#footnote-ref-194)
188. 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 [↑](#footnote-ref-195)
189. Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities. [↑](#footnote-ref-196)
190. 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. [↑](#footnote-ref-197)
191. 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. [↑](#footnote-ref-198)
192. 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 [↑](#footnote-ref-199)
193. Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities. [↑](#footnote-ref-200)
194. Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications. [↑](#footnote-ref-201)
195. 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 [↑](#footnote-ref-202)
196. 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. [↑](#footnote-ref-203)
197. 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. [↑](#footnote-ref-204)
198. Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015 [↑](#footnote-ref-205)
199. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL <http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html>. [↑](#footnote-ref-206)
200. Electric water heaters have recovery efficiency of 98%: <http://www.ahridirectory.org/ahridirectory/pages/home.aspx> [↑](#footnote-ref-207)
201. 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> [↑](#footnote-ref-208)
202. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-209)
203. 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90°F mixed faucet water. [↑](#footnote-ref-210)
204. 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. [↑](#footnote-ref-211)
205. 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. [↑](#footnote-ref-212)
206. 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" [↑](#footnote-ref-213)
207. Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and assess and install time of $5 (20min @ $15/hr) [↑](#footnote-ref-214)
208. 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 [↑](#footnote-ref-215)
209. Based on excel spreadsheet 120911.xls …on SharePoint [↑](#footnote-ref-216)
210. Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009 (RECS) [↑](#footnote-ref-217)
211. Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above. [↑](#footnote-ref-218)
212. 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. [↑](#footnote-ref-219)
213. Representative value from sources 1, 2, 3, 4, 5, and 6 (See Source Table at end of measure section) [↑](#footnote-ref-220)
214. Set equal to L\_base. [↑](#footnote-ref-221)
215. 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> [↑](#footnote-ref-222)
216. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL <http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html>. [↑](#footnote-ref-223)
217. Electric water heaters have recovery efficiency of 98%: <http://www.ahridirectory.org/ahridirectory/pages/home.aspx> [↑](#footnote-ref-224)
218. 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. [↑](#footnote-ref-225)
219. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-226)
220. 77.3% is the proportion of hot 120F water mixed with 54.1°F supply water to give 105°F shower water [↑](#footnote-ref-227)
221. 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 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 [↑](#footnote-ref-228)
222. 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 [↑](#footnote-ref-229)
223. 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. [↑](#footnote-ref-230)
224. 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 [↑](#footnote-ref-231)
225. 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> [↑](#footnote-ref-232)
226. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-233)
227. 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. [↑](#footnote-ref-234)
228. Business Pool Covers.xlsx [↑](#footnote-ref-235)
229. Ibid. [↑](#footnote-ref-236)
230. 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 [↑](#footnote-ref-237)
231. Ibid. [↑](#footnote-ref-238)
232. Act on Energy Technical Reference Manual, Table 9.6.2-3 [↑](#footnote-ref-239)
233. Based on AOE historical average installation data of 42 tankless gas hot water heaters [↑](#footnote-ref-240)
234. <http://www.mncee.org/getattachment/7b8982e9-4d95-4bc9-8e64-f89033617f37/>, Low contractor estimate used to reflect less labor required in new construction of venting. [↑](#footnote-ref-241)
235. 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. [↑](#footnote-ref-242)
236. Act on Energy Technical Reference Manual, Table 9.6.2-3 [↑](#footnote-ref-243)
237. Ibid. [↑](#footnote-ref-244)
238. 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. [↑](#footnote-ref-245)
239. 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. [↑](#footnote-ref-246)
240. 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. [↑](#footnote-ref-247)
241. International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment. Units less than or equal to 75,000 Btu/hr input are governed by the most recent Code of Federal Regulation rulings, consistent with baseline definitions of 4.3.1 Storage Water Heater. [↑](#footnote-ref-248)
242. 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. [↑](#footnote-ref-249)
243. Stand-by loss is provided in 2012/2015 IECC, Table C404.2, Minimum Performance of Water-Heating Equipment [↑](#footnote-ref-250)
244. International Energy Conservation Code (IECC)2012/2015 [↑](#footnote-ref-251)
245. Aligned with other national energy efficiency programs and confirmed with national vendors [↑](#footnote-ref-252)
246. 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) [↑](#footnote-ref-253)
247. 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. [↑](#footnote-ref-254)
248. Assumed average horsepower for boilers connected to applicable washer [↑](#footnote-ref-255)
249. 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. [↑](#footnote-ref-256)
250. 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 [↑](#footnote-ref-257)
251. 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 [↑](#footnote-ref-258)
252. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. [↑](#footnote-ref-259)
253. 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 [↑](#footnote-ref-260)
254. 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 [↑](#footnote-ref-261)
255. 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: [↑](#footnote-ref-262)
256. 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 [↑](#footnote-ref-263)
257. 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 [↑](#footnote-ref-264)
258. 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 [↑](#footnote-ref-265)
259. 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 [↑](#footnote-ref-266)
260. Confirmed through communications with national vendors and available references E.g. <http://ozonelaundry.wordpress.com/2010/11/17/the-importance-of-maintenance/> [↑](#footnote-ref-267)
261. International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment [↑](#footnote-ref-268)
262. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011. [↑](#footnote-ref-269)
263. 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”. [↑](#footnote-ref-270)
264. 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). [↑](#footnote-ref-271)
265. Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012. [↑](#footnote-ref-272)
266. Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission. [↑](#footnote-ref-273)
267. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL [http://www1.eere.energy.gov/buildings/building\_america/analysis\_spreadsheets.html](http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls) [↑](#footnote-ref-274)
268. IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment [↑](#footnote-ref-275)
269. 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”. [↑](#footnote-ref-276)
270. Stand-by loss is provided in IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment [↑](#footnote-ref-277)
271. 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. [↑](#footnote-ref-278)
272. 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. [↑](#footnote-ref-279)
273. 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 savings from electric units but electrical savings from gas-fired units. See ‘CDHW Controls Summary Calculations.xlsx’ for more information. [↑](#footnote-ref-280)
274. See ‘CDHW Controls Summary Calculations.xlsx’ for more information. [↑](#footnote-ref-281)
275. 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. [↑](#footnote-ref-282)
276. 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. [↑](#footnote-ref-283)
277. 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, tlow occ, Rnormal occ and Rlow occ, [↑](#footnote-ref-284)
278. 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, tlow occ, Rnormal occ and Rlow occ, [↑](#footnote-ref-285)
279. Based on results of studies performed in multiple university dormitory buildings in the California region, for Southern California Gas’ PREPS Program, 2012. [↑](#footnote-ref-286)
280. 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. [↑](#footnote-ref-287)
281. Low occupancy periods for dormitory buildings can be assumed as vacation day or holiday occupancy. [↑](#footnote-ref-288)
282. Savings methodology factors are for a constant speed fan. [↑](#footnote-ref-289)
283. Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment. [↑](#footnote-ref-290)
284. Minnesota 2012 Technical Reference Manual, [Electric Food Service\_v03.2.xls](http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls), http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech [↑](#footnote-ref-291)
285. 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. [↑](#footnote-ref-292)
286. 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. [↑](#footnote-ref-293)
287. Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL [↑](#footnote-ref-294)
288. Each filter is 20 X 20 inches. [↑](#footnote-ref-295)
289. Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL [↑](#footnote-ref-296)
290. Minnesota 2012 Technical Reference Manual, [Electric Food Service\_v03.2.xls](http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls), http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Deemed-Savings.jspech [↑](#footnote-ref-297)
291. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-298)
292. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-299)
293. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012 [↑](#footnote-ref-300)
294. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL [http://www1.eere.energy.gov/buildings/building\_america/analysis\_spreadsheets.html](http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls) [↑](#footnote-ref-301)
295. 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%. [↑](#footnote-ref-302)
296. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-303)
297. A full description of the ComEd model development is found in “ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010” [↑](#footnote-ref-304)
298. <http://www.icc.illinois.gov/downloads/public/edocket/397867.pdf> [↑](#footnote-ref-305)
299. Based on model with single duct reheat system with a fixed outdoor air volume. [↑](#footnote-ref-306)
300. Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors. [↑](#footnote-ref-307)
301. Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors. [↑](#footnote-ref-308)
302. 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> [↑](#footnote-ref-309)
303. Act on Energy Commercial Technical Reference Manual No. 2010-4 [↑](#footnote-ref-310)
304. 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. [↑](#footnote-ref-311)
305. 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 [↑](#footnote-ref-312)
306. 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”. [↑](#footnote-ref-313)
307. Savings estimates are determined by applying the findings from DNV-GL “[Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs](http://portal.veic.org/projects/illinoistrm/Shared%20Documents/TRM%20Reference%20Documents/Commercial%20and%20Industrial/4.4%20HVAC%20End%20Use/4.4.1%20Air%20Conditioner%20Tune-up/HVAC3%20Commercial%20Quality%20Maintenance%20Programs-%20Impact%20Evaluation%20Report.pdf)”, 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. [↑](#footnote-ref-314)
308. 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. [↑](#footnote-ref-315)
309. 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 [↑](#footnote-ref-316)
310. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-317)
311. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-318)
312. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012 [↑](#footnote-ref-319)
313. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-320)
314. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up [↑](#footnote-ref-321)
315. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012 [↑](#footnote-ref-322)
316. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012 [↑](#footnote-ref-323)
317. CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan. [↑](#footnote-ref-324)
318. Nexant. Questar DSM Market Characterization Report. August 9, 2006. [↑](#footnote-ref-325)
319. 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. [↑](#footnote-ref-326)
320. DEER 2008 [↑](#footnote-ref-327)
321. 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 [↑](#footnote-ref-328)
322. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018.

     (http://deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls) [↑](#footnote-ref-329)
323. 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 [↑](#footnote-ref-330)
324. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation” [↑](#footnote-ref-331)
325. 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”. [↑](#footnote-ref-332)
326. 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. [↑](#footnote-ref-333)
327. 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 [↑](#footnote-ref-334)
328. 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. [↑](#footnote-ref-335)
329. 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/ [↑](#footnote-ref-336)
330. Federal Baselines defined by Code of Federal Regulations §430.32(d). ENERGY STAR specification defined by Version 4.0 Room Air Conditioners. CEE specification defined by Room Air Conditioner Specification effective January 31, 2017.

     Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

     Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

     Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

     Reverse cycle refers to the heating function found in certain room air conditioner models. [http://www.energystar.gov/ia/partners/product\_specs/program\_reqs/room\_air\_conditioners\_prog\_req.pdf](http://ilsag.org/yahoo_site_admin/assets/docs/ComEd_Res_Lighting_PY2_Evaluation_Report_2010-12-21_Final.12113928.pdf) [↑](#footnote-ref-337)
331. 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](http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf) [↑](#footnote-ref-338)
332. Based on field study conducted by Efficiency Vermont [↑](#footnote-ref-339)
333. 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. [↑](#footnote-ref-340)
334. 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 [↑](#footnote-ref-341)
335. 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](http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm)) to FLH for Central Cooling for the same location (provided by AHRI: [http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Calc\_CAC.xls](http://www.ahrinet.org/ARI/util/showdoc.aspx)) is 31%. This ratio has been applied to the FLH from the unitary and split system air conditioning measure. [↑](#footnote-ref-342)
336. Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 [↑](#footnote-ref-343)
337. 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. [↑](#footnote-ref-344)
338. 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 [↑](#footnote-ref-345)
339. DEER 2008 value for energy management systems [↑](#footnote-ref-346)
340. This value was extracted from Smart Ideas projects in PY1 and PY2. [↑](#footnote-ref-347)
341. 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’. [↑](#footnote-ref-348)
342. Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. [↑](#footnote-ref-349)
343. 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. [↑](#footnote-ref-350)
344. Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California. [↑](#footnote-ref-351)
345. 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. [↑](#footnote-ref-352)
346. 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 [↑](#footnote-ref-353)
347. 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. [↑](#footnote-ref-354)
348. 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. [↑](#footnote-ref-355)
349. 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 [↑](#footnote-ref-356)
350. 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. [↑](#footnote-ref-357)
351. Ibid. [↑](#footnote-ref-358)
352. 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 [↑](#footnote-ref-359)
353. 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. [↑](#footnote-ref-360)
354. 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. [↑](#footnote-ref-361)
355. Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010. [↑](#footnote-ref-362)
356. Assumed to be one third of effective useful life [↑](#footnote-ref-363)
357. 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. [↑](#footnote-ref-364)
358. $2641 inflated using 1.91% rate. [↑](#footnote-ref-365)
359. 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. [↑](#footnote-ref-366)
360. The weighted average value is based on assumption that 75% of buildings installing BPM furnace blower motors have Central AC. [↑](#footnote-ref-367)
361. Hours per year are estimated using the eQuest models as the total number of hours the cooling system is operating for each building type. [↑](#footnote-ref-368)
362. Coincidence Factors are estimated using the eQuest models.. [↑](#footnote-ref-369)
363. 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). [↑](#footnote-ref-370)
364. Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4. [↑](#footnote-ref-371)
365. 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. [↑](#footnote-ref-372)
366. Minimum ENERGY STAR efficiency after 2.1.2012. [↑](#footnote-ref-373)
367. 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 [↑](#footnote-ref-374)
368. Ibid. [↑](#footnote-ref-375)
369. 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. [↑](#footnote-ref-376)
370. Based on 2015 DOE Technical Support Document, as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-377)
371. Standard assumption of one third of effective useful life. [↑](#footnote-ref-378)
372. DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation [↑](#footnote-ref-379)
373. Based on DCEO – IL PHA Efficient Living Program data. [↑](#footnote-ref-380)
374. Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%. [↑](#footnote-ref-381)
375. 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. [↑](#footnote-ref-382)
376. 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 [↑](#footnote-ref-383)
377. 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. [↑](#footnote-ref-384)
378. 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. [↑](#footnote-ref-385)
379. 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. [↑](#footnote-ref-386)
380. 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 [↑](#footnote-ref-387)
381. 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. [↑](#footnote-ref-388)
382. 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 [↑](#footnote-ref-389)
383. *ASHRAE Handbook—Fundamentals*, 23.14; Hart, G., “Saving energy by insulating pipe components on steam and hot water distribution systems”, *ASHRAE Journal*, October 2011 [↑](#footnote-ref-390)
384. 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> [↑](#footnote-ref-391)
385. RS Means 2008. Mechanical Cost Data, pages 106 to 119 [↑](#footnote-ref-392)
386. RS Means 2010: “for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting” [↑](#footnote-ref-393)
387. 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” [↑](#footnote-ref-394)
388. Average efficiencies of units from the California Energy Commission (CEC). [↑](#footnote-ref-395)
389. Ibid. [↑](#footnote-ref-396)
390. Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993. [↑](#footnote-ref-397)
391. 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. [↑](#footnote-ref-398)
392. Thermal Regain Factor\_4-30-14.docx [↑](#footnote-ref-399)
393. 3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association). [↑](#footnote-ref-400)
394. 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. [↑](#footnote-ref-401)
395. Ibid. [↑](#footnote-ref-402)
396. Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19 [↑](#footnote-ref-403)
397. Based on the center to face and diameter dimensions given by ANSI/ASME B36.19 [↑](#footnote-ref-404)
398. 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. [↑](#footnote-ref-405)
399. Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. [↑](#footnote-ref-406)
400. Assumed to be one third of effective useful life [↑](#footnote-ref-407)
401. For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0> [↑](#footnote-ref-408)
402. NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014. [↑](#footnote-ref-409)
403. 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. [↑](#footnote-ref-410)
404. 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 [↑](#footnote-ref-411)
405. 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). [↑](#footnote-ref-412)
406. 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. [↑](#footnote-ref-413)
407. 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. [↑](#footnote-ref-414)
408. 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 [↑](#footnote-ref-415)
409. 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. [↑](#footnote-ref-416)
410. Ibid. [↑](#footnote-ref-417)
411. 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. [↑](#footnote-ref-418)
412. 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. [↑](#footnote-ref-419)
413. 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. [↑](#footnote-ref-420)
414. Ibid. [↑](#footnote-ref-421)
415. Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993. [↑](#footnote-ref-422)
416. 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. [↑](#footnote-ref-423)
417. Since commercial LPS reflect heating systems, Hours/yr are equivalent to HDD55 zone table [↑](#footnote-ref-424)
418. Dry cleaners survey data as referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012. [↑](#footnote-ref-425)
419. Efficiency Vermont TRM 10/26/11 for HVAC VSD motors [↑](#footnote-ref-426)
420. DEER 2008 [↑](#footnote-ref-427)
421. 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. [↑](#footnote-ref-428)
422. 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. [↑](#footnote-ref-429)
423. Ohio TRM 8/6/2010 pp207-209, Com Ed TRM June 1, 2010. [↑](#footnote-ref-430)
424. 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. [↑](#footnote-ref-431)
425. 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. [↑](#footnote-ref-432)
426. Ibid [↑](#footnote-ref-433)
427. Based on eQuest model for VSD v one-speed fan, see “CT Savings Factors.xlsx”. [↑](#footnote-ref-434)
428. DSF assumptions are based upon the same source as the ESFs. [↑](#footnote-ref-435)
429. Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007 [↑](#footnote-ref-436)
430. 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. [↑](#footnote-ref-437)
431. Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013. [↑](#footnote-ref-438)
432. Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper\_PECI\_FinalDraft\_140730\_Redline.docx for details. [↑](#footnote-ref-439)
433. Climate Zones Refrenced in Section 3.7, Table 3.6 [↑](#footnote-ref-440)
434. During the course of conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors have to be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time. [↑](#footnote-ref-441)
435. Discussion with vendors [↑](#footnote-ref-442)
436. California Utilities Statewide Codes and Standards Team. 2011. "2013 California Building Energy Efficiency Standards”, Garage Exhaust, Section 4.2 Page 14 [↑](#footnote-ref-443)
437. The electric energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by 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. [↑](#footnote-ref-444)
438. Savings are estimated based on a study done by California Utilities Statewide Codes and Standards Team, “2013 California Building Energy Efficiency Standards”, 2013,Section 2.4, Table 1. The savings are primarily fan savings, and are not dependent on climate zone. [↑](#footnote-ref-445)
439. The natural gas energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls. [↑](#footnote-ref-446)
440. The standard turndown ratio for boilers is 6:1. Understanding Fuel Savings in the Boiler Room, ASHRAE Journal, David Eoff, December, 2008 p 38 [↑](#footnote-ref-447)
441. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average. [↑](#footnote-ref-448)
442. FES Analysis of bin hours based upon a 30% oversizing factor. [↑](#footnote-ref-449)
443. “Burner,” Obtained from a nation-wide survey conducted by ASHRAE TC 1.8 (Akalin 1978). Data changed by TC 1.8 in 1986. [↑](#footnote-ref-450)
444. FES review of PY2/PY3 costs for custom People’s and North Shore high turndown burner projects. See High Turndown Costs.xlsx for details. [↑](#footnote-ref-451)
445. Release 3.0 Operations & Maintenance Best Practices A Guide to Achieving Operational Efficiency, August 2010, Federal Energy Management Program, US Department of Energy. The equation was determined by plotting the values in Table 9.2.1 – Boiler Cycling Energy Loss. [↑](#footnote-ref-452)
446. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010, Page 4-12. [↑](#footnote-ref-453)
447. Ibid. [↑](#footnote-ref-454)
448. 10:1 ratio used to qualify for efficient equipment. [↑](#footnote-ref-455)
449. Total number of hours for heating with a base temperature of 55°F for Chicago, IL as noted by National Climate Data Center [↑](#footnote-ref-456)
450. [↑](#footnote-ref-457)
451. Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, Prepared by the Sector Policies and Programs Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711, October 2010, Table 1. ICI Boilers – Summary of Greenhouse Gas Emission Reduction Measures, pg. 8 [↑](#footnote-ref-458)
452. Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improve Your Boiler’s Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated. [↑](#footnote-ref-459)
453. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009, Table 1-2. Recommended Measure Life by WISeerts Group Description, pg. 1-4. [↑](#footnote-ref-460)
454. CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22 [↑](#footnote-ref-461)
455. Department of Energy (DOE). 2009. Energy Matters newsletter. Fall 2009- Vol. 1, Iss. 1. Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program. [↑](#footnote-ref-462)
456. Ibid [↑](#footnote-ref-463)
457. [↑](#footnote-ref-464)
458. Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improving Your Boiler’s Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated. [↑](#footnote-ref-465)
459. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009, Table 1-2. Recommended Measure Life by WISeerts Group Description, pg. 1-4. [↑](#footnote-ref-466)
460. CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22 [↑](#footnote-ref-467)
461. Based on internet review of savings potential;

     “Up to 4%”: Use of Automatic Vent Dampers for New and Existing Boilers and Furnaces, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency, Canada, 2002

     “Up to 1%”: Page 9, The Carbon Trust, “Steam and high temperature hot water boilers” <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>. [↑](#footnote-ref-468)
462. CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22 [↑](#footnote-ref-469)
463. 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 [↑](#footnote-ref-470)
464. A market survey was performed to determine these costs. [↑](#footnote-ref-471)
465. This value comes from the reference table “Savings Summary by Building Type and System Type.” The formula and the input tables in this section document assumptions used in calculation spreadsheet “Pipe Insulation Savings 2013-11-12.xlsx” [↑](#footnote-ref-472)
466. Average efficiencies of units from the California Energy Commission (CEC). [↑](#footnote-ref-473)
467. Ibid. [↑](#footnote-ref-474)
468. Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993. [↑](#footnote-ref-475)
469. Thermal regain for *residential* pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation. [↑](#footnote-ref-476)
470. Thermal Regain Factor\_4-30-14.docx [↑](#footnote-ref-477)
471. 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues. [↑](#footnote-ref-478)
472. RSMeans, “Instrumentation and Control for HVAC”, Mechanical Cost Data , Kingston, MA: Reed Construction Data, 2010, pg. 255 & 632 [↑](#footnote-ref-480)
473. Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper\_PECI\_FinalDraft\_140730\_Redline.docx for details. [↑](#footnote-ref-481)
474. Efficiency Vermont TRM 10/26/11 for HVAC VSD motors [↑](#footnote-ref-482)
475. DEER 2008 [↑](#footnote-ref-483)
476. NEEP Incremental Cost Study Phase Two Final Report [↑](#footnote-ref-484)
477. Methodology developed and tested in Del Balso, Ryan Joseph. “Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications”. A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013. [↑](#footnote-ref-485)
478. Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry”. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Golden, CO: National Renewable Energy Laboratory. [↑](#footnote-ref-486)
479. 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> [↑](#footnote-ref-487)
480. Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type. [↑](#footnote-ref-488)
481. Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy [↑](#footnote-ref-489)
482. "Map to HVAC Solutions", by Michigan Air, Issue 3, 2006 [↑](#footnote-ref-490)
483. Weather Station Data, 99.6% Heating DB - 2013 Fundamentals, ASHRAE Handbook [↑](#footnote-ref-491)
484. Energy Recovery Fact Sheet - Center Point Energy, MN [↑](#footnote-ref-492)
485. PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009. [↑](#footnote-ref-493)
486. Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1. [↑](#footnote-ref-494)
487. 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. [↑](#footnote-ref-495)
488. 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. [↑](#footnote-ref-496)
489. 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. [↑](#footnote-ref-497)
490. 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. [↑](#footnote-ref-498)
491. 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. [↑](#footnote-ref-499)
492. 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. [↑](#footnote-ref-500)
493. PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009. [↑](#footnote-ref-501)
494. Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1. [↑](#footnote-ref-502)
495. 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. [↑](#footnote-ref-503)
496. 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. [↑](#footnote-ref-504)
497. 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. [↑](#footnote-ref-505)
498. 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. [↑](#footnote-ref-506)
499. 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. [↑](#footnote-ref-507)
500. 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. [↑](#footnote-ref-508)
501. Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012 [↑](#footnote-ref-509)
502. "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> [↑](#footnote-ref-510)
503. “[Synchronous Belt Drives Offer Low Cost Energy Savings](#3.5 Synchronous Belt Drives Offer Low Cost Energy Savings),” Baldor., February 2009. (attached in Reference Documents) [↑](#footnote-ref-511)
504. "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> [↑](#footnote-ref-512)
505. “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> [↑](#footnote-ref-513)
506. 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. [↑](#footnote-ref-514)
507. “[DEER2014-EUL-table-update\_2014-02-05.xlsx](#3.4 DEER2014-EUL-table-update_2014-02-05.xlsx),” Database for Energy Efficiency Resources (DEER), Deer 2014. [www.deerresources.com](file:///\\peci.org\files\Secure\Programs\14984%20-%20ComEd%20AirCare%20Plus\Engineering\Cogged%20v-belt\Work%20Paper\www.deerresources.com) (attached in Reference Documents) [↑](#footnote-ref-515)
508. Grainger catalog on-line web-site for Dayton v-belt pricing

     <http://www.grainger.com/Grainger/ecatalog/N-1z0r596/Ntt-v-belts> [↑](#footnote-ref-516)
509. Assumed to be $150 based on mechanical contractor estimate. [↑](#footnote-ref-517)
510. 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. [↑](#footnote-ref-518)
511. Com Ed TRM June 1, 2010 [↑](#footnote-ref-519)
512. Efficiency values for motors less than one HP taken from Baldor Electric Catalog 501: <http://www.baldor.com/pdf/501_Catalog/CA501.pdf> [↑](#footnote-ref-520)
513. 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. [↑](#footnote-ref-521)
514. 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%. [↑](#footnote-ref-522)
515. American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html [↑](#footnote-ref-523)
516. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up. [↑](#footnote-ref-524)
517. Fe 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% Fe. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. [↑](#footnote-ref-525)
518. 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 [↑](#footnote-ref-526)
519. For complex systems this value may be obtained from a CHP System design/financial analysis study. [↑](#footnote-ref-527)
520. These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

     Non-Baseload RFC West: 10,539 Btu/kWh \* (1 + Line Losses)

     Non-Baseload SERC Midwest: 9,968 Btu/kWh \* (1 + Line Losses)

     All Fossil Average RFC West: 9,962 Btu/kWh \* (1 + Line Losses)

     All Fossil Average SERC Midwest: 9,996 Btu/kWh \* (1 + Line Losses) [↑](#footnote-ref-528)
521. For complex systems this value may be obtained from a CHP System design/financial analysis study. [↑](#footnote-ref-529)
522. 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B [↑](#footnote-ref-530)
523. 220 ILCS 5/8-104 [↑](#footnote-ref-531)
524. 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). [↑](#footnote-ref-532)
525. 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. [↑](#footnote-ref-533)
526. 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 utilitized 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. [↑](#footnote-ref-534)
527. 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. [↑](#footnote-ref-535)
528. 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. [↑](#footnote-ref-536)
529. “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](http://www.epa.gov/chp/documents/catalog_chptech_full.pdf%20pages%202-16), 3-14, 4-14, 5-14, and 6-16. [↑](#footnote-ref-537)
530. Spentzas, Steve, et. al, “1009: Commercial and Industrial Air Curtains – Public Project Report,” Nicor Gas Emerging Technology Program (Oct 2014): 9 [↑](#footnote-ref-538)
531. 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. [↑](#footnote-ref-539)
532. Based on manufacturer interviews and air curtain specification sheets. [↑](#footnote-ref-540)
533. 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. [↑](#footnote-ref-541)
534. 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 [↑](#footnote-ref-542)
535. ASHRAE, “Ventilation and Infiltration,” in 2013 ASHRAE Handbook – Fundamentals (2013): Ch 16.1 - 16.37 [↑](#footnote-ref-543)
536. 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> [↑](#footnote-ref-544)
537. 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 [↑](#footnote-ref-545)
538. Wang, Liangzhu, “Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use,” Air Movement and Control International, Inc. (2013). 4 [↑](#footnote-ref-546)
539. 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! Reference 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 oF is designated in the Illinois TRM, but building specific base temperatures are recommended for large C&I projects. Additionally, the TRM uses a 30-year normal data for degree-days while the CD calculation was based on TMY3 data; in order to account for this, calculations of CD were also normalized by the ratio of CDD to align the calculated values more closely with the TRM. [↑](#footnote-ref-547)
540. Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section. [↑](#footnote-ref-548)
541. 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 temperature that exceeded the indoor air temperature setpoint. Other enthalpy values may be interpolated for indoor air temperature setpoints not represented in the table. Note that while outdoor air enthalpies increase with higher temperature setpoints, the change in enthalpy from indoor to outdoor will decrease. [↑](#footnote-ref-549)
542. 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 [↑](#footnote-ref-550)
543. ASHRAE, “Ventilation and Infiltration,” in 2013 ASHRAE Handbook – Fundamentals (2013): p 16.13 [↑](#footnote-ref-551)
544. Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed. [↑](#footnote-ref-552)
545. 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 [↑](#footnote-ref-553)
546. 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. [↑](#footnote-ref-554)
547. 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 [↑](#footnote-ref-555)
548. Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section. [↑](#footnote-ref-556)
549. 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 [↑](#footnote-ref-557)
550. 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. [↑](#footnote-ref-558)
551. Kosar, Doug, “1026: Destratification Fans – Public Project Report,” Nicor Gas, Emerging Technology Program (Oct 2014): 16 [↑](#footnote-ref-559)
552. Ibid. [↑](#footnote-ref-560)
553. 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. [↑](#footnote-ref-561)
554. 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. [↑](#footnote-ref-562)
555. 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. [↑](#footnote-ref-563)
556. 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. [↑](#footnote-ref-564)
557. 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 [↑](#footnote-ref-565)
558. 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. [↑](#footnote-ref-566)
559. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain. [↑](#footnote-ref-567)
560. 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. [↑](#footnote-ref-568)
561. 13. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48. [↑](#footnote-ref-569)
562. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 51 [↑](#footnote-ref-570)
563. 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, Rw, be used. A recommended method for determining R­w would be to use the highest R-value for the wall space, neglecting lower R-values associated with windows, thermal bridges, etc. [↑](#footnote-ref-571)
564. 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. [↑](#footnote-ref-572)
565. 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 [↑](#footnote-ref-573)
566. Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48 [↑](#footnote-ref-574)
567. 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. [↑](#footnote-ref-575)
568. ASHRAE, Standard 90.1-2013 - https://www.ashrae.org/resources--publications/bookstore/standard-90-1 [↑](#footnote-ref-576)
569. [California Public Utilities Commission, DEER 2014 EUL Table D08 v2.05](http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx) [↑](#footnote-ref-577)
570. 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. [↑](#footnote-ref-578)
571. 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. [↑](#footnote-ref-579)
572. 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) [↑](#footnote-ref-580)
573. Technician rule of thumb taken from CPUC ‘HVAC Impact Evaluation Final Report’, WO32, 28Jan 2015, p18. [↑](#footnote-ref-581)
574. The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan. [↑](#footnote-ref-582)
575. NREL, “Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection”, August 2013. [↑](#footnote-ref-583)
576. “Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection” states that test buildings with steam balancing measures saved an average of 10.2%. The energy savings estimate assumes additional system balancing through the installation of large capacity air vents on steam main lines and the replacement of radiator vents. This work is assumed to be done in concert with any system being retrofitted with averaging controls. <https://www.nrel.gov/docs/fy13osti/60003.pdf>. [↑](#footnote-ref-584)
577. 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). [↑](#footnote-ref-585)
578. 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). [↑](#footnote-ref-586)
579. 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). [↑](#footnote-ref-587)
580. 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). [↑](#footnote-ref-588)
581. 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). [↑](#footnote-ref-589)
582. 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). [↑](#footnote-ref-590)
583. 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). [↑](#footnote-ref-591)
584. 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). [↑](#footnote-ref-592)
585. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs V4, April 2016 (New York TRM). [↑](#footnote-ref-593)
586. Cost estimates from customer invoices and vendors. Material costs can be lower for bulk orders. [↑](#footnote-ref-594)
587. 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). [↑](#footnote-ref-595)
588. 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. [↑](#footnote-ref-596)
589. “Heating Period” is defined as hours when the TMY3 dry bulb temperature is less than 55°F (balance point) [↑](#footnote-ref-597)
590. Based on NREL’s Typical Meteorological Year 3 (TMY3) data for different weather stations. [↑](#footnote-ref-598)
591. 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. [↑](#footnote-ref-599)
592. Based on TMY3 data, see “Covers for Room AC\_11092016.xls” for more information. [↑](#footnote-ref-600)
593. 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. [↑](#footnote-ref-601)
594. From IECC 2012 Minimum Efficiency Requirements. For a 1 ton PTHP, COP = 2.9 – (0.026 \* 12,000/1,000). [↑](#footnote-ref-602)
595. Energy Independence and Security Act of 2007 – averaged for hot water and steam boilers. [↑](#footnote-ref-603)
596. Based on “Field Demonstation of High Efficiency Gas Heaters”, prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. [↑](#footnote-ref-604)
597. Average costs from CLEAResult’s evaluation of 9 different projects in the Chicagoland area. [↑](#footnote-ref-605)
598. Based on data collected in “Field Demonstation of High Efficiency Gas Heaters”, prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. [↑](#footnote-ref-606)
599. 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. [↑](#footnote-ref-607)
600. 30-year normals from the National Climactic Data Center (NCDC), assuming base temperature 55. [↑](#footnote-ref-608)
601. 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. [↑](#footnote-ref-609)
602. 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. [↑](#footnote-ref-610)
603. Use Typical Meteorological Year (TMY3) data from NREL available here: <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/> [↑](#footnote-ref-611)
604. Typical infiltration rate assumed from Infiltration Modeling Guidelines for Commercial Building Energy Analysis, prepared for US. DOE by Pacific Northwestern National Laboratory, 2009 [↑](#footnote-ref-612)
605. Roof and Wall Insulation R-values are based on ASHRAE 90.1- 2010. (Jim Young 2014) (K. Gowri 2009) [↑](#footnote-ref-613)
606. Based on DOE’s Commercial Prototype Modeled Warehouse building (in Chicago), found here: <https://www.energycodes.gov/commercial-prototype-building-models> [↑](#footnote-ref-614)
607. If an ECM motor in the packaged system is present, savings should be claimed for this measure by referring to the Residential Furnace Blower Motor measure in the IL TRM. [↑](#footnote-ref-615)
608. Katipamula, S., et al, “Advanced Rooftop Control (ARC) Retrofit: Field-Test Results”, Pacific Northwest National Laboratory, July 2013 [↑](#footnote-ref-616)
609. Based on [IL TRM v6.0 Vol. 2 – 4.4.19 Demand Controlled Ventilation](http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf) [↑](#footnote-ref-617)
610. 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. [↑](#footnote-ref-618)
611. 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 [↑](#footnote-ref-619)
612. Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010 [↑](#footnote-ref-620)
613. 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. [↑](#footnote-ref-621)
614. 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 [↑](#footnote-ref-622)
615. Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range. [↑](#footnote-ref-623)
616. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year. Multiplied by 50%. [↑](#footnote-ref-624)
617. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%. [↑](#footnote-ref-625)
618. Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace. [↑](#footnote-ref-626)
619. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year. Multiplied by 50%. [↑](#footnote-ref-627)
620. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%. [↑](#footnote-ref-628)
621. Robert Mowris & Associates, Inc., “Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults,” California Public Utilities Commission, Feb 15, 2016 page 203 [↑](#footnote-ref-629)
622. Assumed to be one third of effective useful life of an RTU (15 years) [↑](#footnote-ref-630)
623. 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. [↑](#footnote-ref-631)
624. 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 [↑](#footnote-ref-632)
625. Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010 [↑](#footnote-ref-633)
626. Robert Mowris & Associates, Inc., “Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults,” California Public Utilities Commission, Feb 15, 2016 Section 5.4 [↑](#footnote-ref-634)
627. The average cooling energy savings for all building types and climate zones, as determined by modeling 13 small commercial building types across 5 weather zones utilizing the prototype TRM eQuest models. For additional reference on the methodology and approach to the calculation of the deemed savings factor, see “Packaged RTU Sealing\_Reference Workbook.docx” [↑](#footnote-ref-635)
628. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year. [↑](#footnote-ref-636)
629. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year [↑](#footnote-ref-637)
630. http://c.ymcdn.com/sites/www.icac.com/resource/resmgr/docs/grzanka\_presentation\_chemsho.pdf [↑](#footnote-ref-638)
631. Ibid. [↑](#footnote-ref-639)
632. EPA Air Pollution Control Cost Manual, Chapter 2, November 2017. The system capital recovery cost is based on an estimated 20-year equipment life. This estimate of oxidizer equipment life is consistent with information available to EPA and is consistent with statements from large vendors for incinerators and oxidizers. [↑](#footnote-ref-640)
633. https://www.epa.gov/sites/production/files/2017-12/documents/oxidizersincinerators\_chapter2\_7theditionfinal.pdf [↑](#footnote-ref-641)
634. ICAC Guidance Method for Estimation of Gas Consumption in a Regenerative Thermal Oxidizer (RTO), July 2002: https://c.ymcdn.com/sites/www.icac.com/resource/resmgr/RTO-F1.pdf?hhSearchTerms=%22RTO%22 [↑](#footnote-ref-642)
635. Ibid. [↑](#footnote-ref-643)
636. <http://cta.ornl.gov/bedb/appendix_a/Lower_and_Higher_Heating_Values_of_Gas_Liquid_and_Solid_Fuels.pdf> [↑](#footnote-ref-644)
637. <https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm> [↑](#footnote-ref-645)
638. https://www.epa.gov/sites/production/files/2017-12/documents/oxidizersincinerators\_chapter2\_7theditionfinal.pdf [↑](#footnote-ref-646)
639. The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost (defined in the Measure Costs section) it can be considered early replacement. [↑](#footnote-ref-647)
640. See ASHRAE Journal *Long-Term Commercial GSHP Performance Parts 1-7 by Steve Kavanaugh* [↑](#footnote-ref-648)
641. [↑](#footnote-ref-649)
642. System life of indoor components as per DOE estimate https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. [↑](#footnote-ref-650)
643. <https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps> [↑](#footnote-ref-651)
644. Assumed to be one third of effective useful life per SAG policy [↑](#footnote-ref-652)
645. Average calculated based on reviewing cost information received from Chicagoland GSHP installers [↑](#footnote-ref-653)
646. Average calculated from Energy Star and RSMeans Mechanical Cost Data 2015 [↑](#footnote-ref-654)
647. Average calucated based on RSMeans Mechanical Cost Data 2015 [↑](#footnote-ref-655)
648. Average calucated based on RSMeans Mechanical Cost Data 2015 for Scroll, air cooled condenser chillers [↑](#footnote-ref-656)
649. 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. [↑](#footnote-ref-657)
650. 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 [↑](#footnote-ref-658)
651. 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). [↑](#footnote-ref-659)
652. The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings). [↑](#footnote-ref-660)
653. From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. [↑](#footnote-ref-661)
654. From Res GSHP measure of the IL-TRM: As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP [↑](#footnote-ref-662)
655. Applicable only for early Replacement Fuel Switch projects. [↑](#footnote-ref-663)
656. Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF. [↑](#footnote-ref-664)
657. As per Res GSHP measure. [↑](#footnote-ref-665)
658. Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 \* 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization. [↑](#footnote-ref-666)
659. Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%. [↑](#footnote-ref-667)
660. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-668)
661. Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%. [↑](#footnote-ref-669)
662. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-670)
663. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL <https://www.energy.gov/eere/buildings/building-america-analysis-spreadsheets> [↑](#footnote-ref-671)
664. 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. [↑](#footnote-ref-672)
665. Ibid [↑](#footnote-ref-673)
666. Based on eQuest model for VSD v one-speed fan, see “CT Savings Factors.xlsx”. [↑](#footnote-ref-674)
667. 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. [↑](#footnote-ref-675)
668. 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. [↑](#footnote-ref-676)
669. These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

     Non-Baseload RFC West: 10,539 Btu/kWh \* (1 + Line Losses)

     Non-Baseload SERC Midwest: 9,968 Btu/kWh \* (1 + Line Losses)

     All Fossil Average RFC West: 9,962 Btu/kWh \* (1 + Line Losses)

     All Fossil Average SERC Midwest: 9,996 Btu/kWh \* (1 + Line Losses) [↑](#footnote-ref-677)
670. Note GasEffbase in the algorithm should be replaced with GasEffExist for early replacement measures. [↑](#footnote-ref-678)
671. Note EERbase in the algorithm should be replaced with EERexist for early replacement measures. [↑](#footnote-ref-679)
672. 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). [↑](#footnote-ref-680)
673. 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. [↑](#footnote-ref-681)
674. 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. [↑](#footnote-ref-682)
675. Coincident diversity factors are based on either combined IL evaluation results (College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse), case lighting projects performed over several years by Michaels Energy in Illinois and other jurisdictions (Refrigerated and Freezer Cases), or based upon schedules defined in the eQuest models described (all others). [↑](#footnote-ref-683)
676. IF Therms value is developed using EQuest models consistent with methodology for Waste Heat Factor for Energy. [↑](#footnote-ref-684)
677. 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) [↑](#footnote-ref-685)
678. Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd’s service territory. See Navigant Memorandum ‘RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017’. [↑](#footnote-ref-686)
679. 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). [↑](#footnote-ref-687)
680. See “IL TRM Ext Lighting.xlsx” for calculation. [↑](#footnote-ref-688)
681. 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’. [↑](#footnote-ref-689)
682. Based upon final weighted (by sales volume) average of the BILD program (ComEd’s commercial lighting program) for PY 4 and PY5 and PY6. [↑](#footnote-ref-690)
683. 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. [↑](#footnote-ref-691)
684. Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. [↑](#footnote-ref-692)
685. 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. [↑](#footnote-ref-693)
686. 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. [↑](#footnote-ref-694)
687. 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 [↑](#footnote-ref-695)
688. Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results. [↑](#footnote-ref-696)
689. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-697)
690. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-698)
691. 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). [↑](#footnote-ref-699)
692. Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. [↑](#footnote-ref-700)
693. Based on ComEd’s estimate of lamp type saturation. [↑](#footnote-ref-701)
694. 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” [↑](#footnote-ref-702)
695. 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. [↑](#footnote-ref-703)
696. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-704)
697. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-705)
698. Based on weighted average of Final ComEd’s Instant Discounts program data from PY7 and PY9. For Residential installations, hours of use assumptions from ‘5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture’ measure should be used. [↑](#footnote-ref-706)
699. <http://library.cee1.org/content/cee-high-performance-t8-specification> [↑](#footnote-ref-707)
700. <http://library.cee1.org/content/reduced-wattage-t8-specification> [↑](#footnote-ref-708)
701. 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-709)
702. ibid [↑](#footnote-ref-710)
703. 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. [↑](#footnote-ref-711)
704. Based on ComEd’s Instant Incentives program data from PY7 and PY9, see “IL Commercial Lighting ISR\_2018.xlsx”. [↑](#footnote-ref-712)
705. 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 [↑](#footnote-ref-713)
706. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-714)
707. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-715)
708. 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. [↑](#footnote-ref-716)
709. Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, Xcel Energy Lighting Efficiency Input Wattage Guide and professional judgment. [↑](#footnote-ref-717)
710. Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment [↑](#footnote-ref-718)
711. 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 [↑](#footnote-ref-719)
712. Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. [↑](#footnote-ref-720)
713. RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See ‘RESvCI Split\_2018.xlsx. [↑](#footnote-ref-722)
714. Based on final ComEd’s Instant Incentives program data from PY7 and PY9. For Residential installations, hours of use assumptions from ‘5.5.6 LED Downlights’ should be used for LED fixtures and ‘5.5.8 LED Screw Based Omnidirectional Bulbs’ should be used for LED bulbs. [↑](#footnote-ref-723)
715. See file “LED baseline and EE wattage table\_2018.xlsx” for details on lamp wattage calculations. [↑](#footnote-ref-724)
716. 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. [↑](#footnote-ref-725)
717. Calculated as 45lm/W for all EISA non-exempt bulbs. [↑](#footnote-ref-726)
718. Calculated as 45lm/W for all EISA non-exempt bulbs [↑](#footnote-ref-727)
719. For 3-way bulbs or fixtures, the product’s median lumens value will be used to determine both LED and baseline wattages. [↑](#footnote-ref-728)
720. Calculated as 45lm/W for all EISA non-exempt bulbs [↑](#footnote-ref-729)
721. [↑](#footnote-ref-730)
722. http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/ [↑](#footnote-ref-731)
723. 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. [↑](#footnote-ref-732)
724. Calculated as 45lm/W for all EISA non-exempt bulbs [↑](#footnote-ref-733)
725. 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. [↑](#footnote-ref-734)
726. Based on ComEd’s Instant Incentives program data from PY7 and PY9 and Ameren’s Instant Incentives program for PY9, see “IL Commercial Lighting ISR\_2018.xlsx”. [↑](#footnote-ref-735)
727. 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 [↑](#footnote-ref-736)
728. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-737)
729. See IL LED Lighting Systems TRM Reference Tables\_2018.xlsx for breakdown of component cost assumptions. [↑](#footnote-ref-738)
730. See C&I OmniDirectional LED O&M Calc\_2018.xlsx” for more information. The commercial values assume the non-residential average hours assumption of 3,612. [↑](#footnote-ref-739)
731. Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren. [↑](#footnote-ref-740)
732. 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. [↑](#footnote-ref-741)
733. 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. [↑](#footnote-ref-742)
734. Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1. See "LED Lighting Systems TRM Reference Tables\_2018.xlsx" for more information and specific product links. [↑](#footnote-ref-743)
735. Note that some measures have blended baselines (T12:T8 18:82). All values are provided to enable calculation of appropriate O&M impacts. Total costs include lamp, labor and disposal cost assumptions where applicable, see IL LED Lighting Systems TRM Reference Tables\_2018.xlsx for more information. [↑](#footnote-ref-744)
736. Estimate of remaining life of existing unit being replaced. [↑](#footnote-ref-745)
737. Price includes new exit sign/fixture and installation. LED exit cost cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming IL labor cost of 15 minutes @ $40/hr. [↑](#footnote-ref-746)
738. Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0. [↑](#footnote-ref-748)
739. Based on review of available product. [↑](#footnote-ref-749)
740. Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. [↑](#footnote-ref-750)
741. Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages. [↑](#footnote-ref-754)
742. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-756)
743. Consistent with assumption for a Standard CFL bulb ($2.45) with an estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes). [↑](#footnote-ref-757)
744. Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years. [↑](#footnote-ref-758)
745. ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals, [http://www.cee1.org/gov/led/led-ace3/ace3led.pdf](http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf) [↑](#footnote-ref-761)
746. Ibid [↑](#footnote-ref-762)
747. 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 [↑](#footnote-ref-763)
748. Technical Reference Manual for Ohio, August 6, 2010 [↑](#footnote-ref-764)
749. 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). [↑](#footnote-ref-765)
750. Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. [↑](#footnote-ref-766)
751. See IECC 2012 and 2015 - Reference Code documentation for additional information. [↑](#footnote-ref-767)
752. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-768)
753. 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. [↑](#footnote-ref-769)
754. 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. [↑](#footnote-ref-770)
755. 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-771)
756. 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. [↑](#footnote-ref-772)
757. 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. [↑](#footnote-ref-773)
758. 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. [↑](#footnote-ref-774)
759. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-775)
760. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-776)
761. Consistent with Occupancy Sensor control measure. [↑](#footnote-ref-777)
762. Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009. [↑](#footnote-ref-778)
763. 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/> [↑](#footnote-ref-779)
764. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-780)
765. 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. [↑](#footnote-ref-781)
766. DEER 2008 [↑](#footnote-ref-782)
767. Based on indicative product cost review as performed for Efficiency Vermont TRM. [↑](#footnote-ref-783)
768. Estimates of watts controlled are based on Efficency Vermont data as provided in the 2018 TRM. Future evaluation should determine appropriate assumptions based on Illinois program data. [↑](#footnote-ref-786)
769. Interior controls % savings based on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls and exterior sensors are based upon data from "Application Assessment of Bi-Level LED Parking Lot Lighting" p6. [↑](#footnote-ref-789)
770. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-792)
771. 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. [↑](#footnote-ref-793)
772. Equal to the manufacturers standard warranty [↑](#footnote-ref-794)
773. 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. [↑](#footnote-ref-795)
774. Solatube Test Report (2005). http://www.mainegreenbuilding.com/files/file/solatube/stb\_lumens\_datasheet.pdf [↑](#footnote-ref-796)
775. Ibid. The lumen values presented in the kW table represent the average of the lightest 2400 hours. [↑](#footnote-ref-797)
776. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-798)
777. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-799)
778. 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. [↑](#footnote-ref-800)
779. 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-801)
780. 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. [↑](#footnote-ref-802)
781. 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 [↑](#footnote-ref-803)
782. 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. [↑](#footnote-ref-804)
783. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-805)
784. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-806)
785. Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011. [↑](#footnote-ref-807)
786. Ibid. [↑](#footnote-ref-808)
787. Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011. [↑](#footnote-ref-809)
788. 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](http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf?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](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf) [↑](#footnote-ref-810)
789. DEER 2008. [↑](#footnote-ref-811)
790. 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. [↑](#footnote-ref-812)
791. 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> [↑](#footnote-ref-813)
792. 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> [↑](#footnote-ref-814)
793. Conservative estimate. [↑](#footnote-ref-815)
794. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-816)
795. 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. [↑](#footnote-ref-817)
796. 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’. [↑](#footnote-ref-818)
797. Based upon final weighted (by sales volume) average of the BILD program (ComEd’s commercial lighting program) for PY 4 and PY5 and PY6. [↑](#footnote-ref-819)
798. 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. [↑](#footnote-ref-820)
799. NEEP Residential Lighting Survey, 2011 [↑](#footnote-ref-821)
800. Based on 15 minutes at $20 per hour. [↑](#footnote-ref-822)
801. 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. [↑](#footnote-ref-823)
802. 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) [↑](#footnote-ref-824)
803. From pg 10 of the Energy Star Specification for lamps v1.1 [↑](#footnote-ref-825)
804. From pg 11 of the Energy Star Specification for lamps v1.1 [↑](#footnote-ref-826)
805. [↑](#footnote-ref-827)
806. http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/ [↑](#footnote-ref-828)
807. 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. [↑](#footnote-ref-829)
808. 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). [↑](#footnote-ref-830)
809. 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. [↑](#footnote-ref-831)
810. 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. [↑](#footnote-ref-832)
811. 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 [↑](#footnote-ref-833)
812. Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results. [↑](#footnote-ref-834)
813. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-835)
814. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-836)
815. NEEP Residential Lighting Survey, 2011 [↑](#footnote-ref-837)
816. 15 years from GDS Measure Life Report, June 2007 [↑](#footnote-ref-838)
817. Measured average demand data. Southern California Edison, “Replace Neon Open Sign with LED Open Sign”, Workpaper SCE13LG070, Revision 2, October 2015. Pg. 10 [↑](#footnote-ref-839)
818. Ibid. [↑](#footnote-ref-840)
819. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-841)
820. Savings can be calculated for additional building types using the default values provided in the Reference Table in Section 4.5. [↑](#footnote-ref-842)
821. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-843)
822. DLC streetlighting measure, PGE workpaper, and current TRM values for exterior lighting all have a measure lives in the 11-12 year range. Assuming 50,000 hours of operation, and an annual operating hours of 4,303 hours results in a lifetime of 11.6 years. Typical streetlighting spec sheets suggest a longer measure life than 50,000 hours so we recommend the 12 year EUL for this measure. [↑](#footnote-ref-844)
823. Assuming operation of streetlight occurs outside the summer peak period of 1-5 PM. Coincidence Factor is assumed to equal 0. [↑](#footnote-ref-845)
824. Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd’s service territory. See Navigant Memorandum ‘RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017’. [↑](#footnote-ref-846)
825. Source: DEER 2014 [↑](#footnote-ref-847)
826. Ibid. [↑](#footnote-ref-848)
827. Measure savings from ComEd TRM developed by KEMA. June 1, 2010 [↑](#footnote-ref-849)
828. Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005. [↑](#footnote-ref-850)
829. ComEd workpapers, 8—15-11.pdf [↑](#footnote-ref-851)
830. Assumed that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based controls. [↑](#footnote-ref-852)
831. USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. <http:// http://www.usatech.com/energy\_management/energy\_productsheets.php> [↑](#footnote-ref-853)
832. Ibid. [↑](#footnote-ref-854)
833. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-855)
834. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010 [↑](#footnote-ref-856)
835. Source partial list from DEER 2008 [↑](#footnote-ref-857)
836. 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. [↑](#footnote-ref-858)
837. 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. [↑](#footnote-ref-859)
838. 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. [↑](#footnote-ref-860)
839. Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010 [↑](#footnote-ref-861)
840. Energy Efficiency Supermarket Refrigeration, Wisconsin Electric Power Company, July 23, 1993 [↑](#footnote-ref-862)
841. DEER [↑](#footnote-ref-863)
842. 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) [↑](#footnote-ref-864)
843. ENERGY STAR [↑](#footnote-ref-865)
844. ENERGY STAR [↑](#footnote-ref-866)
845. Savings from Vending Machine Calculator: http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=VMC [↑](#footnote-ref-867)
846. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-868)
847. Source: DEER [↑](#footnote-ref-869)
848. See ‘EC\_motor\_with\_controller\_182014.xlsx’. [↑](#footnote-ref-870)
849. 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. [↑](#footnote-ref-871)
850. Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers. [↑](#footnote-ref-872)
851. DEER 2014 Effective Useful Life. [↑](#footnote-ref-873)
852. 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. [↑](#footnote-ref-874)
853. 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. [↑](#footnote-ref-875)
854. 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]. [↑](#footnote-ref-876)
855. 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. [↑](#footnote-ref-877)
856. 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. [↑](#footnote-ref-878)
857. Estimated life from Efficiency Vermont TRM [↑](#footnote-ref-879)
858. Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems. [↑](#footnote-ref-880)
859. Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings. [↑](#footnote-ref-881)
860. 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 [↑](#footnote-ref-882)
861. 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). [↑](#footnote-ref-883)
862. 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) [↑](#footnote-ref-884)
863. Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts [↑](#footnote-ref-885)
864. 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 [↑](#footnote-ref-886)
865. Average of two manufacturer estimates of 50% and 75%. [↑](#footnote-ref-887)
866. 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 [↑](#footnote-ref-888)
867. 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). [↑](#footnote-ref-889)
868. 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014. [↑](#footnote-ref-890)
869. 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014. [↑](#footnote-ref-891)
870. 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. [↑](#footnote-ref-892)
871. 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. [↑](#footnote-ref-893)
872. Technischer Uberwachungs-Verein Rheinland E.V. Laboratory test results for energy savings on refrigerated dairy case, conducted for Econofrost. [↑](#footnote-ref-894)
873. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-895)
874. Rite Hite – Industrial High Speed Doors [↑](#footnote-ref-896)
875. 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). [↑](#footnote-ref-897)
876. Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011 [↑](#footnote-ref-898)
877. 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). [↑](#footnote-ref-899)
878. ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7 [↑](#footnote-ref-900)
879. Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD). [↑](#footnote-ref-901)
880. ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.11 [↑](#footnote-ref-902)
881. ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.6 [↑](#footnote-ref-903)
882. Professional judgement [↑](#footnote-ref-904)
883. ASHRAE, “Refrigerated –Facility Loads”, in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7 [↑](#footnote-ref-905)
884. Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives. [↑](#footnote-ref-906)
885. 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. [↑](#footnote-ref-907)
886. Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets. [↑](#footnote-ref-908)
887. Michael Grossman, e-mail message to author, April 16, 2018. [↑](#footnote-ref-909)
888. Michael Grossman, e-mail message to author, April 24, 2018 [↑](#footnote-ref-910)
889. Brian A. Fricke and Bryan R. Becker, “Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits,” Oak Ridge National Laboratory, September 2015. [↑](#footnote-ref-911)
890. M M. Valmiki and Antonio Corradini, “Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators,” Alternative Energy Systems Consulting, August 2016. [↑](#footnote-ref-912)
891. Brian A. Fricke and Bryan R. Becker, “Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits,” Oak Ridge National Laboratory, September 2015. [↑](#footnote-ref-913)
892. NCI (Navigant Consulting Inc.) and PNNL (Pacific Northwest National Laboratory), “Preliminary Technical Support Document (TSD): Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment,” Appliances and Commercial Equipment Standards, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, Washington, D.C., 2011. [↑](#footnote-ref-914)
893. M M. Valmiki and Antonio Corradini, “Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators,” Alternative Energy Systems Consulting, August 2016. [↑](#footnote-ref-915)
894. Michael Deru, et al, “U.S. Department of Energy Commercial Reference Building Models of National Building Stock,” NREL Report TP-5500-46861, February 2011. [↑](#footnote-ref-916)
895. Michael Deru, et al, “U.S. Department of Energy Commercial Reference Building Models of National Building Stock,” NREL Report TP-5500-46861, February 2011. [↑](#footnote-ref-917)
896. Department of Energy Technical Support Document. [↑](#footnote-ref-918)
897. Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost, as sourced from the Efficiency Vermont Technical Reference Manual (TRM). Several Vermont vendors were surveyed to determine the cost of equipment. [↑](#footnote-ref-919)
898. Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island, as developed by DOE through a part load compressor analysis and sourced in the Efficiency Vermont TRM. [↑](#footnote-ref-920)
899. Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM.(The “variable speed drive” compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD). [↑](#footnote-ref-921)
900. Ibid. [↑](#footnote-ref-922)
901. Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-923)
902. Incremental cost research found in LPDF Costs. xlsx [↑](#footnote-ref-924)
903. See “Industrial System Standard Deemed Saving Analysis.xls” [↑](#footnote-ref-925)
904. See “Industrial System Standard Deemed Saving Analysis.xls” [↑](#footnote-ref-926)
905. 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 [↑](#footnote-ref-927)
906. “Optimizing pneumatic systems for extra savings,” 10, 2010, <http://www.compressedairchallenge.org/library/articles/2010-10-CABP.pdf> [↑](#footnote-ref-928)
907. Industrial System Standard Deemed Saving Analysis.xls [↑](#footnote-ref-929)
908. Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls [↑](#footnote-ref-930)
909. 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” [↑](#footnote-ref-931)
910. 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” [↑](#footnote-ref-932)
911. US DOE, Evaluation of the Compressed Air Challenge® Training Program, Page 19 [↑](#footnote-ref-933)
912. PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission. [↑](#footnote-ref-934)
913. 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 [↑](#footnote-ref-935)
914. Review of manufacturer’s information [↑](#footnote-ref-936)
915. 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 [↑](#footnote-ref-937)
916. Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th

     Edition, and manufacturers’ catalog. [↑](#footnote-ref-938)
917. 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” [↑](#footnote-ref-939)
918. 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. [↑](#footnote-ref-940)
919. 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 [↑](#footnote-ref-941)
920. Ibid [↑](#footnote-ref-942)
921. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-943)
922. 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> [↑](#footnote-ref-944)
923. 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 [↑](#footnote-ref-945)
924. Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50% capacity. [↑](#footnote-ref-946)
925. 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 [↑](#footnote-ref-947)
926. 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 [↑](#footnote-ref-948)
927. DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules. [↑](#footnote-ref-949)
928. SCE Pump Test Final Report (2009), Summit Blue Consulting, LLC. This value is a weighted average of estimates provided by program participants. [↑](#footnote-ref-950)
929. 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) [↑](#footnote-ref-951)
930. “Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings,” ACEEE 1994 Summer Study Conference, Asilomar, CA. [↑](#footnote-ref-952)
931. 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> [↑](#footnote-ref-953)
932. 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”. [↑](#footnote-ref-954)
933. 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. [↑](#footnote-ref-955)
934. 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 [↑](#footnote-ref-956)
935. 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> [↑](#footnote-ref-957)
936. 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> [↑](#footnote-ref-958)
937. 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. [↑](#footnote-ref-959)
938. 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 [↑](#footnote-ref-960)
939. 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;). [↑](#footnote-ref-961)
940. Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison [↑](#footnote-ref-962)
941. 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) [↑](#footnote-ref-963)
942. 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 [↑](#footnote-ref-964)
943. Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop. [↑](#footnote-ref-965)
944. 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”. [↑](#footnote-ref-966)
945. Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013. [↑](#footnote-ref-967)
946. 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. [↑](#footnote-ref-968)
947. From DOE’s Federal Register Notices - found here: <http://energy.gov/eere/buildings/recent-federal-register-notices> [↑](#footnote-ref-969)
948. Ibid. [↑](#footnote-ref-970)
949. 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. [↑](#footnote-ref-971)
950. 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. [↑](#footnote-ref-972)
951. From DOE’s Federal Register Notices - found here: <http://energy.gov/eere/buildings/recent-federal-register-notices> [↑](#footnote-ref-973)
952. Ibid. [↑](#footnote-ref-974)
953. 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. [↑](#footnote-ref-975)
954. “The Real Size of a Front Load Washer” <http://laundromat123.com/Laundromat_Washer_Comparison.html> [↑](#footnote-ref-976)
955. “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> [↑](#footnote-ref-977)
956. Third of expected measure life. [↑](#footnote-ref-978)
957. Measure costs are based on data from a quote provided by a commercial washer distributor to Franklin Energy Services. [↑](#footnote-ref-979)
958. “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> [↑](#footnote-ref-980)
959. “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> [↑](#footnote-ref-981)
960. “Laundry Planning Guide.” EDRO, January 2015.

     [http://www.edrocorp.com/do wnloads/Laundry-Planning-Guide%202015.pdf](http://www.edrocorp.com/do%20wnloads/Laundry-Planning-Guide%202015.pdf) [↑](#footnote-ref-982)
961. Based on professional judgement, assuming closed on holidays. [↑](#footnote-ref-983)
962. Clothes washer capacity is based on weight of dry clothing. [↑](#footnote-ref-984)
963. 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. [↑](#footnote-ref-985)
964. 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. [↑](#footnote-ref-986)
965. “Laundry Planning Guide.” EDRO, January 2015. [↑](#footnote-ref-987)
966. “Are We Missing Energy Savings in Clothes Dryers?” Paul Bendt (Ecos), 2010

     <http://aceee.org/files/proceedings/2010/data/papers/2206.pdf> [↑](#footnote-ref-988)
967. “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 [↑](#footnote-ref-989)
968. “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. [↑](#footnote-ref-990)
969. 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 [↑](#footnote-ref-991)
970. Research Into Action, 80 PLUS Market Progress Evaluation Report #5, November 26, 2013. Page 24. [↑](#footnote-ref-992)
971. Algorithm comes from ENERGY STAR Version 6.0 Guide [↑](#footnote-ref-993)
972. 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](https://www.energystar.gov/sites/default/files/specs/Version%206%201%20Computers%20Final%20Program%20Requirements.pdf). [↑](#footnote-ref-994)
973. 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 [↑](#footnote-ref-995)
974. Analysis of current DT I2 category desktops in ES v6.0 QPL, available at http://www.energystar.gov/productfinder/product/certified-computers/results. [↑](#footnote-ref-996)
975. Analysis of current DT I2 category desktops in ES v6.0 QPL, passing with > 20% margin. [↑](#footnote-ref-997)
976. 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. [↑](#footnote-ref-998)
977. 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels. [↑](#footnote-ref-999)
978. 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. [↑](#footnote-ref-1000)
979. This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2. [↑](#footnote-ref-1001)
980. 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). [↑](#footnote-ref-1002)
981. 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”. [↑](#footnote-ref-1003)
982. Based upon review of the PY2 and PY3 ComEd Direct Install Residential program surveys. This value could be modified based upon commercial application evaluation. [↑](#footnote-ref-1004)
983. 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. [↑](#footnote-ref-1005)
984. 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. [↑](#footnote-ref-1006)
985. 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 [↑](#footnote-ref-1007)
986. Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013 [↑](#footnote-ref-1008)
987. 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 [↑](#footnote-ref-1009)
988. Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 45 [↑](#footnote-ref-1010)
989. Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 42 [↑](#footnote-ref-1011)
990. Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009. [↑](#footnote-ref-1012)
991. 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 [↑](#footnote-ref-1013)
992. 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 [↑](#footnote-ref-1014)
993. 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 [↑](#footnote-ref-1015)
994. 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) [↑](#footnote-ref-1016)
995. Ibid. [↑](#footnote-ref-1017)
996. Ibid. [↑](#footnote-ref-1018)
997. Ibid. [↑](#footnote-ref-1019)
998. Ibid. [↑](#footnote-ref-1020)
999. Ibid. [↑](#footnote-ref-1021)
1000. 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. [↑](#footnote-ref-1022)
1001. 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. [↑](#footnote-ref-1023)
1002. Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009. [↑](#footnote-ref-1024)
1003. Ibid. [↑](#footnote-ref-1025)
1004. Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013. [↑](#footnote-ref-1026)
1005. Based on Gas Technology Institute’s analysis of cost data from “Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report,” May 1, 2017. [↑](#footnote-ref-1027)
1006. In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications). [↑](#footnote-ref-1028)
1007. From DOE’s Federal Register Notices - found here: <http://energy.gov/eere/buildings/recent-federal-register-notices> [↑](#footnote-ref-1029)
1008. 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. [↑](#footnote-ref-1030)
1009. Savings factor based on engineering analysis of savings data from “Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report,” May 1, 2017 and “Advanced Commercial Clothes Dryer Technologies Field Test,” prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018. [↑](#footnote-ref-1031)
1010. Estimate based on 45 minutes per cycle. [↑](#footnote-ref-1032)
1011. In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications). [↑](#footnote-ref-1033)
1012. Savings factor based on engineering analysis of savings data from “Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report,” May 1, 2017 and “Advanced Commercial Clothes Dryer Technologies Field Test,” prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018. [↑](#footnote-ref-1034)