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Volume 2: Commercial and Industrial Measures

2.1 Appliances

2.1.1 Clothes Washer

DESCRIPTION

This measure relates to the installation of a commercial-grade clothes washer meeting the ENERGY STAR® minimum qualifications. Note it is assumed the domestic hot water (DHW) and dryer fuels of the installations are known.

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

The commercial-grade clothes washer must meet the ENERGY STAR® minimum qualifications (provided in the table below), as required by the program. The current specification is effective as of February 5, 2018.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial-grade clothes washer meeting the minimum federal baseline as of January 2013¹.

| Efficiency Level | | Top loading | Front Loading |
|------------------|------------------|----------------------------------|-----------------------------------|
| Baseline | Federal Standard | ≥ 1.6 MEF, ≤ 8.5 WF | ≥ 2.00 MEF, ≤ 5.5 WF |
| Efficient | ENERGY STAR® | N/A | ≥ 2.2 MEF, ≤ 4.0 IWF |

The Modified Energy Factor (MEF) includes unit operation, water heating, and drying energy use, with the higher the value the more efficient the unit; *"The quotient of the capacity of the clothes container, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load."*

The Water Factor (WF) indicates the total water consumption of the unit, with the lower the value the less water required; *"The quotient of the total weighted per-cycle water consumption for cold wash, divided by the capacity of the clothes washer."*²

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years.³

¹ See federal standard 10 CFR 431.152.

² Definitions provided on the Energy Star® website.

³ Appliance Magazine, September 2007 as referenced in ENERGY STAR® Commercial Clothes Washer Calculator.

DEEMED MEASURE COST

The incremental cost is assumed to be \$200⁴:

LOADSHAPE

Loadshape – Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left[\left(Capacity * \frac{1}{MEF_{base}} * Ncycles \right) * \left(\%CW_{base} + (\%DHW_{base} * \%Electric_{DHW}) + (\%Dryer_{base} * \%Electric_{Dryer}) \right) \right] - \left[\left(Capacity * \frac{1}{IMEF_{eff}} * Ncycles \right) * \left(\%CWeff + (\%DHW_{eff} * \%Electric_{DHW}) + (\%Dryer_{eff} * \%Electric_{Dryer}) \right) \right]$$

Where:

Capacity = Clothes washer capacity (cubic feet)
 = Actual - If capacity is unknown, assume 3.1 cubic feet⁵

MEFbase = Modified Energy Factor of baseline unit

| Efficiency Level | MEFbase | | |
|------------------|-------------|---------------|-------------------------------|
| | Top loading | Front Loading | Weighted Average ⁶ |
| Federal Standard | 1.6 | 2.0 | 1.7 |

MEFeff = Modified Energy Factor of efficient unit
 = Actual. If unknown, assume average values provided below.

| Efficiency Level | MEFeff | | |
|--------------------------|-------------|---------------|------------------|
| | Top loading | Front Loading | Weighted Average |
| ENERGY STAR [®] | N/A | | 2.2 |

⁴ Based on Industry Data 2007 as referenced in ENERGY STAR[®] Commercial Clothes Washer Calculator.

⁵ Based on the average clothes washer volume of all units that pass the federal standard on the California Energy Commission (CEC) database of commercial clothes washer products (accessed on 11/26/2015).

⁶ Weighted average MEF of federal standard rating for front- loading and top- loading units. Baseline weighting is based upon the relative top front loading percentage of available non-ENERGY STAR[®] commercial products in the CEC database (accessed 11/26/2015) and ENERGY STAR[®] weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in “Commercial Clothes Washer Analysis.xlsx”:

| Efficiency Level | Front | Top |
|--------------------------|-------|-----|
| Baseline | 37% | 63% |
| ENERGY STAR [®] | 99% | 1% |

- Ncycles = Number of Cycles per year
= 2190⁷
- %CW = Percentage of total energy consumption for clothes washer operation (different for baseline and efficient unit – see table below)
- %DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)
- %Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

| | Percentage of Total Energy Consumption ⁸ | | |
|------------------|---|-------|--------|
| | %CW | %DHW | %Dryer |
| Federal Standard | 6.5% | 25.9% | 67.6% |
| ENERGY STAR | 3.5% | 14.1% | 82.4% |

%Electric_{DHW} = Percentage of DHW savings assumed to be electric

| DHW fuel | %Electric _{DHW} |
|-------------|--------------------------|
| Electric | 100% |
| Natural Gas | 0% |

%Electric_{Dryer} = Percentage of dryer savings assumed to be electric

| Dryer fuel | %Electric _{Dryer} |
|-------------|----------------------------|
| Electric | 100% |
| Natural Gas | 0% |

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:⁹

| Efficiency Level | ΔkWH | | | |
|------------------|--------------------------------|---------------------------|---------------------------|----------------------|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer |
| ENERGY STAR® | 808.2 | 229.3 | 725.3 | 146.5 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

⁷ Based on DOE Technical Support Document, 2009; Chapter 8 Life-Cycle Cost and Payback Period Analysis, p 8-15.

⁸ The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer is different depending on the efficiency of the unit. Values are based on a data provided in the ENERGY STAR® Calculator for Commercial Clothes Washers.

⁹ Note that the baseline savings is based on the weighted average baseline MEF (as opposed to assuming front baseline for front-efficient unit and top baseline for top- efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439¹⁰

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

| Efficiency Level | ΔkW | | | |
|------------------|--------------------------------|---------------------------|---------------------------|----------------------|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer |
| ENERGY STAR | 0.1115 | 0.0316 | 0.1001 | 0.0202 |

NATURAL GAS SAVINGS

$$\Delta Therms = \left[\left[\left(Capacity * \frac{1}{IMEF_{base}} * N_{cycles} \right) * \left((\%DHW_{base} * \%Natural\ Gas_{DHW} * R_{eff}) + (\%Dryer_{base} * \%Gas_{Dryer} \%Gas_{Dryer}) \right) \right] - \left[\left(Capacity * \frac{1}{IMEF_{eff}} * N_{cycles} \right) * \left((\%DHW_{eff} * \%Gas_{DHW} \%Natural\ Gas_{DHW} * R_{eff}) + (\%Dryer_{eff} * \%Gas_{Dryer} \%Gas_{Dryer}) \right) \right] \right] * Therm_{convert}$$

Where:

%Gas_{DHW} = Percentage of DHW savings assumed to be Natural Gas

| DHW fuel | %Gas _{DHW} |
|-------------|---------------------|
| Electric | 0% |
| Natural Gas | 100% |

R_{eff} = Recovery efficiency factor
 = 1.26¹¹

%Gas_{Dryer} = Percentage of dryer savings assumed to be Natural Gas

| Dryer fuel | %Gas _{Dryer} |
|-------------|-----------------------|
| Electric | 0% |
| Natural Gas | 100% |

Therm_{convert} = Conversion factor from kWh to Therm
 = 0.03412

Other factors as defined above.

¹⁰ Based on Ameren Missouri 2016 Loadshape for Business Miscellaneous End-Use. Upon inspection and comparison to the residential clothes washer coincidence factor, this is a reasonable assumption until data becomes available to inform a technology specific coincidence factor. Given that business laundry schedules are likely more variable compared to residential, it follows that less overlap with the system peak hour is possible.

¹¹ To account for the different efficiency of electric and natural gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldgs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

| Efficiency Level | ΔTherms | | | |
|------------------|--------------------------------|---------------------------|---------------------------|----------------------|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer |
| ENERGY STAR | 0.0 | 24.9 | 2.8 | 27.7 |

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water \text{ (gallons)} = Capacity * (IWF_{base} - IWF_{eff}) * N_{cycles}$$

Where:

WF_{base} = Water Factor of baseline clothes washer

| Efficiency Level | WF _{base} | | |
|------------------|--------------------|---------------|--------------------------------|
| | Top loading | Front Loading | Weighted Average ¹² |
| Federal Standard | 8.5 | 5.5 | 7.4 |

WF_{eff} = Water Factor of efficient clothes washer
 = Actual - If unknown assume average values provided below

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

| Efficiency Level | WF | | | ΔWater (gallons per year) |
|------------------|-------------|---------------|------------------|------------------------------|
| | Top Loaders | Front Loaders | Weighted Average | Weighted Average |
| Federal Standard | 8.5 | 5.5 | 7.4 | n/a |
| ENERGY STAR | 4.5 | | | 19,874 |

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

¹² Weighted average MEF of federal standard rating for frontloading and top-loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR® commercial product in the CEC database (accessed 11/26/2015) and ENERGY STAR® weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in “Commercial Clothes Washer Analysis.xlsx”:

| Efficiency Level | Front | Top |
|------------------|-------|-----|
| Baseline | 37% | 63% |
| ENERGY STAR® | 99% | 1% |

2.1.2 Clothes Dryer

DESCRIPTION

This measure is for the installation of a residential clothes dryer, utilized in a commercial setting, meeting the ENERGY STAR® criteria. ENERGY STAR® qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions (such as air flow and/or heat input rate) improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers.¹³ ENERGY STAR® provides criteria for both gas and electric clothes dryers.

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

Clothes dryer must meet the ENERGY STAR® criteria, as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.¹⁴

DEEMED MEASURE COST

| Dryer Size | Incremental Cost ¹⁵ |
|------------|--------------------------------|
| Standard | \$75 |
| Compact | \$105 |

LOADSHAPE

Loadshape - Miscellaneous BUS

¹³ ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

¹⁴ Based on an average estimated range of 12-16 years. ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

¹⁵ Cost based on ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \left(\frac{Load}{CEF_{base}} - \frac{Load}{CEF_{eff}} \right) * N_{cycles} * \%Electric$$

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

| Drver Size | Load (lbs) ¹⁶ |
|------------|--------------------------|
| Standard | 8.45 |
| Compact | 3 |

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR[®] analysis.¹⁷ If product class unknown, assume electric, standard.

| Product Class | CEFbase (lbs/kWh) |
|---|--------------------|
| Vented Electric, Standard (≥ 4.4 ft ³) | 3.11 |
| Vented Electric, Compact (120V) (< 4.4 ft ³) | 3.01 |
| Vented Electric, Compact (240V) (< 4.4 ft ³) | 2.73 |
| Ventless Electric, Compact (240V) (< 4.4 ft ³) | 2.13 |
| Vented Gas | 2.84 ¹⁸ |

CEFeff = CEF (lbs/kWh) of the ENERGY STAR[®] unit based on ENERGY STAR[®] requirements.¹⁹ If product class unknown, assume electric, standard.

| Product Class | CEFeff |
|---|--------------------|
| Vented or Ventless Electric, Standard (≥ 4.4 ft ³) | 3.93 |
| Vented or Ventless Electric, Compact (120V) (< 4.4 ft ³) | 3.80 |
| Vented Electric, Compact (240V) (< 4.4 ft ³) | 3.45 |
| Ventless Electric, Compact (240V) (< 4.4 ft ³) | 2.68 |
| Vented Gas | 3.48 ²⁰ |

¹⁶ Based on ENERGY STAR[®] test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

¹⁷ ENERGY STAR[®] Draft 2 Version 1.0 Clothes Dryers Data and Analysis

¹⁸ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

¹⁹ ENERGY STAR[®] Clothes Dryers Key Product Criteria.

https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

²⁰ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, refer to the table below.²¹

| Application | Cycles per Year |
|-----------------------|-----------------|
| Multi-family | 1,074 |
| Laundromat | 1,483 |
| On-Premise Laundromat | 3,607 |

%Electric = The percent of overall savings coming from electricity
 = 100% for electric dryers, 5% for gas dryers²²

Using defaults provided above:

| Product Class | kWh | | |
|---|--------------|------------|-----------------------|
| | Multi-family | Laundromat | On-Premise Laundromat |
| Vented Electric, Standard (≥ 4.4 ft ³) | 608.9 | 840.7 | 2044.9 |
| Vented Electric, Compact (120V) (< 4.4 ft ³) | 222.5 | 307.3 | 747.4 |
| Vented Electric, Compact (240V) (<4.4 ft ³) | 246.3 | 340.1 | 827.2 |
| Ventless Electric, Compact (240V) (<4.4 ft ³) | 310.4 | 428.7 | 1042.6 |
| Vented Gas | 29.4 | 40.6 | 98.7 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439²³

Using defaults provided above:

| Product Class | kW | | |
|--|--------------|------------|-----------------------|
| | Multi-family | Laundromat | On-Premise Laundromat |
| Vented Electric, Standard (≥ 4.4 ft ³) | 0.0840 | 0.1160 | 0.2821 |

²¹ NOPR analysis for DOE Commercial Clothes Washer standard. Annual use cycles of 1,074 and 1,483 for multifamily and laundromat applications, respectively. <https://www.regulations.gov/document?D=EERE-2012-BT-STD-0020-0021>. On-premise laundromat cycle 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.

²² %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc.). 5% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis. Value reported in 2015 EPA EnergySTAR® appliance calculator.

²³ Based on Ameren Missouri 2016 Loadshape for Business Miscellaneous End-Use. Upon inspection and comparison to the Residential clothes washer coincidence factor, this is a reasonable assumption until data becomes available to inform a technology specific coincidence factor. Given that business laundry schedules are likely more variable compared to residential, it follows that less overlap with the system peak hour is possible.

| Product Class | kW | | |
|---|--------------|------------|-----------------------|
| | Multi-family | Laundromat | On-Premise Laundromat |
| Vented Electric, Compact (120V) (< 4.4 ft ³) | 0.0307 | 0.0424 | 0.1031 |
| Vented Electric, Compact (240V) (<4.4 ft ³) | 0.0340 | 0.0469 | 0.1141 |
| Ventless Electric, Compact (240V) (<4.4 ft ³) | 0.0428 | 0.0591 | 0.1438 |
| Vented Gas | 0.0041 | 0.0056 | 0.0136 |

NATURAL GAS ENERGY SAVINGS

Natural gas savings only apply to ENERGY STAR® vented gas clothes dryers.

$$\Delta Therm = \left(\frac{Load}{CEF_{base}} - \frac{Load}{CEF_{eff}} \right) * Ncycles * Therm_convert * \%Gas$$

Where:

Therm_convert = Conversion factor from kWh to Therm
 = 0.03413

%Gas = Percent of overall savings coming from gas
 = 0% for electric units and 84% for gas units²⁴

Using defaults provided above:

$$\Delta Therms = (8.45/2.84 - 8.45/3.48) * Ncycles * 0.03413 * 0.84$$

| Product Class | ΔTherms | | |
|---------------|--------------|------------|-----------------------|
| | Multi-family | Laundromat | On-Premise Laundromat |
| Vented Gas | 16.8 | 23.3 | 56.6 |

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above
 365.25 = Days per year

Using defaults provided above:

²⁴ % Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc.). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

| Product Class | Δ PeakTherms | | |
|---------------|---------------------|------------|-----------------------|
| | Multi-family | Laundromat | On-Premise Laundromat |
| Vented Gas | 0.0461 | 0.0637 | 0.1549 |

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.2 Compressed Air

2.2.1 Compressed Air No Loss Condensate Drain

DESCRIPTION

No-loss condensate drains remove condensate as needed without venting compressed air, resulting in less air demand and better efficiency. Replacement or upgrades of existing no-loss drains are not eligible for this measure.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a no-loss condensate drain.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard condensate drain (open valve, timer, or both).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of a no-loss condensate drain is assumed to be 13 years.²⁵

DEEMED MEASURE COST

The measure cost is \$700 per drain.²⁶

LOADSHAPE

Air Comp BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{reduced} * kW_{CFM} * Hours$$

Where:

$CFM_{reduced}$ = Reduced air consumption (CFM) per drain
= 3 CFM²⁷

kW_{CFM} = System power demand reduction per reduced air consumption (kw/CFM), depending on the type of compressor control, see table below²⁸

²⁵ “Measure Life Study,” Energy & Resource Solutions (prepared for the Massachusetts Joint Utilities): Table 1-1, 2005.

²⁶ Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls.

²⁷ Reduced CFM consumption is based on a timer drain opening for 10 seconds every 300 seconds as the baseline. See “Industrial System Standard Deemed Saving Analysis.xls.”

²⁸ 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.”

| Compressor 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 |

Hours = Compressed air system pressurized hours

= Use actual hours if known, otherwise assume values in table below:

| 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 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

=

= 0.0001379439²⁹

MEASURE CODE:

²⁹ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Compressed Air. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

2.2.2 Compressed Air Nozzle

DESCRIPTION

This measure applies to the replacement of a standard air nozzle with high-efficiency air nozzle used in a compressed air system. High-efficiency air nozzles use the Coandă effect to pull in free air and use significantly less compressed air for blowing off parts or for drying. These nozzles have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a compressed air nozzle meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard air nozzle.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 15 years.³⁰

DEEMED MEASURE COST

Incremental measure costs are presented in the following table.³¹

| Nozzle Diameter | Measure Cost |
|-----------------|--------------|
| 1/8" | \$42 |
| 1/4" | \$57 |
| 5/16" | \$87 |
| 1/2" | \$121 |

LOADSHAPE

Air Comp BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (SCFM * SCFM\%Reduced) * kW/CFM * \%Use * Hours$$

Where:

SCFM = Air flow through standard nozzle.

³⁰ “Focus on Energy Evaluation - Business Programs: Measure Life Study,” prepared for State of Wisconsin Public Service Commission by PA Consulting Group, August 25, 2009.

³¹ 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.

= Actual rated flow at 80 psi, if known. If unknown, use CFM by orifice diameter from table below.^{32, 33}

| Orifice Diameter | SCFM |
|------------------|------|
| 1/8" | 21 |
| 1/4" | 58 |
| 5/16" | 113 |
| 1/2" | 280 |

SCFM%Reduced = Percent reduction in air loss per nozzle.
 = Estimated at 50%³⁴

kW/CFM = System power reduction per air demand (kW/CFM), depending on the type of air compressor; see table below³⁵

| Air Compressor Type | ΔkW/CF |
|--------------------------------|--------|
| 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/ | 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, or if unknown, assume 5%³⁶

Hours = Compressed air system pressurized hours
 = Use actual hours if known, otherwise assume values in table below:

³² Review of manufacturer’s information

³³ 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.

³⁴ Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th Edition, and manufacturers’ catalog.

³⁵ 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.”

³⁶ Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.

| Shift | Hours |
|--------------------|---|
| Single shift (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 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
- =
- = 0.0001379439³⁷

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

³⁷ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Compressed Air. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

2.2.3 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. A baseline modulating compressor regulates output by choking off the inlet air, 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 US Department of Energy (DOE) data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a modulating compressor with blow down ≤ 40 hp

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

10 years.³⁸

DEEMED MEASURE COST³⁹

$$\text{Incremental Cost (\$)} = (127 \times \text{hp}_{\text{compressor}}) + 1446$$

Where:

$$\text{hp}_{\text{compressor}} = \text{compressor motor nominal horsepower}$$

LOADSHAPE

Air Comp BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = 0.9 \times \text{hp}_{\text{compressor}} \times \text{HOURS} \times (\text{CF}_b - \text{CF}_e)$$

Where:

$$\Delta \text{kWh} = \text{gross customer annual kWh savings for the measure}$$

$$\text{hp}_{\text{compressor}} = \text{compressor motor nominal horsepower}$$

³⁸ Based on data provided by vendors, reference file "VSD compressor lifetime and costs.xls."

³⁹ Based on data provided by vendors, reference file "VSD compressor lifetime and costs.xls."

0.9⁴⁰ = compressor motor nominal horsepower to full load kW conversion factor

HOURS = compressor total annual hours of operation. Custom input, if unknown use the following defaults based on shift structure:

| Shift | Hours |
|--------------------|---|
| Single shift (8/5) | 1976 hours 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time |
| 2-shift (16/5) | 3952 hours 7AM – 11 PM, weekdays, minus some holidays and scheduled down time |
| 3-shift (24/5) | 5928 hours 24 hours per day, weekdays, minus some holidays and scheduled down time |
| 4-shift (24/7) | 8320 hours 24 hours per day, 7 days a week minus some holidays and scheduled down time |

CF_b = baseline compressor factor⁴¹
=0.890

CF_e = efficient compressor⁴²
=0.705

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439⁴³

MEASURE CODE:

⁴⁰ Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island. See "BHP Weighted Compressed Air Load Profiles v3.xls."

⁴¹ Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. "See "BHP Weighted Compressed Air Load Profiles v3.xls" for source data and calculations.

⁴² Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. "See "BHP Weighted Compressed Air Load Profiles v3.xls" for source data and calculations. The "variable speed drive" compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD.

⁴³ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Compressed Air. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

2.3 Food Service

2.3.1 Combination Oven

DESCRIPTION

This measure applies to full or half-sized electric ENERGY STAR® combination ovens with a pan capacity ≥ 5 and ≤ 20 and to full or half-sized natural gas fired ENERGY STAR® combination ovens with a pan capacity ≥ 6 installed in a commercial kitchen. Combination ovens combine the function of hot air convection (convection mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating, to perform steaming, baking, roasting, re-thermalizing, and proofing of various food products. ENERGY STAR® certified combination ovens are approximately 20% more efficient than standard ovens.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified combination oven meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by fuel type, operation mode (steam or convection), and pan capacity.

ENERGY STAR® Requirements (Version 2.2, Effective October 7, 2015)

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

Note: P = Pan capacity as defined in Section 1.T of the Commercial Ovens Program Requirements Version 2.2.⁴⁴

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁴⁵

DEEMED MEASURE COST

The incremental capital cost for this measure is \$4,300.⁴⁶

⁴⁴ 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.

<https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf>

⁴⁵ Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.”

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

⁴⁶ Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.

LOADSHAPE

Cooking BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric combination oven below.⁴⁷

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

Where:

- $\Delta CookingEnergy_{ConvElec}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode
 = $FoodCooked_{Elec} * (EFOOD_{ConvElec} / ElecEFF_{ConvBase} - EFOOD_{ConvElec} / ElecEFF_{ConvEE}) * \%Conv$
- $\Delta CookingEnergy_{SteamElec}$ = Difference in cooking energy between baseline and efficient combination oven in steam mode
 = $FoodCooked_{Elec} * (EFOOD_{SteamElec} / ElecEFF_{SteamBase} - EFOOD_{SteamElec} / ElecEFF_{SteamEE}) * \%Steam$
- $\Delta IdleEnergy_{ConvElec}$ = Difference in idle energy between baseline and efficient combination oven in convection mode
 = $((ElecIDLE_{ConvBase} * ((Hours - FoodCooked_{Elec} / ElecPC_{ConvBase}) * \%Conv)) - (ElecIDLE_{ConvEE} * ((Hours - FoodCooked_{Elec} / ElecPC_{ConvEE}) * \%Conv)))$
- $\Delta IdleEnergy_{SteamElec}$ = Difference in idle energy between baseline and efficient combination oven in steam mode
 = $[(ElecIDLE_{SteamBase} * ((Hours - FoodCooked_{Elec} / ElecPC_{SteamBase}) * \%Steam)) - (ElecIDLE_{SteamEE} * ((Hours - FoodCooked_{Elec} / ElecPC_{SteamEE}) * \%Steam))]$
- Days = Annual days of operation
 = Custom or, if unknown, use 365.25 days per year
- 1,000 = Wh to kWh conversion factor

Where:

- $FoodCooked_{Elec}$ = Food cooked per day for electric combination oven
 = Custom, or, if unknown, use 200 lbs if P <15 or 250 lbs if P ≥ 15
- $EFOOD_{ConvElec}$ = ASTM energy to food for electric combination oven in convection mode

⁴⁷ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

= 73.2 Wh/lb

ElecEff = Cooking energy efficiency of electric combination oven
 = Custom or if unknown, use values from table below

| | Base | EE |
|--------------------------------|------|-----|
| ElecEFF_{Conv} | 72% | 76% |
| ElecEFF_{Steam} | 49% | 55% |

%_{Conv} = Percentage of time in convection mode
 = Custom or, if unknown, use 50%

EFOOD_{SteamElec} = ASTM energy to food for electric combination oven in steam mode
 = 30.8 Wh/lb

%_{steam} = Percentage of time in steam mode
 = 1 - %_{conv}

ElecIDLE_{Base} = Idle energy rate (W) of baseline electric combination oven
 = Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode (ElecIDLE _{ConvBase}) | Steam Mode (ElecIDLE _{SteamBase}) |
|--------------|--|--|
| < 15 | 1,320 | 5,260 |
| ≥ 15 | 2,280 | 8,710 |

Hours = Average daily hours of operation
 = Custom or, if unknown, use 12 hours per day

ElecPC_{Base} = Production capacity (lbs/hr) of baseline electric combination oven
 = Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode (ElecPC _{ConvBase}) | Steam Mode (ElecPC _{SteamBase}) |
|--------------|--|--|
| < 15 | 79 | 126 |
| ≥15 | 166 | 295 |

ElecIDLE_{ConvEE} = Idle energy rate of ENERGY STAR electric combination oven in convection mode
 = (0.08*P + 0.4989)*1,000

ElecPC_{EE} = Production capacity (lbs/hr) of ENERGY STAR electric combination oven
 = Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode (ElecPC _{ConvEE}) | Steam Mode (ElecPC _{SteamEE}) |
|--------------|--|--|
| < 15 | 119 | 177 |
| ≥ 15 | 201 | 349 |

$ElecIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR electric combination oven in steam mode
 = $(0.133 * P + 0.64) * 1,000$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above
 CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001998949⁴⁸

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a gas combination oven below:⁴⁹

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

Where:

$\Delta CookingEnergy_{ConvGas}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode
 = $FoodCooked_{Gas} * (E_{FOOD_{ConvGas}} / GasEFF_{ConvBase} - E_{FOOD_{ConvGas}} / GasEFF_{ConvEE}) * \%_{Conv}$

$\Delta CookingEnergy_{SteamGas}$ = Difference in cooking energy between baseline and efficient combination oven in steam mode
 = $FoodCooked_{Gas} * (E_{FOOD_{SteamGas}} / GasEFF_{SteamBase} - E_{FOOD_{SteamGas}} / GasEFF_{SteamEE}) * \%_{Steam}$

$\Delta IdleEnergy_{ConvGas}$ = Difference in idle energy between baseline and efficient combination oven in convection mode
 = $((GasIDLE_{ConvBase} * ((Hours - FoodCooked_{Gas} / GasPC_{ConvBase}) * \%_{Conv})) - (GasIDLE_{ConvEE} * ((Hours - FoodCooked_{Gas} / GasPC_{ConvEE}) * \%_{Conv})))$

$\Delta IdleEnergy_{SteamGas}$ = Difference in idle energy between baseline and efficient combination oven in steam mode

⁴⁸ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

⁴⁹ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

$$= \left[\left(\text{GasIDLE}_{\text{SteamBase}} * \left(\frac{\text{Hours} - \text{FoodCooked}_{\text{Gas}}}{\text{GasPC}_{\text{SteamBase}}} * \% \text{Steam} \right) \right) - \left(\text{GasIDLE}_{\text{SteamEE}} * \left(\frac{\text{Hours} - \text{FoodCooked}_{\text{Gas}}}{\text{GasPC}_{\text{SteamEE}}} * \% \text{Steam} \right) \right) \right]$$

100,000

= Btu to therms conversion factor

Where:

$\text{FoodCooked}_{\text{Gas}}$

= Food cooked per day for gas combination oven

= Custom, or, if unknown, use 200 lbs if $P < 15$, 250 lbs if $15 \leq P < 30$, or 400 lbs if $P \geq 30$

$\text{EFOOD}_{\text{ConvGas}}$

= ASTM energy to food for gas combination oven in convection mode
= 250 Btu/lb

GasEff

= Cooking energy efficiency of gas combination oven
= Custom or, if unknown, use values from table below

| | Base | EE |
|--------------------------------|------|-----|
| $\text{GasEFF}_{\text{Conv}}$ | 52% | 56% |
| $\text{GasEFF}_{\text{Steam}}$ | 39% | 41% |

$\text{EFOOD}_{\text{SteamGas}}$

= ASTM energy to food for gas combination oven in steam mode
= 105 Btu/lb

$\text{GasIDLE}_{\text{Base}}$

= Idle energy rate (Btu/hr) of baseline gas combination oven
= Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode ($\text{GasIDLE}_{\text{ConvBase}}$) | Steam Mode ($\text{GasIDLE}_{\text{SteamBase}}$) |
|------------------|---|---|
| < 15 | 8,747 | 18,656 |
| $15 \leq P < 30$ | 10,788 | 24,562 |
| ≥ 30 | 13,000 | 43,300 |

$\text{GasPC}_{\text{Base}}$

= Production capacity (lbs/hr) of baseline gas combination oven
= Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode ($\text{GasPC}_{\text{ConvBase}}$) | Steam Mode ($\text{GasPC}_{\text{SteamBase}}$) |
|------------------|---|---|
| < 15 | 125 | 195 |
| $15 \leq P < 30$ | 176 | 211 |
| ≥ 30 | 392 | 579 |

$\text{GasIDLE}_{\text{ConvEE}}$

= Idle energy rate of ENERGY STAR gas combination oven in convection mode
= $150 * P + 5,425$

GasPC_{EE}

= Production capacity (lbs/hr) of ENERGY STAR gas combination oven
= Custom or, if unknown, use values from table below

| Pan Capacity | Convection Mode (GasPC _{ConvEE}) | Steam Mode (GasPC _{SteamEE}) |
|--------------|---|---|
| < 15 | 124 | 172 |
| 15 ≤ P 30 | 210 | 277 |
| ≥30 | 394 | 640 |

GasIDLE_{SteamEE} = Idle energy rate of ENERGY STAR gas combination oven in steam mode
 = 200*P +6,511

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.2 Commercial Steam Cooker

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR® steam cookers installed in a commercial kitchen. Commercial steam cookers contain compartments where steam energy is transferred to food by direct contact. ENERGY STAR® certified steam cookers have shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified steam cooker meeting idle energy rate (W or Btu/hr) and cooking efficiency (%) limits, as determined by fuel type and pan capacity.

ENERGY STAR Requirements (Version 1.2, Effective August 1, 2003)

| Pan Capacity | Electric Efficiency Requirements | | Natural Gas Efficiency | |
|------------------|----------------------------------|--------------------|------------------------|--------------------|
| | Idle Energy Rate | Cooking Efficiency | Idle Energy Rate | Cooking Efficiency |
| 3-pan | ≤ 400 W | ≥ 50% | ≤ 6,250 Btu/hr | ≥ 38% |
| 4-pan | ≤ 530 W | | ≤ 8,350 Btu/hr | N/A |
| 5-pan | ≤ 670 W | | ≤ 10,400 Btu/hr | |
| 6-pan and larger | ≤ 800 W | | ≤ 12,500 Btu/hr | |

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁵⁰

DEEMED MEASURE COST

Actual incremental cost for this measure should be used. If actuals are unavailable use \$4,150.⁵¹

LOADSHAPE

Cooking BUS

⁵⁰ Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.”

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁵¹ Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below; otherwise use deemed value from the table that follows.⁵²

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [(1 - SteamMode) * (IdleRate_{Base} + SteamMode * Production_{Base} * Pans * E_{FOOD} / Eff_{Base}) * (Hours - FoodCooked / (Production_{Base} * Pans))] - [(1 - SteamMode) * (IdleRate_{ESTAR} + SteamMode * Production_{ESTAR} * Pans * E_{FOOD} / Eff_{ESTAR}) * (Hours - FoodCooked / (Production_{ESTAR} * Pans))]$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

$\Delta IdleEnergy$ = Difference in idle energy between baseline and efficient steam cooker

$\Delta CookingEnergy$ = Difference in cooking energy between baseline and efficient steam cooker

Days = Annual days of operation
 = Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

SteamMode = Time (%) in constant steam mode
 = Custom or, if unknown, use 40%

IdleRate_{Base} = Idle energy rate (W) of baseline electric steam cooker
 = 1,100 W⁵³

IdleRate_{ESTAR} = Idle energy rate (W) of ENERGY STAR electric steam cooker
 = Custom or, if unknown, use value from table below as determined by pan capacity

| Pan Capacity | IdleRate _{ESTAR} |
|--------------|---------------------------|
| 3 | 400 |
| 4 | 530 |
| 5 | 670 |
| 6 | 800 |
| 10 | 800 |

Production_{Base} = Production capacity (lb/hr) per pan of baseline electric steam cooker
 = 23.3 lb/hr

⁵² Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

⁵³ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR® for steam generator and boiler-based cookers.

- Production_{ESTAR} = Production capacity (lb/hr) per pan of ENERGY STAR® electric steam cooker
= Custom or, if unknown, use 16.7 lb/hr
- Pans = Pan capacity of steam cooker
= Custom or, if unknown, use 6 pans
- EFOOD = ASTM energy to food
= 30.8 Wh/lb
- Eff_{Base} = Cooking efficiency (%) of baseline electric steam cooker⁵⁴
= 28%
- Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR® electric steam cooker
= Custom or, if unknown, use 50%
- Hours = Average daily hours of operation
= Custom or, if unknown, use 12 hours per day
- FoodCooked = Food cooked per day (lbs)
= Custom or, if unknown, use 100 pounds

Savings for all pan capacities are presented in the table below.

| Energy Consumption of Electric Steam Cookers | | | |
|--|---------------------|----------------------|---------------|
| Pan Capacity | kWh _{Base} | kWh _{ESTAR} | Savings (kWh) |
| 3 | 18,438.9 | 7,637.6 | 10,801.3 |
| 4 | 23,018.6 | 9,784.1 | 13,234.5 |
| 5 | 27,563.8 | 11,953.8 | 15,609.9 |
| 6 | 32,091.7 | 14,100.1 | 17,991.6 |
| 10 | 50,134.5 | 21,384.3 | 28,750.1 |
| Average | 30,249.5 | 12,972.0 | 17,277.5 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949⁵⁵

Other variables as defined above.

⁵⁴ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR® Commercial Kitchen Equipment Savings Calculator for steam generator and boiler-based cookers.

⁵⁵ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas steam cooker below; otherwise use deemed value from the table that follows.⁵⁶

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = [(1 - SteamMode) * (IdleRate_{Base} + SteamMode * Production_{Base} * Pans * EFOOD / Eff_{Base}) * (Hours - FoodCooked / (Production_{Base} * Pans))] - [(1 - SteamMode) * (IdleRate_{ESTAR} + SteamMode * Production_{ESTAR} * Pans * EFOOD / Eff_{ESTAR}) * (Hours - FoodCooked / Production_{ESTAR} * Pans)]$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD / Eff_{Base}) - (FoodCooked * EFOOD / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

IdleRate_{Base} = Idle energy rate (Btu/hr) of baseline gas steam cooker
 = 16,500 Btu/hr⁵⁷

IdleRate_{ESTAR} = Idle energy rate (Btu/hr) of ENERGY STAR[®] gas steam cooker
 = Custom or, if unknown, use value from table below as determined by pan capacity

| Pan Capacity | IdleRate _{ESTAR} |
|--------------|---------------------------|
| 3 | 6,250 |
| 5 | 10,400 |
| 6 | 12,500 |
| 10 | 12,500 |

Production_{Base} = Production capacity (lb/hr) per pan of baseline gas steam cooker
 = 23.3 lb/hr

Production_{ESTAR} = Production capacity (lb/hr) per pan of ENERGY STAR[®] gas steam cooker
 = Custom or, if unknown, use 20 lb/hr

EFOOD = ASTM energy to food
 = 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker⁵⁸
 = 16.5%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR[®] gas steam cooker
 = Custom or if unknown, use 38%

⁵⁶ Algorithms and assumptions derived from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator.

⁵⁷ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR[®] for steam generator and boiler-based cookers.

⁵⁸ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR[®] for steam generator and boiler-based cookers.

Other variables as defined above.

Savings for all pan capacities are presented in the table below.

| Energy Consumption of Gas Steam Cookers | | | |
|---|------------------------|-------------------------|------------------|
| Pan Capacity | Therms _{Base} | Therms _{ESTAR} | Savings (Therms) |
| 3 | 1,301.5 | 492.8 | 808.7 |
| 5 | 1,842.1 | 795.7 | 1,046.4 |
| 6 | 2,107.2 | 947.8 | 1,159.4 |
| 10 | 3,157.4 | 1,344.5 | 1,812.9 |
| Average | 1,996.0 | 845.0 | 1,150.0 |

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below; otherwise use deemed value of 134,412.0 gallons per year.⁵⁹ Savings are the same for electric and gas steam cookers.

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

Where:

WaterUse_{Base} = Water use (gal/hr) of baseline steam cooker
 = 40 gal/hr

WaterUse_{ESTAR} = Water use (gal/hr) of ENERGY STAR® steam cooker⁶⁰
 = Custom or, if unknown, use 9.3 gal/hr

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

⁵⁹ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

⁶⁰ Water use for ENERGY STAR® steam cookers is the average of water use values provided by ENERGY STAR® for steam generator, boiler-based, and boilerless cookers.

2.3.3 Fryer

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR[®] certified fryers installed in a commercial kitchen. ENERGY STAR[®] fryers offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses, resulting in lower idle energy rates. Standard-sized ENERGY STAR[®] fryers are up to 30% more efficient, and large-vat ENERGY STAR[®] fryers are up to 35% more efficient, than standard fryers.

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

If applied to other program types, 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 2.0, Effective April 22, 2011)

| 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 | ≤ 1,000 W | ≥ 80% | ≤ 9,000 Btu/hr | ≥ 50% |
| Large Vat Open Deep-Fat Fryer | ≤ 1,100 W | | ≤ 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.⁶¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$210 for standard electric, \$0 for large vat electric, \$0 for standard gas, and \$1,120 for large vat gas fryers.⁶²

⁶¹ Lifetime from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.

⁶² Measure costs from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research using AutoQuotes, 2012.”

LOADSHAPE**Cooking BUSAlgorithm****CALCULATION OF SAVINGS****ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric fryer below; otherwise use deemed value of 952.3 kWh for standard fryers and 2,537.9 kWh for large vat fryers.⁶³

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (ElecIdle_{Base} * (Hours - FoodCooked/ElecPC_{Base})) - (ElecIdle_{ESTAR} * (Hours - FoodCooked/ElecPC_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD_{Elec/ElecEff_{Base}}) - (FoodCooked * EFOOD_{Elec/ElecEff_{ESTAR}})$$

Where:

$\Delta IdleEnergy$ = Difference in idle energy between baseline and efficient fryer

$\Delta CookingEnergy$ = Difference in cooking energy between baseline and efficient fryer

Days = Annual days of operation
= Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

$ElecIdle_{Base}$ = Idle energy rate of baseline electric fryer
= 1,050 W for standard fryers and 1,350 W for large vat fryers

$ElecIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR[®] electric fryer
= Custom or, if unknown, use 1,000 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

FoodCooked = Food cooked per day
= Custom or, if unknown, use 150 pounds

$ElecPC_{Base}$ = Production capacity of baseline electric fryer
= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$ElecPC_{ESTAR}$ = Production capacity of ENERGY STAR[®] electric fryer
= Custom or, if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers

$EFOOD_{Elec}$ = ASTM energy to food

⁶³ Algorithms and assumptions derived from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator.

| | |
|-------------------|--|
| | = 167 Wh/lb |
| $ElecEff_{Base}$ | = Cooking efficiency of baseline electric fryer = 75% for standard fryers and 70% for large vat fryers |
| $ElecEff_{ESTAR}$ | = Cooking efficiency of ENERGY STAR® electric fryer = Custom or, if unknown, use 80% for both standard and large vat fryers |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

| | |
|--------------|---|
| ΔkWh | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0001998949 ⁶⁴ |

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas fryer below; otherwise use deemed value of 507.9 therms/yr for standard fryers and 415.1 therms/yr for large vat fryers.⁶⁵

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

| | |
|------------------------|---|
| $\Delta IdleEnergy$ | = $(GasIdle_{Base} * (Hours - FoodCooked / GasPC_{Base})) - (GasIdle_{ESTAR} * (Hours - FoodCooked / GasPC_{ESTAR}))$ |
| $\Delta CookingEnergy$ | = $(FoodCooked * EFOOD_{Gas} / GasEff_{Base}) - (FoodCooked * EFOOD_{Gas} / GasEff_{ESTAR})$ |

Where:

| | |
|-------------------|--|
| 100,000 | = Btu to therms conversion factor |
| $GasIdle_{Base}$ | = Idle energy rate of baseline gas fryer = 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers |
| $GasIdle_{ESTAR}$ | = Idle energy rate of ENERGY STAR® gas fryer = Custom or, if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers |
| $GasPC_{Base}$ | = Production capacity of baseline gas fryer = 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers |
| $GasPC_{ESTAR}$ | = Production capacity of ENERGY STAR® gas fryer = Custom or, if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers |

⁶⁴ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

⁶⁵ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

- $E_{\text{FOOD}_{\text{Gas}}}$ = ASTM energy to food
= 570 Btu/lb
- $\text{GasEff}_{\text{Base}}$ = Cooking efficiency of baseline gas fryer
= 35% for both standard and large vat fryers
- $\text{GasEff}_{\text{ESTAR}}$ = Cooking efficiency of ENERGY STAR® gas fryer
= Custom or, if unknown, use 50% for both standard and large vat fryers

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.4 Convection Oven

DESCRIPTION

This measure applies to either full or half-sized electric ENERGY STAR® convection ovens and to half-sized natural gas fired ENERGY STAR® convection ovens installed in a commercial kitchen. Convection ovens are general purpose ovens that use fans to circulate hot, dry air over the food surface. ENERGY STAR® certified convection ovens are approximately 20% more efficient than standard ovens.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified convection oven meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by both fuel type and oven capacity (full size versus half size).

ENERGY STAR® Requirements (Version 2.2, Effective October 7, 2015)

| Oven Capacity | Electric Efficiency Requirements | | Natural Gas Efficiency Requirements | |
|---------------|----------------------------------|--------------------|-------------------------------------|--------------------|
| | Idle Energy Rate | Cooking Efficiency | Idle Energy Rate | Cooking Efficiency |
| Full Size | ≤ 1.60 kW | ≥ 71% | ≤ 12,000 Btu/hr | ≥ 46% |
| Half Size | ≤ 1.00 kW | | N/A | N/A |

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is \$0.⁶⁷

⁶⁶ Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.”

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.

⁶⁷Measure cost from ENERGY STAR® which cites reference as “EPA research on available models using AutoQuotes, 2013.”

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CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric convection oven below; otherwise use 1,938.5 kWh for full-size ovens and 192.1 kWh for half-size ovens.⁶⁸

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (ElecIdle_{Base} * (Hours - FoodCooked/ElecPC_{Base})) - (ElecIdle_{ESTAR} * (Hours - FoodCooked/ElecPC_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD_{Elec} / ElecEff_{Base}) - (FoodCooked * EFOOD_{Elec} / ElecEff_{ESTAR})$$

Where:

$\Delta IdleEnergy$ = Difference in idle energy between baseline and efficient convection oven

$\Delta CookingEnergy$ = Difference in cooking energy between baseline and efficient convection oven

Days = Annual days of operation
 = Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

$ElecIdle_{Base}$ = Idle energy rate of baseline electric convection oven
 = 2,000 W for full-size ovens and 1,030 W for half-size ovens

$ElecIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR[®] electric convection oven
 = Custom or, if unknown, use 1,600 W for full-size ovens and 1,000 W for half-size ovens

Hours = Average daily hours of operation
 = Custom or, if unknown, use 12 hours per day

FoodCooked = Food cooked per day
 = Custom or, if unknown, use 100 pounds

$ElecPC_{Base}$ = Production capacity of baseline electric convection oven
 = 90 lb/hr for full-size ovens and 45 lb/hr for half-size ovens

$ElecPC_{ESTAR}$ = Production capacity of ENERGY STAR[®] electric convection oven
 = Custom or, if unknown, use 90 lb/hr for full-size ovens and 50 lb/hr for half-size ovens

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

⁶⁸ Algorithms and assumptions derived from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator.

| | |
|-------------------|--|
| | = 73.2 Wh/lb |
| $ElecEff_{Base}$ | = Cooking efficiency of baseline electric convection oven = 65% for full-size ovens and 68% for half-size ovens |
| $ElecEff_{ESTAR}$ | = Cooking efficiency of ENERGY STAR® electric convection oven = Custom or, if unknown, use 71% for both full-size and half-size ovens |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

| | |
|--------------|---|
| ΔkWh | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0001998949 ⁶⁹ |

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 129.4 therms/yr.⁷⁰

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

| | |
|------------------------|---|
| $\Delta IdleEnergy$ | = $(GasIdle_{Base} * (Hours - FoodCooked / GasPC_{Base})) - (GasIdle_{ESTAR} * (Hours - FoodCooked / GasPC_{ESTAR}))$ |
| $\Delta CookingEnergy$ | = $(FoodCooked * EFOOD_{Gas} / GasEff_{Base}) - (FoodCooked * EFOOD_{Gas} / GasEff_{ESTAR})$ |

Where:

| | |
|-------------------|--|
| 100,000 | = Btu to therms conversion factor |
| $GasIdle_{Base}$ | = Idle energy rate of baseline gas convection oven = 15,100 Btu/hr |
| $GasIdle_{ESTAR}$ | = Idle energy rate of ENERGY STAR® gas convection oven = Custom or, if unknown, use 12,000 Btu/hr |
| $GasPC_{Base}$ | = Production capacity of baseline gas convection oven = 83 lb/hr |
| $GasPC_{ESTAR}$ | = Production capacity of ENERGY STAR® gas convection oven = Custom or, if unknown, use 86 lb/hr |

⁶⁹ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

⁷⁰ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

| | |
|--------------------------------|--|
| $E_{\text{FOOD}_{\text{Gas}}}$ | = ASTM energy to food for gas convection oven = 250 Btu/lb |
| $\text{GasEff}_{\text{Base}}$ | = Cooking efficiency of baseline gas convection oven = 44% |
| $\text{GasEff}_{\text{ESTAR}}$ | = Cooking efficiency of ENERGY STAR [®] gas convection oven = Custom or, if unknown, use 46% |

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.5 Griddle

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR® certified griddles installed in a commercial kitchen. ENERGY STAR® commercial griddles achieve approximately 10% higher efficiency than standard griddles with strategies such as highly conductive or reflective plate materials and improved thermostatic controls.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR® electric or natural gas fired griddle meeting idle energy rate limits as determined by fuel type.

ENERGY STAR® Requirements (Version 1.2, Effective May 8, 2009 for natural gas and January 1, 2011 for electric griddles)

| Electric Efficiency Requirements | | Natural Gas Efficiency Requirements | |
|---|--------------------------------|---|--------------------------------|
| Idle Energy Rate | Cooking Efficiency Consumption | Idle Energy Rate | Cooking Efficiency Consumption |
| $\leq 320 \text{ W/ft}^2$ $\leq 1.00 \text{ kW}$ | Reported | $\leq 2,650 \text{ Btu/hr/ft}^2$ N/A | Reported |

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁷¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$0 for an electric griddle and \$360 for a gas griddle.⁷²

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CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric griddle below; otherwise use deemed value of 1,910.4 kWh.⁷³

⁷¹ Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.”

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁷² Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, 2012.”

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG.

⁷³ Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [(ElecIdle_{Base} * Width * Depth) * (Hours - FoodCooked/ElecPC_{Base})] - [(ElecIdle_{ESTAR} * Width * Depth) * (Hours - FoodCooked/ElecPC_{ESTAR})]$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD_{Elec} / ElecEff_{Base}) - (FoodCooked * EFOOD_{Elec} / ElecEff_{ESTAR})$$

Where:

| | |
|------------------------|---|
| $\Delta IdleEnergy$ | = Difference in idle energy between baseline and efficient griddle |
| $\Delta CookingEnergy$ | = Difference in cooking energy between baseline and efficient griddle |
| Days | = Annual days of operation = Custom or, if unknown, use 365.25 days per year |
| 1,000 | = Wh to kWh conversion factor |
| $ElecIdle_{Base}$ | = Idle energy rate of baseline electric griddle = 400 W/ft ² |
| $ElecRate_{ESTAR}$ | = Idle energy rate of ENERGY STAR [®] electric griddle = Custom or, if unknown, use 320 W/ft ² |
| Width | = Griddle width = Custom or, if unknown, use 3 feet |
| Depth | = Griddle depth = Custom or, if unknown, use 2 feet |
| Hours | = Average daily hours of operation = Custom or, if unknown, use 12 hours per day |
| FoodCooked | = Food cooked per day = Custom or, if unknown, use 100 pounds |
| $ElecPC_{Base}$ | = Production capacity of baseline electric griddle = 35 lb/hr |
| $ElecPC_{ESTAR}$ | = Production capacity of ENERGY STAR [®] electric griddle = Custom or, if unknown, use 40 lb/hr |
| $EFOOD_{Elec}$ | = ASTM energy to food = 139 Wh/lb |
| $ElecEff_{Base}$ | = Cooking efficiency of baseline electric griddle = 65% |
| $ElecEff_{ESTAR}$ | = Cooking efficiency of ENERGY STAR [®] electric griddle = Custom or, if unknown, use 70% |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949⁷⁴
- Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas griddle below; otherwise use deemed value of 131.4 therms.⁷⁵

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100,000$$

Where:

- $\Delta IdleEnergy$ = $[GasIdle_{Base} * (Width * Depth) * (Hours - FoodCooked/GasPC_{Base})] - [GasIdle_{ESTAR} * (Width * Depth) * (Hours - FoodCooked/GasPC_{ESTAR})]$
- $\Delta CookingEnergy$ = $(FoodCooked * EFOOD_{Gas} / GasEff_{Base}) - (FoodCooked * EFOOD_{Gas} / GasEff_{ESTAR})$

Where:

- 100,000 = Btu to therms conversion factor
- $GasIdle_{Base}$ = Idle energy rate of baseline gas griddle
= 3,500 Btu/hr/ft²
- $GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR[®] gas griddle
= Custom or, if unknown, use 2,650 Btu/hr/ft²
- $GasPC_{Base}$ = Production capacity of baseline gas griddle
= 25 lb/hr
- $GasPC_{ESTAR}$ = Production capacity of ENERGY STAR[®] gas griddle
= Custom or, if unknown, use 45 lb/hr
- $EFOOD_{Gas}$ = ASTM energy to food
= 475 Btu/lb
- $GasEff_{Base}$ = Cooking efficiency of baseline gas griddle
= 32%
- $GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR[®] gas griddle
= Custom or, if unknown, use 38%
- Other variables as defined above.

⁷⁴ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

⁷⁵ Algorithms and assumptions derived from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.6 Kitchen Demand Ventilation Controls

DESCRIPTION

This measure related to the installation of commercial kitchen demand ventilation controls that vary the kitchen ventilation exhaust and make-up airflow based on cooking load and/or time of day.

This measure was developed to be applicable to the following program types: TOS and RF. For TOS applications, ASHRAE 90.1 and local codes should be applied to situations where hood exhaust rates exceed 5,000 cfm. 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 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 system that has constant speed, continuously operating ventilation motor(s).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁷⁶

DEEMED MEASURE COST

The capital cost for this measure is proportional to the rated horsepower of the exhaust motor(s), based on installation classification:

$$\text{Measure Cost} = \text{HP}_{\text{exhaust}} * \text{Cost}_{\text{HP}}$$

Where:

$\text{HP}_{\text{exhaust}}$ = total rated horsepower of the exhaust motor(s)

Cost_{HP} = cost per horsepower as listed in the table below

| Measure Category | Incremental Cost ⁷⁷ , \$/HP |
|------------------|--|
| Retrofit | \$1,988 |
| Time of Sale | \$994 |

⁷⁶ Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009.

⁷⁷ Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009.

LOADSHAPE**Cooking BUS Algorithm****CALCULATION OF SAVINGS****ELECTRIC ENERGY SAVINGS**

Fan energy savings:

$$\Delta kWh = HP_{\text{exhaust}} * (0.76 \text{ kW/HP}^{78}) * \text{Hours} * \text{Days}$$

Where:

Hours = Average daily hours of operation. If unknown, assume 12 hours.

Days = Annual days of operation. If unknown assume 365.25 days.

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949⁷⁹

NATURAL GAS ENERGY SAVINGS

For applications where 100% make-up air is tempered, annual gas savings attributed to heating can be estimated as:

$$\Delta \text{Therms} = \text{CFM} * HP_{\text{exhaust}} * \text{Hours}/24 * Q * /(\text{Eff}_{\text{heat}} * 100,000)$$

Where:

CFM = average airflow reduction for the system, per rated horsepower of exhaust motor(s).

= custom input, or 448 cfm/HP⁸⁰ if unknown.

Q = Annual heating energy required (tabulated values represent continuous operation) to heat kitchen make-up air, Btu/cfm.⁸¹

⁷⁸ Normalized demand savings per rated HP of exhaust motor. Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009.

⁷⁹ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

⁸⁰ Based on data presented in Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009. See workbook KDVC.xlsx for derivation.

⁸¹ Assuming a base temperature of 65. It is assumed that kitchens often separate dedicated 100% outdoor air make up units and kitchen staff prefer to have outside air heated to 65 degrees. See workbook KDVC.xlsx for derivation.

| Zone | Q, Btu/cfm |
|----------|------------|
| St Louis | 125,363 |

Eff_{heat} = Heating efficiency of unit supplying make-up air.

= actual if known, otherwise assume 80%⁸²

100,000 = conversion from Btu to Therm

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

⁸² IECC code minimum thermal efficiency requirements for a warm air duct furnace.

2.3.7 Hot Food Holding Cabinet

DESCRIPTION

This measure applies to electric ENERGY STAR® certified hot food holding cabinets (HFHCs) installed in a commercial kitchen. ENERGY STAR® HFHCs achieve approximately 70% higher efficiency than standard models by incorporating better insulation which reduces heat loss, offers better temperature uniformity within the cabinet from top to bottom, and keeps the external cabinet cooler. In addition, many certified HFHCs may include additional energy saving devices such as magnetic door gaskets, auto-door closures, or dutch doors.

This measure was developed to be applicable to the following program type: 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 ENERGY STAR® electric HFHC meeting idle energy rate limits as determined by product interior volume.

ENERGY STAR® Requirements (Version 2.0, Effective October 1, 2011)

| Interior Volume (ft ³) | Idle Energy Consumption Rate (W) |
|------------------------------------|----------------------------------|
| $0 < V < 13$ | $\leq 21.5 V$ |
| $13 \leq V < 28$ | $\leq 2.0 V + 254.0$ |
| $28 \leq V$ | $\leq 3.8 V + 203.5$ |

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric HFHC that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁸³

DEEMED MEASURE COST

Actual incremental costs should be used if available. If actual costs are unknown, assume \$1,783.⁸⁴

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Cooking BUS

⁸³ Lifetime from ENERGY STAR® Commercial Kitchen Equipment Calculator, which cites reference as “FSTC research on available models, 2009.”

⁸⁴ Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Custom calculation below.⁸⁵

$$\Delta kWh = (IdleRate_{Base} - IdleRate_{EE}) * Hours * Days / 1,000$$

$$\begin{aligned} IdleRate_{Base} &= \text{Idle energy rate (W) of baseline HFHC} \\ &= 40 * V \end{aligned}$$

Where:

$$\begin{aligned} V &= \text{Interior volume (ft}^3\text{) of new HFHC} \\ &= \text{Custom} \end{aligned}$$

$$\begin{aligned} IdleRate_{ESTAR} &= \text{Idle energy rate (W) of ENERGY STAR}^{\text{®}}\text{ HFHC} \\ &= \text{See table below for idle energy rates based on interior volume} \end{aligned}$$

| Interior Volume (ft ³) | Idle Energy Consumption Rate (W) |
|------------------------------------|----------------------------------|
| $0 < V < 13$ | $21.5 * V$ |
| $13 \leq V < 28$ | $(2.0 * V) + 254.0$ |
| $28 \leq V$ | $(3.8 * V) + 203.5$ |

$$\begin{aligned} \text{Hours} &= \text{Average daily hours of operation} \\ &= \text{Custom or, if unknown, use 15 hours per day} \\ \text{Days} &= \text{Annual days of operation} \\ &= \text{Custom or, if unknown, use 365.25 days per year} \\ 1,000 &= \text{Wh to kWh conversion factor} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$$\begin{aligned} \Delta kWh &= \text{Electric energy savings, calculated above} \\ CF &= \text{Summer peak coincidence demand (kW) to annual energy (kWh) factor} \\ &= 0.0001998949^{86} \end{aligned}$$

Other variables as defined above.

⁸⁵ Algorithms and assumptions derived from Commercial Kitchen Equipment Calculator.

⁸⁶ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.8 Pre-Rinse Spray Valve

DESCRIPTION

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

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

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 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. | Actual existing flow rates should be used when possible. If unknown, baseline can be assumed to be 2.23 gallons per minute. ⁸⁷ 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 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 years⁸⁸

DEEMED MEASURE COST

When available, the actual cost of the measure should be used. If unknown, a default value of \$92.90⁸⁹ may be assumed.

⁸⁷ Verification measurements taken at 195 installations showed average pre flowrates of 2.23 gallons per minute. 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).

⁸⁸Consistent with Ameren Missouri MEEIA 2016-18 and KCPL TRM assumptions.

⁸⁹Average of costs recognized by Ameren Missouri (\$85.8) and KCPL (\$100).

LOADSHAPE**Cooking BUSAlgorithm****CALCULATION OF ENERGY SAVINGS****ELECTRIC ENERGY SAVINGS (NOTE WATER SAVINGS MUST FIRST BE CALCULATED)**

$$\Delta kWh = \Delta Gallons * 8.33 * 1 * (T_{out} - T_{in}) * (1/EFF_{Elec}) / 3,413$$

Where:

| | |
|------------------|---|
| $\Delta Gallons$ | = amount of water saved as calculated below in Water Impact Calculation |
| 8.33 | = specific mass in pounds of one gallon of water (lbm/gal) |
| 1 | = Specific heat of water: 1 Btu/lbm/°F |
| T_{out} | = Water Heater Outlet Water Temperature = Custom, otherwise assume $T_{in} + 70^{\circ}F$ temperature rise from T_{in} ⁹⁰ |
| T_{in} | = Inlet Water Temperature = Custom, otherwise assume 57.9F ⁹¹ |
| EFF_{Elec} | = Efficiency of electric water heater supplying hot water to pre-rinse spray valve = Custom, otherwise assume 97% ⁹² |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

| | |
|--------------|---|
| ΔkWh | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0001998949 ⁹³ |

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \Delta Gallons * 8.33 * 1 * (T_{out} - T_{in}) * (1/EFF_{Gas}) / 100,000$$

Where (new variables only):

| | |
|-------------|---|
| EFF_{Gas} | = Efficiency of gas water heater supplying hot water to pre-rinse spray valve = Custom, otherwise assume 80% ⁹⁴ |
|-------------|---|

⁹⁰If unknown, assume a 70 degree temperature rise from T_{in} per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies.

⁹¹ Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061>.

⁹²This 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.

⁹³ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

⁹⁴ IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment.

WATER IMPACT CALCULATION

$$\Delta\text{Gallons} = (\text{FLObase} - \text{FLOeff}) * 60 * \text{HOURSday} * \text{DAYYear}$$

Where:

FLObase = Base case flow in gallons per minute (Gal/min). Use actual when appropriate if available, otherwise assume:

| Time of Sale | Retrofit, Direct Install |
|---------------------------|----------------------------|
| 1.6 gal/min ⁹⁵ | 2.23 gal/min ⁹⁶ |

FLOeff = Efficient case flow in gallons per minute (Gal/min). Use actual flow rate of installed equipment if known, otherwise assume:

| Time of Sale | Retrofit, Direct Install |
|----------------------------|----------------------------|
| 1.06 gal/min ⁹⁷ | 1.06 gal/min ⁹⁸ |

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise:⁹⁹

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

DAYYear = 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.

MEASURE CODE:

⁹⁵The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPA) 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.

⁹⁶ Verification measurements taken at 195 installations showed average pre flowrates of 2.23 gallons per minute. 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).

⁹⁷1.6 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.

⁹⁸1.6 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.

⁹⁹ Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves.

2.4 Hot Water

2.4.1 Low Flow Faucet Aerator

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. 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 type: 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. 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 9 years.¹⁰⁰

DEEMED MEASURE COST

The incremental cost for this measure is \$8¹⁰¹ or program actual

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per faucet retrofitted*.¹⁰²

$$\Delta\text{kWh} = \% \text{ElectricDHW} * ((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \text{Usage} * \text{EPG}_{\text{electric}} * \text{ISR}$$

Where:

¹⁰⁰ Table C-6, 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."

¹⁰¹ 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).

¹⁰² 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.

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

| DHW fuel | %Electric DHW |
|-------------|--------------------|
| Electric | 100% |
| Fossil Fuel | 0% |
| Unknown | 43% ¹⁰³ |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet “as-used”
 = 1.2¹⁰⁴ or custom based on metering studies¹⁰⁵

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”
 = 0.94¹⁰⁶ or custom based on metering studies¹⁰⁷

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 ¹⁰⁸ (A) | Unit | Estimated % hot water from Faucets ¹⁰⁹ (B) | Multiplier ¹¹⁰ (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 |

¹⁰³ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region (see ‘HC8.9 Water Heating in Midwest Region.xls’). If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹⁰⁴ Representative baseline flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. This accounts for all throttling and differences from rated flow rates. 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.

¹⁰⁵ 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.

¹⁰⁶ Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. 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.

¹⁰⁷ 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.

¹⁰⁸ Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

¹⁰⁹ 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.

¹¹⁰ 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.

| Building Type | Gallons hot water per unit per day ¹⁰⁸ (A) | Unit | Estimated % hot water from Faucets ¹⁰⁹ (B) | Multiplier ¹¹⁰ (C) | Unit | Days per year (D) | Annual gallons mixed water per faucet (A*B*C*D) |
|---------------------|---|----------|---|-------------------------------|----------------------|-------------------|---|
| 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)

$$= (8.33 * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$$

$$= (8.33 * 1.0 * (90 - 57.9)) / (0.98 * 3412)$$

$$= 0.0800 \text{ kWh/gal}$$

8.33 = Specific weight of water (lbs/gallon)

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

WaterTemp = Assumed temperature of mixed water
= 90F¹¹¹

SupplyTemp = Assumed temperature of water entering building
= 57.9F¹¹²

RE_{electric} = Recovery efficiency of electric water heater
= 98%¹¹³

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators
= Assumed to be 1.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

¹¹¹Temperature cited from SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm. This is a variable that would benefit from further evaluation.

¹¹² Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061>

¹¹³ Electric water heater have recovery efficiency of 98%: <http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>

Where:

ΔkWh = calculated value above on a per faucet basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001811545 FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

$\Delta Therms$ = %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% |
| Unknown | 57% ¹¹⁴ |

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)
 = (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)
 = 0.00772 Therm/gal

Where:

RE_gas = Recovery efficiency of gas water heater
 = 67%¹¹⁵

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

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

$\Delta gallons$ = ((GPM_base - GPM_low)/GPM_base) * Usage * ISR

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES USED FOR GPM ASSUMPTIONS

| Source ID | Reference |
|-----------|--|
| 1 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |

¹¹⁴ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region (see 'HC8.9 Water Heating in Midwest Region.xls'). If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹¹⁵ 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.

| | |
|---|--|
| 2 | 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. |
| 3 | 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. |
| 4 | 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:

2.4.2 Circulator Pump

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, and 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 is an existing, un-controlled recirculation pump on a gas-fired Central Domestic Hot Water System.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years.¹¹⁶

DEEMED MEASURE COST

The assumed measure cost is \$1,200 per pump.¹¹⁷

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh.¹¹⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

¹¹⁶ 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.

¹¹⁷ Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report*. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

¹¹⁸ Based on results from the Nicor Gas Emerging Technology Program study, this value is the average kWh saved per pump. Note this value does not reflect savings from electric units but electrical savings from gas-fired units.

ΔkWh = calculated value above on a per faucet basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001379439

NATURAL GAS SAVINGS

ΔTherms = 55.9 * number of dwelling units¹¹⁹

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

¹¹⁹ Based on results from the Nicor Gas Emerging Technology Program study, this value is the average therms saved per dwelling unit.

2.4.3 Heat Pump Water Heater

DESCRIPTION

This measure applies to the installation of a heat pump water heater (HPWH) in place of a standard electric water heater in a commercial building. Savings are presented dependent on the heating system installed in the building due to the impact of the heat pump water heater on the heating and cooling loads.

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

To qualify for this measure, the installed equipment must be a heat pump water heater meeting program efficiency requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a new, electric storage water heater meeting federal minimum efficiency standards.¹²⁰

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.¹²¹

DEEMED MEASURE COST

Actual costs should be used where available. Incremental capital costs are presented in the table below for heat pump water heaters with energy factors (EF) of 2.0 and 2.4 and rated volumes of 40 gallons and 50 gallons, respectively.¹²²

| EF | Rated Volume (gal) | Incremental Cost |
|-----|--------------------|------------------|
| 2.0 | 40 | \$1,340.30 |
| 2.4 | 50 | \$1,187.58 |

For larger heat pump water heaters, incremental capital costs are presented in the table below based on heating capacity.¹²³

| Heating Capacity (MBtu/hr) | Incremental Cost |
|----------------------------|------------------|
| 10-50 | \$4,000.00 |
| >50-100 | \$7,000.00 |
| >100-300 | \$10,000.00 |
| >300-500 | \$14,000.00 |

¹²⁰ Federal standards for ≤55 gallon and ≤12 kW storage water heaters are from 10 CFR §430.32(d). Federal standards for >120 gallon and >12 kW storage water heaters are from 10 CFR §431.110. Since the federal standard effectively requires a heat pump water heater for residential electric storage water heaters >55 gallons and ≤120 gallons, this measure excludes those units.

¹²¹ 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.

¹²² 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_August2016.xls” for more information.

¹²³ Costs for larger heat pump water heaters are from 2017 Michigan Energy Measures Database.xlsx and are based on heat pump water heaters with a COP ≥3.0.

| Heating Capacity (MBtu/hr) | Incremental Cost |
|----------------------------|------------------|
| >500 | \$18,000.00 |

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{(1/EF_{BASE} - 1/EF_{EE}) * HotWaterUse_{Gallon} * \gamma_{Water} * (T_{Out} - T_{In}) * 1.0}{3,412} \right) + kWh_{cool} - kWh_{heat}$$

Where:

EF_{BASE} = Efficiency of baseline water heater according to federal standards, expressed as Energy Factor (EF) or Thermal Efficiency (E_t)
 = See table below

| Equipment Type | Size Category | Federal Standard Minimum Efficiency |
|----------------|---------------|---|
| HPWH ≤12 kW | ≤55 gallon | EF: 0.96 – (0.0003 * rated volume in gallons) |
| HPWH >12kW | >120 gallon | E _t : 98% ¹²⁴ |

EF_{EE} = EF of heat pump water heater
 = Actual

HotWaterUse_{Gallon} = Estimated annual hot water consumption (gallons)
 = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

- Consumption per water heater capacity
 = Consumption/cap * Capacity

Where:

Consumption/cap = Estimate of consumption per gallon of tank capacity, dependent on building type:¹²⁵

¹²⁴ Efficiency of baseline water heaters >120 gallons based on search of electric storage water heaters >120 gallons available on AHRI directory.

¹²⁵ Based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2003) consumption data for West North Central (removed outliers of 1,000 kBtu/hr 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 “Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting,” Lawrence Berkeley National Library, December 1995. VEIC considers these values to be relatively conservative estimates that may benefit from future evaluation.

| Building Type | Consumption/cap |
|--|-----------------|
| Grocery, Convenience Store, and Restaurant | 803 |
| Lodging, Hospital, and Multifamily | 630 |
| Health Clinic, Church, Warehouse | 433 |
| Education, Office, and Retail | 594 |
| Industrial | 558 |
| Agriculture | 558 |
| Average Non Residential | 558 |

Capacity = Capacity of hot water heater in gallons
 = Actual

2. Consumption by facility size¹²⁶

| Building Type | Gallons hot water per unit per day | Unit | Units/1000 ft ² | Days per year | Gallons/1000 ft ² floor area |
|---------------------|------------------------------------|----------|----------------------------|---------------|---|
| Small Office | 1 | person | 2.3 | 250 | 575 |
| Large Office | 1 | person | 2.3 | 250 | 575 |
| Fast Food Rest | 0.7 | meal/day | 784.6 | 365 | 200,458 |
| Sit-Down Rest | 2.4 | meal/day | 340 | 365 | 297,840 |
| Retail | 2 | employee | 1 | 365 | 730 |
| Grocery | 2 | employee | 1.1 | 365 | 803 |
| Warehouse | 2 | employee | 0.5 | 250 | 250 |
| Elementary School | 0.6 | person | 9.5 | 200 | 1,140 |
| Jr High/High School | 1.8 | person | 9.5 | 200 | 3,420 |
| Health | 90 | patient | 3.8 | 365 | 124,830 |
| Motel | 20 | room | 5 | 365 | 36,500 |
| Hotel | 14 | room | 2.2 | 365 | 11,242 |
| Other | 1 | employee | 0.7 | 250 | 175 |

γ_{Water} = Specific weight of water
 = 8.33 pounds per gallon
 T_{OUT} = Tank temperature
 = Actual, if unknown assume 125°F¹²⁷

¹²⁶ Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting,” Lawrence Berkeley National Library, December 1995.

¹²⁷ Ideally, the actual set point of the water heater should be used. If not available, 125 degrees is provided as an estimate of unmixed output temperature. While plumbing code generally limits temperatures at the end use, it typically does not limit the water heater system, which can be anywhere in the range 120 -201 degrees. For applications such as laundry and dishwashing, health and safety regulations may require water to be initially heated to higher temperatures. Since temperature set points can vary widely, market, program, or site-specific data should be used whenever possible.

- T_{IN} = Incoming water temperature from well or municipal system
= 57.898°F¹²⁸
- 1.0 = Heat capacity of water (1 Btu/lb*°F)
- 3,412 = Conversion factor from Btu to kWh
- kWh_cool = Cooling savings from conversion of heat in building to water heat¹²⁹

$$= \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}} \right) * HotWaterUse_{Gallon} * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 53\% * LM}{COP_{COOL} * 3412} \right] * \%Cool$$

Where:

- LF = Location Factor
= 1.0 for HPWH installation in a conditioned space
= 0.5 for HPWH installation in an unknown location¹³⁰
= 0.0 for installation in an unconditioned space
- 53% = Portion of reduced waste heat that results in cooling savings¹³¹
- COP_{COOL} = COP of central air conditioner
= Actual
- LM = Latent multiplier to account for latent cooling demand:¹³²

| Weather Basis (City based upon) | LM |
|---------------------------------|-----|
| St Louis, MO | 3.0 |

%Cool = Percentage of buildings with central cooling

| Home | %Cool |
|------------|-------|
| Cooling | 100% |
| No Cooling | 0% |

¹²⁸ Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061>

¹²⁹ This algorithm calculates the heat removed from the air by subtracting the heat pump water heater electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the heat pump unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling, and latent cooling demands.

¹³⁰ Professional judgment.

¹³¹ Based on 193 days where CDD 65>0, divided by 365.25. CDD days determined from TMY data with a base temp of 65°F.

¹³² The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEARResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

kWh_heat = Heating cost from conversion of heat in building to water heat (dependent on heating fuel)

$$= \left(\frac{\left(\left(1 - \frac{1}{EF_{EE}} \right) * HotWaterUse_{Gallon} * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 43\%}{COP_{HEAT} * 3412} \right) * \%ElectricHeat$$

Where:

43% = Portion of reduced waste heat that results in increased heating load¹³³

COP_{HEAT} = Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

%ElectricHeat = Percentage of buildings with electric heat

| Heating fuel | %ElectricHeat |
|--------------|---------------|
| Electric | 100% |
| Natural Gas | 0% |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001811545¹³⁴

NATURAL GAS SAVINGS

$$\Delta Therms = - \left(\frac{\left(\left(1 - \frac{1}{EF_{EE}} \right) * HotWaterUse_{Gallon} * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 53\%}{\eta_{Heat} * 100,000} \right) * \%GasHeat$$

Where:

ΔTherms = Heating cost from conversion of heat in building to water heat for buildings with natural gas heat¹³⁵

100,000 = Conversion factor from Btu to therms

ηHeat = Efficiency of heating system

¹³³ Based on 157 days where HDD 60>0, divided by 365.25. HDD days determined from TMY data with a base temp of 60°F.
¹³⁴ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Water Heating. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”
¹³⁵ This is the additional energy consumption required to replace the heat removed from the building during the heating season by the heat pump water heater. The variable kWh_heating (electric resistance) is that additional heating energy for a building with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance building to the MMBtu required in a natural gas heated building, applying the relative efficiencies.

= Actual
%GasHeat = Percentage of buildings with gas heat

| Heating Fuel | %GasHeat |
|--------------|----------|
| Electric | 0% |
| Gas | 100% |

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5 HVAC

Table: Effective Full Load Heating and Cooling Hours, by building type.

| Building Type | Whiteman AFB (Avg) | | Lincoln, NE (NW) | | Fort Madison, IA (NE) | | Kaiser (SW) | | Cape Girardeau (SE) | | St Louis | | Kansas City | |
|------------------------------|--------------------|--------------|------------------|--------------|-----------------------|--------------|--------------|--------------|---------------------|--------------|--------------|--------------|--------------|--------------|
| | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH |
| Large Office | 1039 | 1846 | 1141 | 1756 | 1088 | 1539 | 997 | 1918 | 861 | 1784 | 988 | 1869 | 1056 | 1792 |
| Medium Office | 649 | 1350 | 740 | 1245 | 728 | 1146 | 567 | 1412 | 528 | 1323 | 645 | 1386 | 708 | 1325 |
| Small Office | 946 | 1114 | 1030 | 1041 | 1029 | 975 | 926 | 1165 | 769 | 1082 | 893 | 1159 | 989 | 1097 |
| Warehouse | 991 | 415 | 1201 | 380 | 1227 | 357 | 1189 | 457 | 851 | 391 | 1059 | 433 | 1207 | 400 |
| Stand-alone Retail | 1012 | 1000 | 1125 | 903 | 1139 | 808 | 968 | 1076 | 891 | 965 | 994 | 986 | 1036 | 946 |
| Strip Mall | 1030 | 970 | 1124 | 884 | 1148 | 794 | 984 | 1044 | 905 | 944 | 1001 | 956 | 1039 | 916 |
| Primary School | 806 | 1019 | 892 | 958 | 898 | 852 | 798 | 1155 | 666 | 1016 | 785 | 1195 | 840 | 971 |
| Secondary School | 719 | 812 | 803 | 724 | 867 | 677 | 754 | 911 | 603 | 800 | 712 | 873 | 779 | 779 |
| Supermarket | 1279 | 875 | 1367 | 800 | 1405 | 672 | 1330 | 902 | 1120 | 837 | 1248 | 846 | 1344 | 820 |
| Quick Service Restaurant | 1233 | 1013 | 1414 | 916 | 1513 | 819 | 1316 | 1127 | 1025 | 973 | 1262 | 1035 | 1387 | 970 |
| Full Service Restaurant | 1367 | 1119 | 1499 | 1014 | 1655 | 952 | 1442 | 1234 | 1156 | 1114 | 1380 | 1124 | 1473 | 1059 |
| Hospital | 3388 | 3318 | 3205 | 3055 | 3467 | 2733 | 3891 | 3448 | 2913 | 3312 | 3170 | 3413 | 3372 | 3215 |
| Outpatient Health Care | 3203 | 3113 | 3261 | 2834 | 3150 | 2627 | 3128 | 3217 | 3001 | 3109 | 3013 | 3265 | 3164 | 2994 |
| Small Hotel - Building | 602 | 2247 | 697 | 2097 | 760 | 1914 | 620 | 2386 | 436 | 2304 | 575 | 2277 | 669 | 2207 |
| Large Hotel - Building | 1656 | 2148 | 1472 | 2016 | 1980 | 1916 | 1943 | 2369 | 1202 | 2186 | 1551 | 2363 | 1692 | 2155 |
| Midrise Apartment - Building | 1462 | 1132 | 1599 | 1028 | 1710 | 901 | 1590 | 1214 | 1208 | 1085 | 1433 | 1171 | 1580 | 1090 |
| C&I Average ¹³⁶ | 1067 | 1018 | 1196 | 937 | 1217 | 865 | 1118 | 1085 | 910 | 996 | 1060 | 1053 | 1164 | 986 |

¹³⁶ See Volume 1 for details on modeling calculations and assumptions.

2.5.1 Small Commercial Learning Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new programmable thermostat for reduced cooling and heating energy consumption through temperature set-back during unoccupied or reduced demand times as well as automatic adjustments based on occupancy patterns and various independent variables such as weather. This measure is limited to small businesses as defined by programs,¹³⁷ 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. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for learning thermostats installed in multi-zone systems.

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

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 set-points according to various independent variables without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature set-point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a learning thermostat is assumed to be 10 years¹³⁸ based upon equipment life only.¹³⁹

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be \$224.¹⁴⁰

LOADSHAPE

Cooling BUS

Heating BUS

¹³⁷ The square footage of the small office prototype building modeled in is 7,500 sf.

¹³⁸ Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

¹³⁹ 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.

¹⁴⁰ 2012Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{1}{eff} * EFLH_{COOL} * \frac{Btuh_{COOL}}{1000} * ESF_{COOL}$$

Where:

| | |
|----------------------|--|
| eff | = Efficiency of HVAC unit = Actual; If not available, assume 10 SEER |
| EFLH _{COOL} | = Effective Full Load Cooling Hours = Actual; If not available, refer to section 2.7 HVAC |
| Btuh _{COOL} | = Cooling System Capacity = Actual |
| ESF _{COOL} | = Cooling energy savings factor = Assume 0.139 ¹⁴¹ |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

| | |
|-----|---|
| kWh | = Electric energy savings, as calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0009106840 |

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{Sqft * Savings Factor * PF}{100 * AFUE(exist)}$$

Where:

| | |
|----------------|--|
| Sqft | = Square footage of building controlled by thermostat |
| AFUE (exist) | = Efficiency rating of existing heating equipment (AFUE), in decimal form. |
| 100 | = Converts kBtu to therms, 1 therm = 100 kBtu |
| Savings Factor | = 9.940 kBtu/sf-yr ¹⁴² |

¹⁴¹ Cadmus (Aarish, C., M. Perussi, A. Rietz, and D. Korn). *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program*. Prepared for Northern Indiana Public Service Company and Vectren Corporation. 2015.

¹⁴² Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (5,500 sf) and converted to kBtu.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.2 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new programmable thermostat for reduced heating and cooling energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs,¹⁴³ 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. 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 and 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 set-points according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature set-point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years¹⁴⁴ based upon equipment life only.¹⁴⁵

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be \$181.¹⁴⁶

LOADSHAPE

Cooling BUS

¹⁴³ The square footage of the small office prototype building modeled in is 7,500 sf.

¹⁴⁴ Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

¹⁴⁵ 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.

¹⁴⁶ Based upon Nicor, Illinois Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013. If Missouri average costs are available, they should be used.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{Sqft * Savings Factor * PF}{EER(exist)}$$

Where:

| | |
|----------------|---|
| Sqft | = Square footage of building controlled by thermostat |
| EER(exist) | = Efficiency rating of existing cooling equipment EER (btu hr/W) |
| Savings Factor | = 0.578 kWh/sf-yr ¹⁴⁷ |
| PF | = Persistence Factor to account for thermostat being placed on hold, reset or bypassed. |
| | = Actual if provided in program evaluation, else assume 50% ¹⁴⁸ |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

| | |
|-----|---|
| kWh | = Electric energy savings, as calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0009106840 |

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{Sqft * Savings Factor * PF}{100 * AFUE(exist)}$$

Where:

| | |
|--------------|--|
| Sqft | = Square footage of building controlled by thermostat |
| AFUE (exist) | = Efficiency rating of existing heating equipment (AFUE), in decimal form. |
| 100 | = Converts kBtu to therms, 1 therm = 100 kBtu |

¹⁴⁷ Cooling savings factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the small office prototype building (5,500 sf).

¹⁴⁸ This factor is based on consideration of the findings from a number of evaluations, including Sachs et al, "Field Evaluation of Programmable Thermostats," US DOE Building Technologies Program, December 2012, p35; "low proportion of households that ended up using thermostat-enabled energy saving settings"

http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/field_eval_thermostats.pdf20, and Meier et al, "Usability of residential thermostats: Preliminary investigations," Lawrence Berkeley National Laboratory, March 2011, p1; "The majority of occupants operated thermostats manually, rather than relying on their programmable features and almost 90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one on-line survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on "long term hold" (or its equivalent)." http://eec.ucdavis.edu/files/Usability_of_residential_thermostats.pdf

Savings Factor = 9.940 kBtu/sf-yr¹⁴⁹

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

¹⁴⁹ Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (5,500 sf) and converted to kBtu.

2.5.3 Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) automatically adjusts building ventilation rates based on occupancy. 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 modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new CO₂ sensors installed on return air systems where no other sensors were previously installed. Additionally, commissioned control logic and installed hardware must be capable of reducing ventilation rates based on sensor input. 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.¹⁵⁰

DEEMED MEASURE COST

As a retrofit measure, the actual cost of installation should be used for screening. Costs should include the hardware and labor costs to install the sensors. Additional purchase and installation costs for any other component of the DCV system that was not previously existing should also be included.

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas, cooling savings are:

$$\Delta\text{kWh} = \text{SQFT}_{\text{cond}}/1000 * \text{SF}_{\text{cooling}}$$

¹⁵⁰ Based on CO₂ sensor estimated life, determined through conversations with contractors to have a minimum lifetime of 10 years. It is recommended that they are part of a normal preventive maintenance program, as calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they can fall out of tolerance over time.

For facilities heated by heat pumps, heating and cooling savings are:

$$\Delta kWh = SQFT_{cond}/1000 * SF_{cooling} + SQFT_{cond}/1000 * SF_{Heat HP}$$

For facilities heated by electric resistance heating and cooling savings are:

$$\Delta kWh = SQFT_{cond}/1000 * SF_{cooling} + SQFT_{cond}/1000 * SF_{Heat ER}$$

Where:

- SQFT_{cond} = Square footage of conditioned space commissioned with DCV
- SF_{cooling} = Cooling Savings Factor, including cooling and fan energy savings
- SF_{Heat HP} = Heating Savings factor for facilities heated by Heat Pump (HP)
- SF_{Heat ER} = Heating Savings factor for facilities heated by Electric Resistance (ER)

All Savings Factors are based on building type and weather zone, as listed in the following tables:¹⁵¹

| Building Type | SF _{cooling} (kWh/1000 SqFt) | | | | | | |
|-----------------------------|---------------------------------------|--------------------------|---------------------------------|-------------------------|--------------|-----------------|-----------------------------------|
| | North East (Fort Madison, IA) | North West (Lincoln, NE) | South East (Cape Girardeau, MO) | South West (Kaiser, MO) | St Louis, MO | Kansas City, MO | Average/Unknown (Knob Noster, MO) |
| Office - Low-rise | 475 | 533 | 535 | 634 | 649 | 555 | 579 |
| Office - Mid-rise | 448 | 502 | 504 | 597 | 611 | 523 | 545 |
| Office - High-rise | 468 | 525 | 527 | 624 | 639 | 547 | 570 |
| Religious Building | 567 | 635 | 639 | 756 | 774 | 662 | 690 |
| Restaurant | 561 | 629 | 632 | 748 | 765 | 655 | 683 |
| Retail - Department Store | 654 | 734 | 737 | 873 | 893 | 764 | 797 |
| Retail - Strip Mall | 399 | 447 | 449 | 532 | 544 | 466 | 486 |
| Convenience Store | 631 | 708 | 711 | 842 | 862 | 737 | 769 |
| Elementary School | 353 | 395 | 397 | 470 | 481 | 412 | 430 |
| High School | 340 | 382 | 384 | 454 | 465 | 398 | 415 |
| College/University | 442 | 495 | 498 | 589 | 603 | 516 | 538 |
| Healthcare Clinic | 384 | 431 | 433 | 513 | 525 | 449 | 468 |
| lodging | 605 | 679 | 682 | 808 | 827 | 707 | 738 |
| Manufacturing | 500 | 560 | 563 | 666 | 682 | 584 | 609 |
| Special Assembly Auditorium | 476 | 534 | 536 | 635 | 650 | 556 | 580 |

| Building Type | SF _{Heat HP} (kWh/1000 SqFt) | | | | | | |
|--------------------|---------------------------------------|--------------------------|---------------------------------|-------------------------|--------------|-----------------|-----------------------------------|
| | North East (Fort Madison, IA) | North West (Lincoln, NE) | South East (Cape Girardeau, MO) | South West (Kaiser, MO) | St Louis, MO | Kansas City, MO | Average/Unknown (Knob Noster, MO) |
| Office - Low-rise | 171 | 191 | 145 | 151 | 156 | 176 | 159 |
| Office - Mid-rise | 114 | 128 | 97 | 100 | 104 | 117 | 106 |
| Office - High-rise | 154 | 172 | 130 | 135 | 140 | 158 | 143 |
| Religious Building | 1,118 | 1,248 | 945 | 983 | 1,018 | 1,149 | 1,036 |
| Restaurant | 799 | 892 | 675 | 702 | 727 | 821 | 740 |

¹⁵¹ Energy savings factors were calculated using weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given weather zone in Missouri. Original energy savings for DCV were developed for Illinois utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1. These savings factors were then translated into Missouri-specific values using adjustment factors based on differences in heating and cooling degree hours. See DCV savings factors v1.xlsx for derivation.

| Building Type | SF _{Heat HP} (kWh/1000 SqFt) | | | | | | |
|--------------------------------|--|-----------------------------------|--|-------------------------------|-----------------|-----------------------|---|
| | North East (Fort Madison, IA) | North West (Lincoln, NE) | South East (Cape Girardeau, MO) | South West (Kaiser, MO) | St Louis, MO | Kansas City, MO | Average/Un known (Knob Noster, MO) |
| Retail - Department Store | 277 | 310 | 234 | 244 | 252 | 285 | 257 |
| Retail - Strip Mall | 184 | 205 | 155 | 161 | 167 | 189 | 170 |
| Convenience Store | 134 | 150 | 114 | 118 | 122 | 138 | 125 |
| Elementary School | 475 | 531 | 402 | 418 | 433 | 488 | 440 |
| High School | 465 | 519 | 393 | 409 | 423 | 478 | 431 |
| College/University | 923 | 1,031 | 780 | 812 | 840 | 949 | 856 |
| Healthcare Clinic | 331 | 370 | 280 | 291 | 301 | 340 | 307 |
| lodging | 157 | 175 | 132 | 138 | 143 | 161 | 145 |
| Manufacturing | 122 | 136 | 103 | 107 | 111 | 125 | 113 |
| Special Assembly Auditorium | 1,335 | 1,490 | 1,128 | 1,173 | 1,215 | 1,371 | 1,236 |

| Building Type | SF _{Heat ER} (kWh/1000 SqFt) | | | | | | |
|--------------------------------|--|--------------------------------|--|-------------------------------|-----------------|-----------------------|--|
| | North East (Fort Madison, IA) | North West (Lincoln, NE) | South East (Cape Girardeau, MO) | South West (Kaiser, MO) | St Louis, MO | Kansas City, MO | Average/Unk nown (Knob Noster, MO) |
| Office - Low-rise | 514 | 574 | 434 | 452 | 468 | 528 | 476 |
| Office - Mid-rise | 343 | 383 | 290 | 301 | 312 | 352 | 318 |
| Office - High-rise | 461 | 515 | 390 | 406 | 420 | 474 | 428 |
| Religious Building | 3,354 | 3,744 | 2,835 | 2,948 | 3,053 | 3,446 | 3,108 |
| Restaurant | 2,396 | 2,675 | 2,025 | 2,106 | 2,181 | 2,462 | 2,220 |
| Retail - Department Store | 832 | 929 | 703 | 731 | 757 | 855 | 771 |
| Retail - Strip Mall | 551 | 615 | 465 | 484 | 501 | 566 | 510 |
| Convenience Store | 403 | 450 | 341 | 354 | 367 | 414 | 374 |
| Elementary School | 1,426 | 1,592 | 1,205 | 1,253 | 1,298 | 1,465 | 1,321 |
| High School | 1,395 | 1,557 | 1,179 | 1,226 | 1,270 | 1,433 | 1,292 |
| College/University | 2,770 | 3,093 | 2,341 | 2,435 | 2,521 | 2,846 | 2,567 |
| Healthcare Clinic | 993 | 1,109 | 839 | 873 | 904 | 1,020 | 920 |
| lodging | 470 | 525 | 397 | 413 | 428 | 483 | 436 |
| Manufacturing | 365 | 408 | 309 | 321 | 332 | 375 | 338 |
| Special Assembly Auditorium | 4,004 | 4,470 | 3,384 | 3,519 | 3,644 | 4,114 | 3,709 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh_{cooling} * CF$$

Where:

kWh_{cooling} = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840

NATURAL GAS SAVINGS

$$\Delta Therms = SQFT_{cond}/1000 * SF_{Heat Gas}$$

Where:

$SF_{Heat\ Gas}$ = Savings factor for facilities heated by natural gas, as listed in the following table:

| Building Type | $SF_{Heat\ Gas}$ (Therm/1000 sq ft) | | | | | | |
|-----------------------------|-------------------------------------|--------------------------|---------------------------------|-------------------------|--------------|-----------------|-----------------------------------|
| | North East (Fort Madison, IA) | North West (Lincoln, NE) | South East (Cape Girardeau, MO) | South West (Kaiser, MO) | St Louis, MO | Kansas City, MO | Average/Unknown (Knob Noster, MO) |
| Office - Low-rise | 22 | 24 | 19 | 19 | 20 | 23 | 20 |
| Office - Mid-rise | 15 | 16 | 12 | 13 | 13 | 15 | 14 |
| Office - High-rise | 20 | 22 | 17 | 17 | 18 | 20 | 18 |
| Religious Building | 143 | 160 | 121 | 126 | 130 | 147 | 133 |
| Restaurant | 102 | 114 | 86 | 90 | 93 | 105 | 95 |
| Retail - Department Store | 35 | 40 | 30 | 31 | 32 | 36 | 33 |
| Retail - Strip Mall | 23 | 26 | 20 | 21 | 21 | 24 | 22 |
| Convenience Store | 17 | 19 | 15 | 15 | 16 | 18 | 16 |
| Elementary School | 61 | 68 | 51 | 53 | 55 | 62 | 56 |
| High School | 60 | 66 | 50 | 52 | 54 | 61 | 55 |
| College/University | 118 | 132 | 100 | 104 | 108 | 121 | 109 |
| Healthcare Clinic | 42 | 47 | 36 | 37 | 39 | 44 | 39 |
| lodging | 20 | 22 | 17 | 18 | 18 | 21 | 19 |
| Manufacturing | 16 | 17 | 13 | 14 | 14 | 16 | 14 |
| Special Assembly Auditorium | 171 | 191 | 144 | 150 | 155 | 175 | 158 |

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.4 Advanced Roof Top Unit (RTU) Controls

DESCRIPTION

A traditional packaged HVAC rooftop unit uses a zone thermostat to control the operation of the compressor or the gas furnace, depending on whether the zone thermostat is calling for cooling or heating. Under a conventional control scheme, the compressor or furnace is cycled on or off to maintain the zone thermostat set point with the supply fan operating continuously (when the building is occupied) to provide sufficient ventilation air and provide comfort heating and cooling for the space. The supply-fan speed is typically not capable of modulation, so it supplies constant air volume under all modes of operations.

Modulating the supply fan in conjunction with demand-controlled ventilation (DCV) can reduce both heating/cooling energy and fan energy requirements. This measure describes the energy savings realized by retrofitting traditional RTUs with advanced controllers that enable integrated air-side economization, supply-fan speed control (by installing a variable speed drive), and demand-controlled ventilation.

This measure is applicable to the following program type: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

A traditional RTU retrofitted and commissioned with advanced controls that allow for modulation of supply fan speed in conjunction with demand-controlled ventilation (DCV).

DEFINITION OF BASELINE EQUIPMENT

Packaged heating and cooling equipment with constant speed supply fans providing ventilation at the design rate at all times when the fan is operating and when the building is occupied.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.¹⁵²

DEEMED MEASURE COST

As a retrofit measure, actual costs should be specified when available. Default measure costs are listed below based on RTU supply fan horsepower rating:¹⁵³

| Supply Fan ¹⁵⁴ Size (hp) | Controller | Installation Labor | Total Retrofit Cost |
|-------------------------------------|------------|--------------------|---------------------|
| 1 | \$2,200 | \$750 | \$2,950 |
| 2 | \$2,600 | \$750 | \$3,350 |
| 3 | \$3,500 | \$750 | \$4,250 |
| 5 | \$4,000 | \$750 | \$4,750 |
| 7.5 | \$4,142 | \$750 | \$4,892 |

¹⁵² Consistent with other HVAC variable speed drive lifetimes.

¹⁵³ Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656. U.S. Department of Energy, July 2013.

¹⁵⁴ Interpolation may be used to estimate controller cost for motor sizes not listed.

LOADSHAPE**HVAC BUS Algorithm****CALCULATION OF SAVINGS**

Although advanced RTUs controls can enable operating strategies that result in heating and cooling savings, field testing has shown variable results (in some instances increased heating/cooling energy consumption has been observed). Field testing has suggested that upwards of 90% of total energy savings can be attributed to reduced fan energy requirements, and therefore the following savings estimates are limited to those relating to fan energy consumption.

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = P_{sf} * SF * \text{Hours}_{fan}$$

Where:

P_{sf} = Nominal horsepower of supply fan motor

SF = Fan energy savings factor¹⁵⁵ (kWh/hour/horsepower)
= 0.558

Hours_{fan} = Annual operating hours for fan motor based on building type.

Default hours are provided for HVAC applications which vary by building type.¹⁵⁶ When available, actual hours should be used, especially in instances where RTU operation is seasonal.

| Building Type | Total Fan Run Hours |
|----------------------------|---------------------|
| Large Office | 6753 |
| Medium Office | 6968 |
| Small Office | 6626 |
| Warehouse | 6263 |
| Stand-alone Retail | 6679 |
| Strip Mall | 6687 |
| Primary School | 5906 |
| Secondary School | 6702 |
| Supermarket | 6900 |
| Quick Service Restaurant | 7679 |
| Full Service Restaurant | 7664 |
| Hospital | 8760 |
| Outpatient Health Care | 8760 |
| Small Hotel - Building | 8760 |
| Large Hotel - Building | 8760 |
| Midrise Apartment Building | 8728 |
| Nonresidential Average | 6773 |

¹⁵⁵ Based on average field testing results outlined in Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656. U.S. Department of Energy, July 2013. Savings factors were consistent across the capacity range. See “RTU Control Savings.xlsx” for additional details.

¹⁵⁶ Hours per year are estimated using the modeling results and represent the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = As calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004439830

NATURAL GAS ENERGY SAVINGS

If fossil fuel impacts are expected, a custom analysis should be used to support them.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.5 Electric Chiller

DESCRIPTION

This measure involves 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), for which a custom analysis should be used to establish savings.

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 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 set forth by local jurisdictions. In most cases, this will be some version of International Energy Conservation Code (IECC). Depending on the version, this will correspond to the requirements defined within Table 503.2.3(7) in the case of IECC 2009 or Table 403.2.3(7) in the case of either IECC 2012 or the IECC 2015.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.¹⁵⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$106.23 per ton.¹⁵⁸

| Water cooled, electrically operated, positive displacement (rotary screw and scroll) (\$/ton) | | | | |
|---|--------------|----------------------|----------------------|---------------------|
| Capacity (tons) | > .72 kW/ton | .72 and > .68 kW/ton | .68 and > .64 kW/ton | .64 kW/ton and less |
| < 50 | \$76 | \$126 | n/a | n/a |
| >= 50 and <100 | \$38 | \$63 | n/a | n/a |
| >= 100 and <150 | \$25 | \$42 | n/a | n/a |
| >= 150 and <200 | \$0 | \$61 | \$122 | \$183 |
| >= 200 | \$0 | \$31 | \$61 | \$92 |

| Water cooled, electrically operated, positive displacement (reciprocating) (\$/ton) | | | |
|---|--------------|----------------------|---------------------|
| Capacity (tons) | > .60 kW/ton | .60 and > .58 kW/ton | .58 kw/ton and less |
| | | | |

¹⁵⁷ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values,” California Public Utilities Commission, December 16, 2008.

¹⁵⁸ Ameren Missouri Technical Resource Manual Effective January 1, 2018.

| Water cooled, electrically operated, positive displacement (reciprocating) (\$/ton) | | | |
|---|------|-------|-------|
| < 100 | \$73 | \$110 | \$183 |
| >= 100 and <150 | \$49 | \$73 | \$122 |
| >= 150 and <200 | \$37 | \$55 | \$92 |
| >= 200 and <300 | \$61 | \$91 | \$152 |
| >= 300 | \$30 | \$46 | \$76 |

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWH = TONS * ((IPLV_{base}) - (IPLV_{ee})) * EFLH$$

Where:

- TONS = Chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)
= Actual installed
- IPLV_{base} = Efficiency of baseline equipment expressed as Integrated Part Load Value(kW/ton). Chiller units are dependent on chiller type. See ‘Chiller Units, Conversion Values’ and ‘Baseline Efficiency Values by Chiller Type’ and Capacity in the Reference Tables section.
- IPLV_{ee}¹⁵⁹ = Efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)¹⁶⁰
= Actual installed
- EFLH = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWH * CF$$

Where:

- ΔkWH = Annual electricity savings, as calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

¹⁵⁹ 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, it is expressed in terms of IPLV here.

¹⁶⁰ 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/>.

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

Baseline Efficiency Values by Chiller Type and Capacity:

Note: Efficiency requirements depend on the path (Path A or Path B) that the building owner has chosen to meet compliance requirements. For air cooled and absorption chillers, Path A should be assumed. For water cooled chillers, the building owner should be consulted and the relevant path used for calculations. When unknown, Path A should be used.

2009 IECC Baseline Efficiency Values by Chiller Type and Capacity

**TABLE 503.2.3(7)
WATER CHILLING PACKAGES, EFFICIENCY REQUIREMENTS***

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 | | AS OF 1/1/2010 ^c | | | | TEST PROCEDURE ^b |
|--|---------------------------|--------|-----------------|----------|--|----------|-----------|---------|-----------------------------|
| | | | FULL LOAD | IPLV | PATH A | | PATH B | | |
| | | | | | FULL LOAD | IPLV | FULL LOAD | IPLV | |
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.416 | ≥ 9.562 | ≥ 12.500 | NAd | NAd | AHRI 550/590 |
| | ≥ 150 tons | EER | | | ≥ 9.562 | ≥ 12.750 | NAd | NAd | |
| Air cooled without condenser, electrical operated | All capacities | EER | ≥ 10.586 | ≥ 11.782 | Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements | | | | |
| Water cooled, electrically operated, reciprocating | All capacities | kW/ton | ≤ 0.837 | ≤ 0.696 | Reciprocating units must comply with water cooled positive displacement efficiency requirements | | | | |
| Water cooled, electrically operated, positive displacement | < 75 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | |
| | ≥ 75 tons and < 150 tons | kW/ton | | | ≤ 0.775 | ≤ 0.615 | ≤ 0.790 | ≤ 0.586 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.717 | ≤ 0.627 | ≤ 0.680 | ≤ 0.580 | ≤ 0.718 | ≤ 0.540 | |
| | ≥ 300 tons | kW/ton | ≤ 0.639 | ≤ 0.571 | ≤ 0.620 | ≤ 0.540 | ≤ 0.639 | ≤ 0.490 | |
| Water cooled, electrically operated, centrifugal | < 150 tons | kW/ton | ≤ 0.703 | ≤ 0.669 | ≤ 0.634 | ≤ 0.596 | ≤ 0.639 | ≤ 0.450 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.634 | ≤ 0.596 | | | | | |
| | ≥ 300 tons and < 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.576 | ≤ 0.549 | ≤ 0.600 | ≤ 0.400 | |
| | ≥ 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.570 | ≤ 0.539 | ≤ 0.590 | ≤ 0.400 | |
| Air cooled, absorption single effect | All capacities | COP | ≥ 0.600 | NRe | ≥ 0.600 | NRe | NAd | NAd | AHRI560 |
| Water-cooled, absorption single effect | All capacities | COP | ≥ 0.700 | NRe | ≥ 0.700 | NRe | NAd | NAd | |
| Absorption double effect, indirect-fired | All capacities | COP | ≥ 1.000 | ≥ 1.050 | ≥ 1.000 | ≥ 1.050 | NAd | NAd | |
| Absorption double effect, direct fired | All capacities | COP | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | NAd | NAd | |

For SI: 1 ton = 907 kg, 1 British thermal unit per hour = 0.2931 W

- a. The chiller equipment requirements do not apply for chillers used in ICMT-temperature applications where the design leaving fluid temperature is < 40°F.
- b. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- c. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.
- d. NA means that this requirement is not applicable and cannot be used for compliance.

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity

**TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS:
WATER CHILLING PACKAGES***

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 | | AS OF 1/1/2010 ^b | | | | TEST PROCEDURE ^c |
|--|---------------------------|--------|-----------------|----------|---|----------|-----------|---------|-----------------------------|
| | | | FULL LOAD | IPLV | PATH A | | PATH B | | |
| | | | | | FULL LOAD | IPLV | FULL LOAD | IPLV | |
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.4 | ≥ 9.562 | ≥ 12.500 | NA | NA | AHRI 550/590 |
| | ≥ 150 tons | EER | | 16 | ≥ 9.562 | ≥ 12.750 | NA | NA | |
| Air cooled without condenser, electrical operated | All capacities | EER | ≥ 10.586 | ≥ 11.782 | Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements | | | | |
| Water cooled, electrically operated, reciprocating | All capacities | kW/ton | ≤ 0.837 | ≤ 0.696 | Reciprocating units shall comply with water cooled positive displacement efficiency requirements | | | | |
| Water cooled, electrically operated, positive displacement | < 75 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | |
| | ≥ 75 tons and < 150 tons | kW/ton | | | ≤ 0.775 | ≤ 0.615 | ≤ 0.790 | ≤ 0.586 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.717 | ≤ 0.627 | ≤ 0.680 | ≤ 0.580 | ≤ 0.718 | ≤ 0.540 | |
| | ≥ 300 tons | kW/ton | ≤ 0.639 | ≤ 0.571 | ≤ 0.620 | ≤ 0.540 | ≤ 0.639 | ≤ 0.490 | |
| Water cooled, electrically operated, centrifugal | < 150 tons | kW/ton | ≤ 0.703 | ≤ 0.669 | ≤ 0.634 | ≤ 0.596 | ≤ 0.639 | ≤ 0.450 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.634 | ≤ 0.596 | | | | | |
| | ≥ 300 tons and < 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.576 | ≤ 0.549 | ≤ 0.600 | ≤ 0.400 | |
| | ≥ 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.570 | ≤ 0.539 | ≤ 0.590 | ≤ 0.400 | |
| Air cooled, absorption single effect | All capacities | COP | ≥ 0.600 | NR | ≥ 0.600 | NR | NA | NA | AHRI 560 |
| Water cooled, absorption single effect | All capacities | COP | ≥ 0.700 | NR | ≥ 0.700 | NR | NA | NA | |
| Absorption double effect, indirect fired | All capacities | COP | ≥ 1.000 | ≥ 1.050 | ≥ 1.000 | ≥ 1.050 | NA | NA | |
| Absorption double effect, direct fired | All capacities | COP | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | NA | NA | |

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

NA = Not applicable, not to be used for compliance; NR = No requirement.

- a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
- b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
- c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.2.3(7)
WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS^{a, b, d}

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2015 | | AS OF 1/1/2015 | | TEST PROCEDURE ^c | |
|---|---------------------------|-------------|--|-----------------|----------------|-----------------|-----------------------------|--------------|
| | | | Path A | Path B | Path A | Path B | | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA ^c | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 | |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15.800 IPLV | | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA ^c | ≥ 10.100 FL | ≥ 9.700 FL | | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | | AHRI 550/590 |
| | | | ≤ 0.630 IPLV | ≤ 0.600 IPLV | ≤ 0.600 IPLV | ≤ 0.500 IPLV | | |
| | ≥ 75 tons and < 150 tons | | ≤ 0.775 FL | ≤ 0.790 FL | ≤ 0.720 FL | ≤ 0.750 FL | | |
| | | | ≤ 0.615 IPLV | ≤ 0.586 IPLV | ≤ 0.560 IPLV | ≤ 0.490 IPLV | | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.680 FL | ≤ 0.718 FL | ≤ 0.660 FL | ≤ 0.680 FL | | |
| | | | ≤ 0.580 IPLV | ≤ 0.540 IPLV | ≤ 0.540 IPLV | ≤ 0.440 IPLV | | |
| | ≥ 300 tons and < 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.625 FL | | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.520 IPLV | ≤ 0.410 IPLV | | |
| | ≥ 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.560 FL | ≤ 0.585 FL | | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | | |
| Water cooled, electrically operated centrifugal | < 150 Tons | kW/ton | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.695 FL | AHRI 560 | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA ^c | ≥ 0.600 FL | NA ^c | AHRI 560 | |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA ^c | ≥ 0.700 FL | NA ^c | | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA ^c | ≥ 1.000 FL | NA ^c | | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA ^c | ≥ 1.000 FL | NA ^c | | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | | |

- a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
- b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.
- c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.
- d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

MEASURE CODE:

2.5.6 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 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 high-efficiency air-cooled, water source, ground water source, or ground source heat pump system that exceeds the energy efficiency requirements specified by the building code applicable to local jurisdiction. This may be a version of the 2009, 2012 or 2015 International Energy Conservation Code (IECC) or ASHRAE 90.1 standard.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-cooled, water source, ground water source, or ground source heat pump system that meets the energy efficiency requirements of local building code. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.¹⁶¹

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for this measure is assumed as \$100 per ton for air-cooled units.¹⁶² The incremental cost for all other equipment types should be determined on a site-specific basis.

LOADSHAPE

Cooling BUS Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{SEER}_{\text{base}}) - (1/\text{SEER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBtu/hr}_{\text{heat}}) * [(1/\text{HSPF}_{\text{base}}) - (1/\text{HSPF}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

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

¹⁶¹Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

¹⁶² Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.

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

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}}$$

Where:

| | |
|--------------------------------|---|
| $\text{kBtu/hr}_{\text{cool}}$ | = Capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr). = Actual installed |
| $\text{SEER}_{\text{base}}$ | = Seasonal Energy Efficiency Ratio of the baseline equipment = SEER from tables below, if applicable code is based on IECC, or custom input as necessary. |
| SEER_{ee} | = Seasonal Energy Efficiency Ratio of the energy efficient equipment. = Actual installed |
| $\text{EFLH}_{\text{cool}}$ | = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use. |
| $\text{HSPF}_{\text{base}}$ | = Heating Seasonal Performance Factor of the baseline equipment = HSPF from tables below, if applicable code is based on IECC, or custom input as necessary. |
| HSPF_{ee} | = Heating Seasonal Performance Factor of the energy efficient equipment. = Actual installed. If rating is COP, $\text{HSPF} = \text{COP} * 3.413$ |
| $\text{EFLH}_{\text{heat}}$ | = Heating mode equivalent full load hours are provided in section 2.7 HVAC End Use. |
| EER_{base} | = Energy Efficiency Ratio of the baseline equipment = EER from tables below, based on the applicable IECC. For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings: ¹⁶³ |
| | $\text{EER} = (-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ |
| EER_{ee} | = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EER_{ee} is unknown, assume the conversion from SEER to EER as provided above. = Actual installed |
| $\text{kBtu/hr}_{\text{heat}}$ | = Capacity of the heating equipment in kBtu per hour. = Actual installed |
| 3.412 | = Btu per Wh. |
| COP_{base} | = Coefficient of performance of the baseline equipment |

¹⁶³ 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.

= COP from tables below, based on the applicable IECC. If rating is HSPF, COP
= HSPF / 3.413

COP_{ee} = Coefficient of performance of the energy efficient equipment.
= Actual installed

Minimum Efficiency Requirements: 2009 IECC

TABLE 503.2.3(2)
UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

| EQUIPMENT TYPE | SIZE CATEGORY | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|---|--|---|---|-----------------------------|
| Air cooled, (Cooling mode) | < 65,000 Btu/h ^d | Split system | 13.0 SEER | AHRI210/240 |
| | | Single package | 13.0 SEER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 10.1 EER _c (before Jan 1, 2010) 11.0 EER _c (as of Jan 1, 2010) | AHRI 340/360 |
| | | Split system and single package | 9.3 EER _c (before Jan 1, 2010) 10.6 EER _c (as of Jan 1, 2010) | |
| ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.0 EER _c 9.2 IPLY _c (before Jan 1, 2010) 9.5 EER _c 9.2 IPLY _c (as of Jan 1, 2010) | AHRI 340/360 | |
| | Split system and single package | 9.0 EER _c 9.2 IPLY _c (before Jan 1, 2010) 9.5 EER _c 9.2 IPLY _c (as of Jan 1, 2010) | | |
| Through-the-Wall (Air cooled, cooling mode) | < 30,000 Btu/h ^d | Split system | 10.9 SEER (before Jan 23, 2010) 12.0 SEER (as of Jan 23, 2010) | AHRI210/240 |
| | | Single package | 10.6 SEER (before Jan 23, 2010) 12.0 SEER (as of Jan 23, 2010) | |
| Water Source (Cooling mode) | < 17,000 Btu/h | 86°F entering water | 11.2 EER | AHRI/ASHRAE 13256-1 |
| | ≥ 17,000 Btu/h and < 135,000 Btu/h | 86°F entering water | 12.0 EER | AHRI/ASHRAE 13256-1 |
| Groundwater Source (Cooling mode) | < 135,000 Btu/h | 59°F entering water | 16.2 EER | AHRI/ASHRAE 13256-1 |
| Ground source (Cooling mode) | < 135,000 Btu/h | 77°F entering water | 13.4 EER | AHRI/ASHRAE 13256-1 |
| Air cooled (Heating mode) | < 65,000 Btu/h ^d (Cooling capacity) | Split system | 7.7 HSPF | AHRI210/240 |
| | | Single package | 7.7 HSPF | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling capacity) | 47°F db/43°F wb Outdoor air | 3.2 COP (before Jan 1, 2010) 3.3 COP (as of Jan 1, 2010) | AHRI 340/360 |
| ≥ 135,000 Btu/h (Cooling capacity) | 47°F db/43°F wb Outdoor air | 3.1 COP (before Jan 1, 2010) 3.2 COP (as of Jan 1, 2010) | | |

**TABLE 503.2.3(2)-continued
UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS**

| EQUIPMENT TYPE | SIZE CATEGORY | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|--|---------------------------------------|---------------------------------|---|-----------------------------|
| Through-the-wall (Air cooled, heating mode) | < 30,000 Btu/h | Split System | 7.1 HSPE (before Jan 23, 2010) 7.4 HSPF (as of Jan 23, 2010) | AHRI210/240 |
| | | Single package | 7.0 HSPF (before Jan 23, 2010) 7.4 HSPF (as of Jan 23, 2010) | |
| Water source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 68°F entering water | 4.2 COP | AHRI/ASHRAE 13256-1 |
| Groundwater source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 50°F entering water | 3.6 COP | AHRI/ASHRAE 13256-1 |
| Ground source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 32°F entering water | 3.1 COP | AHRI/ASHRAE 13256-1 |

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

db = dry-bulb temperature, of, wb = wet-bulb temperature, of.

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

b. IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.

c. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

d. Single-phase air-cooled heat pumps < 65,000 Btu/h are regulated by the National Appliance Energy Conservation Act of 1987 (NAECA), SEER and HSPF values are those set by NAECA.

Minimum Efficiency Requirements: 2012 IECC

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

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE* |
|---|--|-------------------------------|---------------------------------|-----------------------|-----------------|
| Air cooled (cooling mode) | < 65,000 Btu/h ^b | All | Split System | 13.0 SEER | AHRI 210/240 |
| | | | Single Packaged | 13.0 SEER | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h ^b | All | Split System | 13.0 SEER | |
| | | | Single Packaged | 13.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h ^b | All | Split System | 10.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER 10.7 IEER | |
| | | All other | Split System and Single Package | 10.4 EER 10.5 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER 9.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER 9.4 IEER | |
| Water source (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 11.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 12.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 12.0 EER | |
| Ground water source (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.2 EER | |
| | | All | 77°F entering water | 13.4 EER | |
| Water-source water to water (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | ISO 13256-2 |
| | | | 59°F entering water | 16.3 EER | |
| Ground water source Brine to water (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | |
| Air cooled (heating mode) | < 65,000 Btu/h ^b | — | Split System | 7.7 HSPF | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h ^b (cooling capacity) | — | Split System | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h ^b | — | Split System | 6.8 HSPF | |

(continued)

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

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

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

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

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

Minimum Efficiency Requirements: 2015 IECC

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

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE* |
|---|-------------------------------------|-------------------------------|---------------------------------|------------------------|------------------------|-----------------|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (cooling mode) | < 65,000 Btu/h ^b | All | Split System | 13.0 SEER ^c | 14.0 SEER ^c | AHRI 210/240 |
| | | | Single Package | 13.0 SEER ^c | 14.0 SEER ^c | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h ^b | All | Split System | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h ^b | All | Split System | 11.0 SEER | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 12.0 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 10.8 EER 11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER 10.7 IEER | 10.6 EER 11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER 10.5 IEER | 10.4 EER 11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER 9.6 IEER | 9.5 EER 10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER 9.4 IEER | 9.3 EER 9.4 IEER | |
| Water to Air: Water Loop (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 12.2 EER | 12.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| Water to Air: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 18.0 EER | 18.0 EER | ISO 13256-1 |
| Brine to Air: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering water | 14.1 EER | 14.1 EER | ISO 13256-1 |
| Water to Water: WaterLoop (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | 10.6 EER | ISO 13256-2 |
| Water to Water: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.3 EER | 16.3 EER | |
| Brine to Water: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | 12.1 EER | |

(continued)

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

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE ^a |
|---|---|----------------------|---------------------------------|-----------------------|-----------------------|-----------------------------|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (heating mode) | < 65,000 Btu/h ^b | — | Split System | 7.7 HSPF ^c | 8.2 HSPF ^c | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF ^c | 8.0 HSPF ^c | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h ^b (cooling capacity) | — | Split System | 7.4 HSPF | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h ^b | — | Split System | 6.8 HSPF | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | 3.3 COP | |
| | | | 17°F db/15°F wb outdoor air | 2.25 COP | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | 3.2 COP | |
| | | | 17°F db/15°F wb outdoor air | 2.05 COP | 2.05 COP | |
| Water to Air: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.3 COP | 4.3 COP | ISO 13256-1 |
| Water to Air: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.7 COP | 3.7 COP | |
| Brine to Air: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.2 COP | 3.2 COP | |
| Water to Water: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | 3.7 COP | ISO 13256-2 |
| Water to Water: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.1 COP | 3.1 COP | |
| Brine to Water: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | 2.5 COP | |

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

- a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.
- c. Minimum efficiency as of January 1, 2015.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{Cool} * CF$$

Where:

ΔkWh = Annual cooling electricity savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.7 Packaged Terminal Air Conditioner (PTAC) and Packaged Terminal Heat Pump (PTHP)

DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and 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 a space and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into a space, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

- a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
- b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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

TOS: the baseline conditions is provided in the Federal Baseline reference table provided below.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.¹⁶⁴

Remaining life of existing equipment is assumed to be 5 years.¹⁶⁵

DEEMED MEASURE COST

TOS: The incremental capital cost for this equipment is estimated to be \$84/ton.¹⁶⁶

EREP: 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.¹⁶⁷

¹⁶⁴ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

¹⁶⁵ Standard assumption of one third of effective useful life.

¹⁶⁶ DEER 2008. This assumes that baseline shifts between IECC versions carries the same incremental costs. Values should be verified during evaluation

¹⁶⁷ Based on DCEO – IL PHA Efficient Living Program data.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be \$1,039 per ton.¹⁶⁸ This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

ENERGY SAVINGS

TOS:

$$\begin{aligned} \text{PTAC } \Delta \text{kWh}^{169} &= \text{Annual kWh Savings}_{\text{cool}} \\ \text{PTHP } \Delta \text{kWh} &= \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}} \\ \text{Annual kWh Savings}_{\text{cool}} &= (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}} \\ \text{Annual kWh Savings}_{\text{heat}} &= (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}} \end{aligned}$$

EREP:

$$\Delta \text{kWh for remaining life of existing unit (1}^{\text{st}} \text{ 5years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\begin{aligned} \text{Annual kWh Savings}_{\text{cool}} &= (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{exist}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}} \\ \text{Annual kWh Savings}_{\text{heat}} &= (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{exist}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}} \end{aligned}$$

$$\Delta \text{kWh for remaining measure life (next 10 years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\begin{aligned} \text{Annual kWh Savings}_{\text{cool}} &= (\text{kBtu/hr}_{\text{cool}}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}_{\text{cool}} \\ \text{Annual kWh Savings}_{\text{heat}} &= (\text{kBtu/hr}_{\text{heat}})/3.412 * [(1/\text{COP}_{\text{base}}) - (1/\text{COP}_{\text{ee}})] * \text{EFLH}_{\text{heat}} \end{aligned}$$

Where:

$\text{kBtu/hr}_{\text{cool}}$ = Capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

$\text{EFLH}_{\text{cool}}$ = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use:

$\text{EFLH}_{\text{heat}}$ = Equivalent Full Load Hours for heating are provided in section 2.7 HVAC End Use

$\text{EER}_{\text{exist}}$ = Energy Efficiency Ratio of the existing equipment

¹⁶⁸ Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

¹⁶⁹ 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.

= Actual. If unknown assume 8.1 EER¹⁷⁰

EERbase = Energy Efficiency Ratio of the baseline equipment.

= See the table below for requirements where local code is based on IECC. Content is based on tables 503.3.3(3) (IECC 2009) and C403.2.3(3) (IECC 2012, 2015): Minimum Efficiency Requirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps. An alternate, custom input may be necessary for jurisdictions recognizing alternative code.

| Equipment Type | IECC 2009 Minimum Efficiency | IECC 2012 Minimum Efficiency | IECC 2015 Minimum Efficiency |
|---|----------------------------------|----------------------------------|----------------------------------|
| PTAC (Cooling mode) New Construction | 12.5 - (0.213 . Cap/1000) EER | 13.8 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER |
| PTAC (Cooling mode) Replacements | 10.9 - (0.213 . Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER |
| PTHP (Cooling mode) New Construction | 12.3 - (0.213 . Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER |
| PTHP (Cooling mode) Replacements | 10.8 - (0.213 . Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER |
| PTHP (Heating mode) New Construction | 3.2 - (0.026 . Cap/1000) COP | 3.2 – (0.026 x Cap/1000) COP | 3.2 – (0.026 x Cap/1000) COP |
| PTHP (Heating mode) Replacements | 2.9 - (0.026 . Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP |

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

Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS,” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the following conversion from SEER to EER for calculation of peak savings:¹⁷¹ $EER = (-0.02 * SEER^2) + (1.12 * SEER)$

= Actual installed

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

= Actual installed

3.412 = Btu per Wh.

COPexist = Coefficient of performance of the existing equipment

¹⁷⁰ 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; $EER = 10 - (0.16 * 12,000/1,000) = 8.1$.

¹⁷¹ 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.

| | |
|---------------------|--|
| | = Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP ¹⁷² for PTHPs. |
| COP _{base} | = Coefficient of performance of the baseline equipment; see table above for values. |
| COP _{ee} | = Coefficient of performance of the energy efficient equipment. |
| | = Actual installed |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

TOS:

$$\Delta kW = \Delta kWh_{cool} * CF$$

EREP:

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

$$\Delta kW = \Delta kWh_{cool(1st\ 5\ years)} * CF$$

ΔkW for remaining measure life (next 10 years)

$$\Delta kW = \Delta kWh_{cool(next\ 10\ years)} * CF$$

Where:

ΔkWh_{cool} = Annual cooling electricity savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

¹⁷²Estimated 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.

2.5.8 Single-Package and Split System Unitary Air Conditioner

DESCRIPTION

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiencies can save considerable amounts of energy. This measure could apply to the replacement 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 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 high-efficiency air-, water-, or evaporatively cooled air conditioner that exceeds the energy efficiency requirements specified by the building code applicable to local jurisdiction. This may be a version of the 2009, 2012 or 2015 IECC or ASHRAE 90.1 standard.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively cooled air conditioner that meets the energy efficiency requirements of local building code. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.¹⁷³

DEEMED MEASURE COST

The incremental capital cost for this measure is assumed to be \$100 per ton.¹⁷⁴

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

$$\Delta\text{kWH} = (\text{kBtu/hr}) * [(1/\text{SEER}_{\text{base}}) - (1/\text{SEER}_{\text{ee}})] * \text{EFLH}$$

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

$$\Delta\text{kWH} = (\text{kBtu/hr}) * [(1/\text{EER}_{\text{base}}) - (1/\text{EER}_{\text{ee}})] * \text{EFLH}$$

Where:

¹⁷³ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

¹⁷⁴ Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California. This assumes that baseline shift from between IECC versions carries the same incremental costs. Values should be verified during evaluation.

| | |
|----------|---|
| 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, if applicable code is based on IECC, or custom input as necessary. |
| SEERee | = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed) |
| EERbase | = Energy Efficiency Ratio of the baseline equipment = EER values from tables below, if applicable code is based on IECC, or custom input as necessary. (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings: ¹⁷⁵ $EER = (-0.02 * SEER^2) + (1.12 * SEER)$) |
| EERee | = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above). = Actual installed |
| EFLH | = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use |

¹⁷⁵ 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.

2009 IECC Minimum Efficiency Requirements

TABLE 503.2.3(1)
UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

| EQUIPMENT TYPE | SIZE CATEGORY | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|--|-------------------------------------|---|---|-----------------------------|
| Air conditioners, Air cooled | < 65,000 Btu/h ^d | Split system | 13.0 SEER | AHRI210/240 |
| | | Single package | 13.0 SEER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 10.3 EER _c (before Jan 1, 2010) 11.2 EER _c (as of Jan 1, 2010) | AHRI 340/360 |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.7 EER _c (before Jan 1, 2010) 11.0 EER _c (as of Jan 1, 2010) | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Split system and single package | 9.5 EER _c 9.7 IPLY _c (before Jan 1, 2010) 10.0 EER _c 9.7 IPLY _g (as of Jan 1, 2010) | |
| ≥ 760,000 Btu/h | Split system and single package | 9.2 EER _c 9.4 IPLY _c (before Jan 1, 2010) 9.7 EER _c 9.4 IPLY _c (as of Jan 1, 2010) | | |
| Through-the-wall, Air cooled | < 30,000 Btu/h ^d | Split system | 10.9 SEER (before Jan 23, 2010) 12.0 SEER (as of Jan 23, 2010) | AHRI210/240 |
| | | Single package | 10.6 SEER (before Jan 23, 2010) 12.0 SEER (as of Jan 23, 2010) | |
| Air conditioners, Water and evaporatively cooled | < 65,000 Btu/h | Split system and single package | 12.1 EER | AHRI210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 11.5 EER _c | AHRI 340/360 |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 11.0 EER _c | |
| | ≥ 240,000 Btu/h | Split system and single package | 11.5 EER _c | |

For SI: 1 British thermal unit per hour = 0.2931 W

- a. Chapter 6 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. IPLVs are only applicable to equipment with capacity modulation.
- c. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.
- d. Single-phase air-cooled air conditioners < 65,000 Btu/h are regulated by the National Appliance Energy Conservation Act of 1987 (NAECA); SEER values are those set by NAECA.

2012 IECC Minimum Efficiency Requirements

**TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE ^a | | |
|---------------------------------------|-------------------------------------|-------------------------------|---------------------------------|---------------------------------|-----------------------|-----------------------------|--------------|--------------|
| | | | | Before 6/1/2011 | As of 6/1/2011 | | | |
| Air conditioners, air cooled | < 65,000 Btu/h ^b | All | Split System | 13.0 SEER | 13.0 SEER | AHRI 210/240 | | |
| | | | Single Package | 13.0 SEER | 13.0 SEER | | | |
| Through-the-wall (air cooled) | ≤ 30,000 Btu/h ^b | All | Split system | 12.0 SEER | 12.0 SEER | | | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | | | |
| Small-duct high-velocity (air cooled) | < 65,000 Btu/h ^b | All | Split System | 10.0 SEER | 10.0 SEER | | | |
| Air conditioners, air cooled | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.2 EER 11.4 IEER | 11.2 EER 11.4 IEER | | AHRI 340/360 | |
| | | All other | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 11.2 IEER | | | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 11.2 IEER | | | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 10.8 EER 11.0 IEER | | | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 10.1 IEER | 10.0 EER 10.1 IEER | | | |
| | | All other | Split System and Single Package | 9.8 EER 9.9 IEER | 9.8 EER 9.9 IEER | | | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.7 EER 9.8 IEER | 9.7 EER 9.8 IEER | | | |
| | | All other | Split System and Single Package | 9.5 EER 9.6 IEER | 9.5 EER 9.6 IEER | | | |
| | Air conditioners, water cooled | < 65,000 Btu/h ^b | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | | AHRI 210/240 |
| | | | | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | | |
| ≥ 65,000 Btu/h and < 135,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 11.5 EER 11.7 IEER | 12.1 EER 12.3 IEER | AHRI 340/360 | | |
| | | All other | Split System and Single Package | 11.3 EER 11.5 IEER | 11.9 EER 12.1 IEER | | | |
| ≥ 135,000 Btu/h and < 240,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 12.5 EER 12.7 IEER | | | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 12.3 EER 12.5 IEER | | | |
| ≥ 240,000 Btu/h and < 760,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 12.4 EER 12.6 IEER | | | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.2 EER 12.4 IEER | | | |
| ≥ 760,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 12.0 EER 12.4 IEER | | | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.0 EER 12.2 IEER | | | |

(continued)

**TABLE C403.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUB-CATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE ^a | |
|--|-------------------------------------|-------------------------------|----------------------------------|-----------------------|-----------------------|-----------------------------|-----------------------|
| | | | | Before 6/1/2011 | As of 6/1/2011 | | |
| Air conditioners, evaporatively cooled | < 65,000 Btu/h ^b | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | AHRI 210/240 | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.5 EER 11.7 IEER | 12.1 EER 12.3 IEER | AHRI 340/360 | |
| | | All other | Split System and Single Package | 11.3 EER 11.5 IEER | 11.9 EER 12.1 IEER | | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 12.0 EER 12.2 IEER | | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 11.8 EER 12.0 IEER | | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 11.9 EER 12.1 IEER | | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.2 EER 11.9 IEER | | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 11.1 IEER | 11.7 EER 11.9 IEER | | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 11.5 EER 11.7 IEER | | |
| | Condensing units, air cooled | ≥ 135,000 Btu/h | | | 10.1 EER 11.4 IEER | | 10.5 EER 14.0 IEER |
| Condensing units, water cooled | ≥ 135,000 Btu/h | | | 13.1 EER 13.6 IEER | 13.5 EER 14.0 IEER | | |
| Condensing units, evaporatively cooled | ≥ 135,000 Btu/h | | | 13.1 EER 13.6 IEER | 13.5 EER 14.0 IEER | | |

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

2015 IECC Minimum Efficiency Requirements

TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE ^b | | |
|---------------------------------------|-------------------------------------|---------------------------------|---------------------------------|------------------------------------|-------------------------------|---------------------------------|--------------|-----------------------|
| | | | | Before 1/1/2016 | As of 1/1/2016 | | | |
| Air conditioners, air cooled | < 65,000 Btu/h ^b | All | Split System | 13.0 SEER | 13.0 SEER | AHRI 210/240 | | |
| | | | Single Package | 13.0 SEER | 14.0 SEER ^c | | | |
| Through-the-wall (air cooled) | ≤ 30,000 Btu/h ^b | All | Split system | 12.0 SEER | 12.0 SEER | | | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | | | |
| Small-duct high-velocity (air cooled) | < 65,000 Btu/h ^b | All | Split System | 11.0 SEER | 11.0 SEER | | | |
| Air conditioners, air cooled | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.2 EER 11.4 IEER | 11.2 EER 12.8 IEER | | AHRI 340/360 | |
| | | All other | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 12.6 IEER | | | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 12.4 IEER | | | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 10.8 EER 12.2 IEER | | | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 10.1 IEER | 10.0 EER 11.6 IEER | | | |
| | | All other | Split System and Single Package | 9.8 EER 9.9 IEER | 9.8 EER 11.4 IEER | | | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.7 EER 9.8 IEER | 9.7 EER 11.2 IEER | | | |
| | | All other | Split System and Single Package | 9.5 EER 9.6 IEER | 9.5 EER 11.0 IEER | | | |
| | Air conditioners, water cooled | < 65,000 Btu/h ^b | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | | AHRI 210/240 |
| | | | | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | | 12.1 EER 12.3 IEER |
| All other | | Split System and Single Package | 11.9 EER 12.1 IEER | | 11.9 EER 13.7 IEER | | | |
| ≥ 135,000 Btu/h and < 240,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 12.5 EER 12.5 IEER | 12.5 EER 13.9 IEER | | | |
| | | All other | Split System and Single Package | 12.3 EER 12.5 IEER | 12.3 EER 13.7 IEER | | | |
| ≥ 240,000 Btu/h and < 760,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 12.4 EER 12.6 IEER | 12.4 EER 13.6 IEER | | | |
| | | All other | Split System and Single Package | 12.2 EER 12.4 IEER | 12.2 EER 13.4 IEER | | | |
| ≥ 760,000 Btu/h | | Electric Resistance (or None) | Split System and Single Package | 12.2 EER 12.4 IEER | 12.2 EER 13.5 IEER | | | |
| | | All other | Split System and Single Package | 12.0 EER 12.2 IEER | 12.0 EER 13.3 IEER | | | |

(continued)

TABLE C403.2.3(1)—continued
 MINIMUM EFFICIENCY REQUIREMENTS:
 ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUB-CATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE ^c | | |
|--|--|-------------------------------|----------------------------------|-----------------------|-----------------------|-----------------------------|-----------------------|----------|
| | | | | Before 1/1/2016 | As of 1/1/2016 | | | |
| Air conditioners, evaporatively cooled | < 65,000 Btu/h ^b | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | AHRI 210/240 | | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | AHRI 340/360 | | |
| | | All other | Split System and Single Package | 11.9 EER 12.1 IEER | 11.9 EER 12.1 IEER | | | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.0 EER 12.2 IEER | 12.0 EER 12.2 IEER | | | |
| | | All other | Split System and Single Package | 11.8 EER 12.0 IEER | 11.8 EER 12.0 IEER | | | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.9 EER 12.1 IEER | 11.9 EER 12.1 IEER | | | |
| | | All other | Split System and Single Package | 11.7 EER 11.9 IEER | 11.7 EER 11.9 IEER | | | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.7 EER 11.9 IEER | 11.7 EER 11.9 IEER | | | |
| | | All other | Split System and Single Package | 11.5 EER 11.7 IEER | 11.5 EER 11.7 IEER | | | |
| | Condensing units, air cooled | ≥ 135,000 Btu/h | | | 10.5 EER 11.8 IEER | | 10.5 EER 11.8 IEER | AHRI 365 |
| | Condensing units, water cooled | ≥ 135,000 Btu/h | | | 13.5 EER 14.0 IEER | | 13.5 EER 14.0 IEER | |
| | Condensing units, evaporatively cooled | ≥ 135,000 Btu/h | | | 13.5 EER 14.0 IEER | | 13.5 EER 14.0 IEER | |

For SI: 1 British thermal unit per hour = 0.2931 W.
 a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
 b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.
 c. Minimum efficiency as of January 1, 2015.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Annual electricity savings, as calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
 = 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

Measure Code:

2.6 Lighting

| Building Type | Fixture Annual Operating Hours ¹⁷⁶ (Hours) | Waste Heat Cooling Energy Factor ¹⁷⁷ (WHFe) | Summer Demand Factor ¹⁷⁸ (CF) | Waste Heat Electric Resistance Heating ¹⁷⁹ (IFkWh) | Waste Heat Electric Heat Pump Heating (IFkWh) | Waste Heat Gas Heating IFTherms ¹⁸⁰ |
|------------------------------|--|---|---|--|--|---|
| Large Office | 3170 | 1.06 | 0.0002555753 | 0.32 | 0.14 | 0.014 |
| Medium Office | 3170 | 1.14 | 0.0002596721 | 0.19 | 0.08 | 0.008 |
| Small Office | 2884 | 1.11 | 0.0002154904 | 0.21 | 0.09 | 0.009 |
| Warehouse | 2827 | 1.04 | 0.0001361421 | 0.26 | 0.11 | 0.011 |
| Stand-alone Retail | 3421 | 1.08 | 0.0002844436 | 0.21 | 0.09 | 0.009 |
| Strip Mall | 3694 | 1.08 | 0.0002830978 | 0.22 | 0.10 | 0.009 |
| Primary School | 3466 | 1.08 | 0.0001747332 | 0.28 | 0.12 | 0.012 |
| Secondary School | 3466 | 1.14 | 0.0001643556 | 0.30 | 0.13 | 0.013 |
| Supermarket | 3765 | 1.07 | 0.0002892094 | 0.26 | 0.11 | 0.011 |
| Quick Service Restaurant | 6443 | 1.12 | 0.0001572418 | 0.27 | 0.12 | 0.012 |
| Full Service Restaurant | 6443 | 1.11 | 0.0001432272 | 0.22 | 0.10 | 0.009 |
| Hospital | 3812 | 1.11 | 0.0002249500 | 0.34 | 0.15 | 0.015 |
| Outpatient Health Care | 3898 | 1.21 | 0.0000693793 | 0.28 | 0.12 | 0.012 |
| Small Hotel - Building | 3713 | 1.21 | 0.0001225280 | 0.22 | 0.09 | 0.009 |
| Large Hotel - Building | 3713 | 1.24 | 0.0000877617 | 0.01 | 0.00 | 0.000 |
| Midrise Apartment - Building | 2876 | 1.14 | 0.0002048600 | 0.44 | 0.19 | 0.019 |
| C&I Average | 3351 | 1.09 | 0.0001861116 | 0.24 | 0.10 | 0.010 |

¹⁷⁶Fixtures hours of use are based upon schedule assumptions used in the computer models. Nonresidential Average is a weighted average of indoor spaces using the relative area of each building type in the region (CBECS).

¹⁷⁷ The Waste Heat Factor for Energy is developed using computer models for the various building types. Exterior and garage values are 1, unknown is a weighted average of the other building types.

¹⁷⁸Summer peak coincidence demand (kW) to annual energy (kWh) factor. Calculated using modeling results and Ameren Missouri coincident peak demand methodology.

¹⁷⁹ 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 80% AFUE, electric resistance is assumed to be 100%, Heat Pump is assumed to be 2.3COP.

¹⁸⁰ IF Therms value is developed using computer models consistent with methodology for Waste Heat Factor for Energy.

2.6.1 Fluorescent Delamping

DESCRIPTION

This measure entails the permanent removal of an existing 4-foot or 8-foot T8 lamp and the associated lamp holders and ballasts from the fixture.

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.

This measure was developed to be applicable to RF.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition will vary depending on the existing fixture and number of lamps removed, however for the purposes of this measure, savings are defined on a per removed lamp basis. The retrofit wattage (efficient condition) is therefore assumed to be zero.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a T8 lamp with default wattages provided below.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years.¹⁸¹

DEEMED MEASURE COST

| Measure | Cost |
|------------------------------------|---------|
| 8-Foot Lamp Removal | \$16.00 |
| 4-Foot Lamp Removal | \$12.00 |
| 8-Foot Lamp Removal with reflector | \$30.00 |
| 4-Foot Lamp Removal with Reflector | \$25.00 |

LOADSHAPE

Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS¹⁸²

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

Where:

¹⁸¹ KCP&L measure life assumption.

¹⁸² The savings numbers are for the straight lamp removal measures, as well as the lamp removal and install reflector measures.

Watts_{Base} = Wattage reduction of lamp removed. Custom input, otherwise assume:

| T8 Lamp Size | Wattage ¹⁸³ |
|--------------|------------------------|
| 8-ft T8 | 38.6 |
| 4-ft T8 | 19.4 |

Watts_{EE} = 0

Hours = Average annual lighting hours of use as provided by the customer. If unknown, the default value based on building type may be selected from the Lighting Reference Table in Section 2.8.

WHF_e = Waste heat factor for energy to account for cooling energy savings from light removal is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0 and if unknown use C&I Average value.

ISR = In Service Rate, 100% since permanent removal is assumed.

Heating Penalty¹⁸⁴

If electrically heated building:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001899635

NATURAL GAS ENERGY SAVINGS¹⁸⁵

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * -IFTherms$$

Where:

¹⁸³ Default wattage reduction 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 that can be expected when delamping fixtures with parallel ballasts. See "Delamping calculation.xlsx" for details.

¹⁸⁴Negative value because this is an increase in heating consumption due to the efficient lighting.

¹⁸⁵ Negative value because this is an increase in heating consumption due to the efficient lighting.

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.6.2 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.

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.

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 O&M 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) |
|---|---|
| <p>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.</p> | <p>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.</p> <p>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.</p> |

DEFINITION OF EFFICIENT EQUIPMENT

This characterization assumes the efficient condition for all applications are qualifying HP or RWT8 fixture and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products¹⁸⁶ and qualifying RWT8 products.¹⁸⁷

The definition of efficient equipment varies based on the program and is defined below:

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|--|
| <p>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.</p> <p>High bay fixtures must have fixture efficiencies of 85% or greater.</p> | <p>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.</p> <p>High bay fixtures will have fixture efficiencies of 85% or greater.</p> |

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) |
|--|--|
| <p>The baseline is standard efficiency T8 systems that would have been installed. The baseline for high-bay fixtures is pulse start metal halide fixtures.</p> | <p>The baseline is the existing system.</p> <p>In July 14, 2012, federal standards were enacted that were expected to eliminate T12s as an option for linear fluorescent fixtures. However, due to significant loopholes in the legislation, T12 compliant product is still freely available.</p> <p>There will be a baseline shift applied to all T12 in 2020, at which point it is assumed no remaining T12 products will remain in operation.</p> |

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of efficient equipment varies based on the program and is defined below:

¹⁸⁶ <http://library.cee1.org/content/cee-high-performance-t8-specification>

¹⁸⁷ <http://library.cee1.org/content/reduced-wattage-t8-specification>

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| <p>Fixture lifetime is 15 years.¹⁸⁸</p> <p>Fixture retrofits which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below. RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 15 years.¹⁸⁹</p> | <p>Fixture lifetime is 15 years.</p> <p>Note, since the fixture lifetime is deemed at 15 years, the replacement cost of both the lamp and ballast should be incorporated in to the O&M calculation.</p> |

DEEMED MEASURE COST

The deemed measure cost is found in the reference table at the end of this characterization.

LOADSHAPE

Lighting BUS Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the existing system.

| Program | Reference Table |
|---------------------------------------|---|
| Time of Sale | A-1: HPT8 and RWT8 New and Baseline Assumptions |
| Retrofit | A-2: HPT8 and RWT8 New and Baseline Assumptions |
| High-Bay T8 Time of Sale and Retrofit | A-3: High Bay T8 New and Baseline Assumptions |

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected

¹⁸⁸ 15 years from GDS Measure Life Report, June 2007.

¹⁸⁹ 15 years from GDS Measure Life Report, June 2007.

from the appropriate reference table, or a custom value can be entered if the configurations in the tables is not representative of the existing system.

- Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 2.8. If hours or building type are unknown, use the C&I Average value.
- WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.
- ISR = In Service Rate is assumed to be 100%

Heating Penalty

If electrically heated building:

$$\Delta kWh_{\text{heatpenalty}}^{190} = (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * -\text{IFkWh})$$

Where:

- IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 2.8. If unknown, use the C&I Average value.

Midlife Adjustment

A midlife savings adjustment should be applied to retrofit projects in 2020 to account for the baseline lamp replacement assumption changing from a T12 to 100% Standard T8 by 2020.¹⁹¹ The savings adjustment is calculated as follows, and is provided in the HP/RW T8 Reference Table below:

$$\% \text{ Adjustment} = \left(\frac{\text{Watts}_{\text{T8base}} - \text{Watts}_{\text{EE}}}{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}} \right)$$

Where:

- Watts_{T8Base} = Input wattage of the of a 100% T8 fixture baseline.
- Watts_{Base} = Input wattage of the T12 baseline

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001899635

¹⁹⁰Negative value because this is an increase in heating consumption due to the efficient lighting.
¹⁹¹ As of July 1, 2010, a federal mandate states that the magnetic ballasts used in many T12 fixtures can no longer be produced for commercial and industrial applications. However, there have been many loopholes that have meant T12 lamps continue to hold a significant market share. It is expected that new mandates will close the loophole within the next few years. T12 lamps have an average life of 20,000 hours and if we assume they are operated on average for 4500 hours annually, this would mean a lamp would have to be replaced every 4.5 years. We therefore assume that by 2020 all replacement lamps are Standard T8s. Therefore, while the more likely scenario would be a gradual shift in baseline to T8s over the timeframe, to simplify this assumption, a single midlife adjustment in 2020 is assumed.

NATURAL GAS SAVINGS

$$\Delta\text{Therms}^{192} = ((\text{WattsBase}-\text{WattsEE})/1000) * \text{ISR} * \text{Hours} * \text{IFTherms}$$

Where:

IFTherms = Lighting-HVAC Interaction 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 2.8 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 O&M values;

| Program | Reference Table |
|---------------------------------------|---|
| TOS | B-1: HPT8 and RWT8 New and Baseline Assumptions |
| RF | B-2: HPT8 and RWT8 New and Baseline Assumptions |
| High-Bay T8 Time of Sale and Retrofit | B-3: High Bay T8 New and Baseline Assumptions |

REFERENCE TABLES

A-1: Time of Sale: HPT8 and RWT8 New and Baseline Assumptions¹⁹³

| EE Measure Description | Watt _{SEE} | Baseline Description | Watts _{BASE} | Incremental Cost |
|-----------------------------|---------------------|----------------------|-----------------------|------------------|
| 1-Lamp 32w HPT8 (BF < 0.79) | 24.0 | Standard T8 | 29.1 | \$15.00 |
| 2-Lamp 32w HPT8 (BF < 0.77) | 48.0 | Standard T8 | 57.0 | \$17.50 |
| 3-Lamp 32w HPT8 (BF < 0.76) | 71.0 | Standard T8 | 84.5 | \$20.00 |
| 4-Lamp 32w HPT8 (BF < 0.78) | 98.0 | Standard T8 | 112.6 | \$22.50 |
| 6-Lamp 32w HPT8 (BF < 0.76) | 142.0 | Standard T8 | 169.0 | \$40.00 |
| 1-Lamp 28w RWT8 (BF < 0.76) | 21.3 | Standard T8 | 29.1 | \$15.00 |
| 2-Lamp 28w RWT8 (BF < 0.76) | 42.6 | Standard T8 | 57.0 | \$17.50 |
| 3-Lamp 28w RWT8 (BF < 0.77) | 63.0 | Standard T8 | 84.5 | \$20.00 |
| 4-Lamp 28w RWT8 (BF < 0.79) | 88.5 | Standard T8 | 112.6 | \$22.50 |
| 6-Lamp 28w RWT8 (BF < 0.77) | 126.0 | Standard T8 | 169.0 | \$40.00 |

A-2: Retrofit: HPT8 and RWT8 New and Baseline Assumptions

¹⁹² Negative value because this is an increase in heating consumption due to the efficient lighting.

¹⁹³ 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. See "HPT8 TRM Reference Tables.xlsx" for more information and specific product links. Currently, 25WT8 are not considered under this measure as their lower light trade off and limitations on temperature and dimming have caused most distributors/contractors to use 28W almost exclusively in other markets.

| EE Measure Description | Watts _{EE} | Baseline Description | Watts _{BASE} | Full Cost | Mid Life Savings Adjustment (2020) |
|-------------------------------------|---------------------|----------------------|-----------------------|-----------|------------------------------------|
| 1-Lamp Relamp/Reballast T12 to HPT8 | 24.0 | 1-Lamp 40w T12 | 31.0 | \$50.00 | 73% |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 48.0 | 2-Lamp 40w T12 | 62.0 | \$55.00 | 64% |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 71.0 | 3-Lamp 40w T12 | 108.0 | \$60.00 | 36% |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 98.0 | 4-Lamp 40w T12 | 144.0 | \$65.00 | 32% |
| 6-Lamp Relamp/Reballast T12 to HPT8 | 142.0 | 6-Lamp 40w T12 | 216.0 | \$75.00 | 36% |
| 1-Lamp Relamp/Reballast T12 to RWT8 | 21.3 | 1-Lamp 40w T12 | 31.0 | \$50.00 | 81% |
| 2-Lamp Relamp/Reballast T12 to RWT8 | 42.6 | 2-Lamp 40w T12 | 62.0 | \$55.00 | 74% |
| 3-Lamp Relamp/Reballast T12 to RWT8 | 63.0 | 3-Lamp 40w T12 | 108.0 | \$60.00 | 48% |
| 4-Lamp Relamp/Reballast T12 to RWT8 | 88.5 | 4-Lamp 40w T12 | 144.0 | \$65.00 | 44% |
| 6-Lamp Relamp/Reballast T12 to RWT8 | 126.0 | 6-Lamp 40w T12 | 216.0 | \$75.00 | 48% |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 24.0 | 1-Lamp 32w T8 | 29.1 | \$50.00 | N/A |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 48.0 | 2-Lamp 32w T8 | 57.0 | \$55.00 | N/A |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 71.0 | 3-Lamp 32w T8 | 84.5 | \$60.00 | N/A |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 98.0 | 4-Lamp 32w T8 | 112.6 | \$65.00 | N/A |
| 6-Lamp Relamp/Reballast T8 to HPT8 | 142.0 | 6-Lamp 32w T8 | 169.0 | \$75.00 | N/A |
| 1-Lamp Relamp/Reballast T8 to RWT8 | 21.3 | 1-Lamp 32w T8 | 29.1 | \$50.00 | N/A |
| 2-Lamp Relamp/Reballast T8 to RWT8 | 42.6 | 2-Lamp 32w T8 | 57.0 | \$55.00 | N/A |
| 3-Lamp Relamp/Reballast T8 to RWT8 | 63.0 | 3-Lamp 32w T8 | 84.5 | \$60.00 | N/A |
| 4-Lamp Relamp/Reballast T8 to RWT8 | 88.5 | 4-Lamp 32w T8 | 112.6 | \$65.00 | N/A |
| 6-Lamp Relamp/Reballast T8 to RWT8 | 126.0 | 6-Lamp 32w T8 | 169.0 | \$75.00 | N/A |

* New T12’s that meeting EISA efficacy standards changed from 34w to 40w to meet the lumen/per watt requirement.

A-2: Retrofit: HPT8 and RWT8 New and Baseline Assumptions

| EE Measure Description | Watts _{EE} | Baseline Description | Watts _{BASE} | Full Cost | Mid Life Savings Adjustment (2020) |
|-------------------------------------|---------------------|----------------------|-----------------------|-----------|------------------------------------|
| 1-Lamp Relamp/Reballast T12 to HPT8 | 24.0 | 1-Lamp 40w T12 | 31.0 | \$50.00 | 73% |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 48.0 | 2-Lamp 40w T12 | 62.0 | \$55.00 | 64% |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 71.0 | 3-Lamp 40w T12 | 108.0 | \$60.00 | 36% |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 98.0 | 4-Lamp 40w T12 | 144.0 | \$65.00 | 32% |
| 6-Lamp Relamp/Reballast T12 to HPT8 | 142.0 | 6-Lamp 40w T12 | 216.0 | \$75.00 | 36% |
| 1-Lamp Relamp/Reballast T12 to RWT8 | 21.3 | 1-Lamp 40w T12 | 31.0 | \$50.00 | 81% |
| 2-Lamp Relamp/Reballast T12 to RWT8 | 42.6 | 2-Lamp 40w T12 | 62.0 | \$55.00 | 74% |
| 3-Lamp Relamp/Reballast T12 to RWT8 | 63.0 | 3-Lamp 40w T12 | 108.0 | \$60.00 | 48% |
| 4-Lamp Relamp/Reballast T12 to RWT8 | 88.5 | 4-Lamp 40w T12 | 144.0 | \$65.00 | 44% |
| 6-Lamp Relamp/Reballast T12 to RWT8 | 126.0 | 6-Lamp 40w T12 | 216.0 | \$75.00 | 48% |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 24.0 | 1-Lamp 32w T8 | 29.1 | \$50.00 | N/A |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 48.0 | 2-Lamp 32w T8 | 57.0 | \$55.00 | N/A |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 71.0 | 3-Lamp 32w T8 | 84.5 | \$60.00 | N/A |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 98.0 | 4-Lamp 32w T8 | 112.6 | \$65.00 | N/A |
| 6-Lamp Relamp/Reballast T8 to HPT8 | 142.0 | 6-Lamp 32w T8 | 169.0 | \$75.00 | N/A |
| 1-Lamp Relamp/Reballast T8 to RWT8 | 21.3 | 1-Lamp 32w T8 | 29.1 | \$50.00 | N/A |

| EE Measure Description | Watts _{EE} | Baseline Description | Watts _{BASE} | Full Cost | Mid Life Savings Adjustment (2020) |
|------------------------------------|---------------------|----------------------|-----------------------|-----------|------------------------------------|
| 2-Lamp Relamp/Reballast T8 to RWT8 | 42.6 | 2-Lamp 32w T8 | 57.0 | \$55.00 | N/A |
| 3-Lamp Relamp/Reballast T8 to RWT8 | 63.0 | 3-Lamp 32w T8 | 84.5 | \$60.00 | N/A |
| 4-Lamp Relamp/Reballast T8 to RWT8 | 88.5 | 4-Lamp 32w T8 | 112.6 | \$65.00 | N/A |
| 6-Lamp Relamp/Reballast T8 to RWT8 | 126.0 | 6-Lamp 32w T8 | 169.0 | \$75.00 | N/A |

A-3: Time of Sale/Retrofit: High Bay T8 New and Baseline Assumptions

| EE Measure Description | Watts _E | Baseline Description | Watts _{BAS E} | Incremental Cost | Full Cost |
|---|--------------------|---|------------------------|------------------|-----------|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 218.5 | 200 Watt Pulse Start Metal-Halide | 232.0 | \$75 | \$200 |
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 218.5 | 250 Watt Metal Halide | 295.0 | \$75 | \$200 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 330.1 | 320 Watt Pulse Start Metal-Halide | 348.8 | \$75 | \$225 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 330.1 | 400 Watt Pulse Start Metal Halide | 455.0 | \$75 | \$225 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 418.6 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | 476.0 | \$75 | \$250 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 418.6 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide | 618.0 | \$75 | \$250 |

B-1: Time of Sale: HPT8 and RWT8 Component Costs and Lifetime

| EE Measure Description | Lamp Quantity | EE Measure | | | | Baseline | | | |
|-----------------------------|---------------|-----------------|-----------------------------|--------------------|--------------------------------|-----------------|-----------------------------|--------------------|--------------------------------|
| | | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| 1-Lamp 32w HPT8 (BF < 0.79) | 1 | 24,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.67 | 70,000 | \$35.00 |
| 2-Lamp 32w HPT8 (BF < 0.77) | 2 | 24,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| 3-Lamp 32w HPT8 (BF < 0.76) | 3 | 24,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| 4-Lamp 32w HPT8 (BF < 0.78) | 4 | 24,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$22.68 | 70,000 | \$35.00 |
| 6-Lamp 32w HPT8 (BF < 0.76) | 6 | 24,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$34.02 | 70,000 | \$35.00 |
| 1-Lamp 28w RWT8 (BF < 0.76) | 1 | 18,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.67 | 70,000 | \$35.00 |
| 2-Lamp 28w RWT8 (BF < 0.76) | 2 | 18,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| 3-Lamp 28w RWT8 (BF < 0.77) | 3 | 18,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| 4-Lamp 28w RWT8 (BF < 0.79) | 4 | 18,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$22.68 | 70,000 | \$35.00 |
| 6-Lamp 28w RWT8 (BF < 0.77) | 6 | 18,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$34.02 | 70,000 | \$35.00 |

B-2: Retrofit: HPT8 and RWT8 Component Costs and Lifetime

| EE Measure Description | Lamp Quantity | EE Measure | | | | Baseline | | | |
|-------------------------------------|---------------|-----------------|-----------------------------|--------------------|--------------------------------|-----------------|-----------------------------|--------------------|--------------------------------|
| | | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| 1-Lamp Relamp/Reballast T12 to HPT8 | 1 | 24,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.87 | 40,000 | \$35.00 |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 2 | 24,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.74 | 40,000 | \$35.00 |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 3 | 24,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.61 | 40,000 | \$35.00 |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 4 | 24,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$23.48 | 40,000 | \$35.00 |
| 6-Lamp Relamp/Reballast T12 to HPT8 | 6 | 24,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$35.22 | 40,000 | \$35.00 |
| 1-Lamp Relamp/Reballast T12 to RWT8 | 1 | 18,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.87 | 40,000 | \$35.00 |
| 2-Lamp Relamp/Reballast T12 to RWT8 | 2 | 18,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.74 | 40,000 | \$35.00 |
| 3-Lamp Relamp/Reballast T12 to RWT8 | 3 | 18,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.61 | 40,000 | \$35.00 |
| 4-Lamp Relamp/Reballast T12 to RWT8 | 4 | 18,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$23.48 | 40,000 | \$35.00 |
| 6-Lamp Relamp/Reballast T12 to RWT8 | 6 | 18,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$35.22 | 40,000 | \$35.00 |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 1 | 24,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.67 | 70,000 | \$35.00 |

| EE Measure Description | Lamp Quantity | EE Measure | | | | Baseline | | | |
|------------------------------------|---------------|-----------------|-----------------------------|--------------------|--------------------------------|-----------------|-----------------------------|--------------------|--------------------------------|
| | | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 2 | 24,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 3 | 24,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 4 | 24,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$22.68 | 70,000 | \$35.00 |
| 6-Lamp Relamp/Reballast T8 to HPT8 | 6 | 24,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$34.02 | 70,000 | \$35.00 |
| 1-Lamp Relamp/Reballast T8 to RWT8 | 1 | 18,000 | \$8.17 | 70,000 | \$52.50 | 20,000 | \$5.67 | 70,000 | \$35.00 |
| 2-Lamp Relamp/Reballast T8 to RWT8 | 2 | 18,000 | \$16.34 | 70,000 | \$52.50 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| 3-Lamp Relamp/Reballast T8 to RWT8 | 3 | 18,000 | \$24.51 | 70,000 | \$52.50 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| 4-Lamp Relamp/Reballast T8 to RWT8 | 4 | 18,000 | \$32.68 | 70,000 | \$52.50 | 20,000 | \$22.68 | 70,000 | \$35.00 |
| 6-Lamp Relamp/Reballast T8 to RWT8 | 6 | 18,000 | \$49.02 | 70,000 | \$105.00 | 20,000 | \$34.02 | 70,000 | \$35.00 |

B-3: High Bay HPT8 Component Costs and Lifetime

| EE Measure Description | EE Measure | | | | Baseline Description | Baseline | | | |
|---|-----------------|-----------------------------|--------------------|--------------------------------|---|-----------------|-----------------------------|--------------------|--------------------------------|
| | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 24000 | \$46.68 | 70000 | \$47.50 | 200 Watt Pulse Start Metal-Halide | 12000 | \$35.67 | 40000 | \$110.25 |
| | | | | | 250 Watt Metal Halide | 10000 | \$27.67 | 40000 | \$114.50 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 24000 | \$70.02 | 70000 | \$47.50 | 320 Watt Pulse Start Metal-Halide | 20000 | \$78.67 | 40000 | \$131.85 |
| | | | | | 400 Watt Metal-Halide | 20000 | \$23.67 | 40000 | \$136.50 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 24000 | \$93.36 | 70000 | \$47.50 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | 20000 | \$23.67 | 40000 | \$131.85 |

MEASURE CODE:

2.6.3 LED Bulbs and Fixtures

DESCRIPTION

The installation of Light-Emitting Diode (LED) lighting systems have comparable luminosity to incandescent bulbs and equivalent fluorescent lamps at significantly less wattage, lower heat, and with significantly longer lifetimes.

This measure provides savings assumptions for a variety of efficient lighting fixtures including internal and external LED fixtures, recess (troffer), canopy, and pole fixtures as well as refrigerator and display case lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, all LED fixtures are assumed to be ENERGY STAR® labeled or on the Design Light Consortium qualifying fixture list.¹⁹⁴

DEFINITION OF BASELINE EQUIPMENT

For TOS and RF installations, the baselines efficiency case is project specific and is determined using actual fixture types and counts from the existing space. The existing fluorescent fixture end connectors and ballasts must be completely removed to qualify.

Where the installation technology is not known, the assumed baselines condition for an outdoor pole/arm, wall-mounted, garage/canopy fixture and high-bay luminaire with a high intensity discharge light source is a metal halide fixture. Deemed fixture wattages are provided in reference tables at the end of this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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.¹⁹⁵

DEEMED MEASURE COST

Actual incremental costs should be used if available. For default values, refer to the reference tables below.

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

¹⁹⁴ Design Lights Consortium Qualified Products List <http://www.designlights.org/qpl>.

¹⁹⁵ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures.

 Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

- Watts_{Base} = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.
- Watts_{EE} = Actual wattage of LED fixture purchased / installed. If unknown, use default provided in “LED New and Baseline Assumptions.”
- Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.8. by building type. If hours or building type are unknown, use the C&I Average value.
- WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.
- ISR = In Service Rate is assumed to be 98.7% for Time of Sale and 100% for Retrofit.¹⁹⁶

Heating Penalty:

If electrically heated building:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

- IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts;¹⁹⁷ this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

Mid Life Adjustment:

A midlife savings adjustment should be applied to any retrofit measure using a T12 baseline. The adjustment should occur in 2020 to account for the baseline lamp replacement assumption changing from a T12 to 100% Standard T8 by 2020.¹⁹⁸ The savings adjustment is calculated as follows:

$$\% \text{ Adjustment} = \left(\frac{Watts_{T8base} - Watts_{EE}}{Watts_{T12 Base} - Watts_{EE}} \right)$$

Where:

- Watts_{T8 Base} = Input wattage of the existing system based on 100% T8 fixture.
- Watts_{T12 Base} = Input wattage of the existing T12 system.

¹⁹⁶ Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015 and consistent with other program ISR in neighboring states (Illinois and Iowa).

¹⁹⁷ Negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
- = 0.0001899635 for indoor lighting
- = 0.0000056160 for exterior lighting
- = 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):

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

Where:

- IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts.¹⁹⁹ This factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

REFERENCE TABLES²⁰⁰

LED New and Baseline Assumptions:

| LED Category | EE Measure | | Baseline | | Incremental Cost |
|--------------------------|---|---------------------|--|----------------------|------------------|
| | Description | Watt _{SEE} | Description | Watt _{BASE} | |
| LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 17.6 | 40% CFL 26W Pin Based & 60% PAR30/38 | 54.3 | \$27 |
| LED Interior Directional | LED Track Lighting | 12.2 | 10% CMH PAR38 & 90% Halogen PAR38 | 60.4 | \$59 |
| | LED Wall-Wash Fixtures | 8.3 | 40% CFL 42W Pin Base & 60% Halogen PAR38 | 17.7 | \$59 |
| LED Display Case | LED Display Case Light Fixture | 7.1 / ft | 50% 2'T5 Linear & 50% 50W Halogen | 36.2 / ft | \$11/ft |

¹⁹⁹ Negative value because this is an increase in heating consumption due to the efficient lighting.

²⁰⁰ Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE "Energy Savings Potential of Solid-State Lighting in General Illumination Applications," Table A.1. See "LED Lighting Systems TRM Reference Tables.xlsx" for more information and specific product links.

| LED Category | EE Measure | | Baseline | | Incremental Cost |
|------------------------------------|--|---------------------|-----------------------------------|----------------------|------------------|
| | Description | Watt _{SEE} | Description | Watt _{BASE} | |
| | LED Undercabinet Shelf-Mounted Task Light Fixtures | 7.1 / ft | 50% 2'T5 Linear & 50% 50W Halogen | 36.2 / ft | \$11/ft |
| | LED Refrigerated Case Light, Horizontal or Vertical | 7.6 / ft | 5'T8 | 15.2 / ft | \$11/ft |
| | LED Freezer Case Light, Horizontal or Vertical | 7.7 / ft | 6'T12HO | 18.7 / ft | \$11/ft |
| LED Linear Replacement Lamps | LED 4' Linear Replacement Lamp | 18.7 | Lamp Only 32w T8 | 32.0 | \$24 |
| | LED 2' Linear Replacement Lamp | 9.7 | Lamp Only 17w T8 | 17.0 | \$13 |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 34.1 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | \$48 |
| | LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 42.8 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | \$91 |
| | LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 37.9 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | \$62 |
| | LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 54.3 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | \$99 |
| | LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 72.7 | 4-Lamp 32w T8 (BF < 0.88) | 112.6 | \$150 |
| | LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 18.1 | 1-Lamp 32w T8 (BF < 0.91) | 29.1 | \$36 |
| | LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 39.6 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | \$76 |
| | LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 53.1 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | \$130 |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, ≤ 3000 lumens | 19.7 | 1-Lamp 32w T8 (BF < 0.91) | 29.1 | \$54 |
| | LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 37.8 | 2-Lamp 32w T8 (BF < 0.89) | 57.0 | \$104 |
| | LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 55.9 | 3-Lamp 32w T8 (BF < 0.88) | 84.5 | \$158 |
| | LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 62.6 | T5HO 2L-F54T5HO - 4' | 120.0 | \$215 |
| | LED Surface & Suspended Linear Fixture, > 7500 lumens | 95.4 | T5HO 3L-F54T5HO - 4' | 180.0 | \$374 |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, ≤ 10,000 lumens | 90.3 | 3-Lamp T8HO Low-Bay | 157.0 | \$191 |
| | LED High-Bay Fixtures, 10,001-15,000 lumens | 127.5 | 4-Lamp T8HO High-Bay | 196.0 | \$331 |
| | LED High-Bay Fixtures, 15,001-20,000 lumens | 191.0 | 6-Lamp T8HO High-Bay | 294.0 | \$482 |
| | LED High-Bay Fixtures, > 20,000 lumens | 249.7 | 8-Lamp T8HO High-Bay | 392.0 | \$818 |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, ≤ 2,000 lumens | 17.0 | 25% 73 Watt EISA Inc, 75% 1L T8 | 42.0 | \$33 |

| LED Category | EE Measure | | Baseline | | Incremental Cost |
|-----------------------|--|---------------------|-----------------------------------|-----------------------|------------------|
| | Description | Watts _{EE} | Description | Watts _{BASE} | |
| | LED Ag Interior Fixtures, 2,001-4,000 lumens | 27.8 | 25% 146 Watt EISA Inc, 75% 2L T8 | 81.0 | \$54 |
| | LED Ag Interior Fixtures, 4,001-6,000 lumens | 51.2 | 25% 217 Watt EISA Inc, 75% 3L T8 | 121.0 | \$125 |
| | LED Ag Interior Fixtures, 6,001-8,000 lumens | 71.7 | 25% 292 Watt EISA Inc, 75% 4L T8 | 159.0 | \$190 |
| | LED Ag Interior Fixtures, 8,001-12,000 lumens | 103.5 | 200W Pulse Start Metal Halide | 227.3 | \$298 |
| | LED Ag Interior Fixtures, 12,001-16,000 lumens | 143.8 | 320W Pulse Start Metal Halide | 363.6 | \$450 |
| | LED Ag Interior Fixtures, 16,001-20,000 lumens | 183.3 | 350W Pulse Start Metal Halide | 397.7 | \$595 |
| | LED Ag Interior Fixtures, > 20,000 lumens | 305.0 | (2) 320W Pulse Start Metal Halide | 727.3 | \$998 |
| LED Exterior Fixtures | LED Exterior Fixtures, ≤ 5,000 lumens | 42.6 | 100W Metal Halide | 113.6 | \$190 |
| | LED Exterior Fixtures, 5,001-10,000 lumens | 68.2 | 175W Pulse Start Metal Halide | 198.9 | \$287 |
| | LED Exterior Fixtures, 10,001-15,000 lumens | 122.5 | 250W Pulse Start Metal Halide | 284.1 | \$391 |
| | LED Exterior Fixtures, > 15,000 lumens | 215.0 | 400W Pulse Start Metal Halide | 454.5 | \$793 |

LED Component Costs and Lifetimes:

| LED Category | EE Measure Description | EE Measure | | | | Baseline | | | |
|------------------------------|---|-----------------|-------------------------|-----------------------|-------------------------------|-----------------|-------------------------|--------------------|----------------------------|
| | | Lamp Life (hrs) | Total Lamp Replace Cost | LED Driver Life (hrs) | Total LED Driver Replace Cost | Lamp Life (hrs) | Total Lamp Replace Cost | Ballast Life (hrs) | Total Ballast Replace Cost |
| LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 35,000 | \$30.75 | 70,000 | \$47.50 | 2,500 | \$8.86 | 40,000 | \$14.40 |
| LED Interior Directional | LED Track Lighting | 35,000 | \$39.00 | 70,000 | \$47.50 | 2,500 | \$12.71 | 40,000 | \$11.00 |
| | LED Wall-Wash Fixtures | 35,000 | \$39.00 | 70,000 | \$47.50 | 2,500 | \$9.17 | 40,000 | \$27.00 |
| LED Display Case | LED Display Case Light Fixture | 35,000 | \$9.75/ft | 70,000 | \$11.88/ft | 2,500 | \$6.70 | 40,000 | \$5.63 |
| | LED Undercabinet Shelf-Mounted Task Light Fixtures | 35,000 | \$9.75/ft | 70,000 | \$11.88/ft | 2,500 | \$6.70 | 40,000 | \$5.63 |
| | LED Refrigerated Case Light, Horizontal or Vertical | 35,000 | \$8.63/ft | 70,000 | \$9.50/ft | 15,000 | \$1.13 | 40,000 | \$8.00 |
| | LED Freezer Case Light, Horizontal or Vertical | 35,000 | \$7.88/ft | 70,000 | \$7.92/ft | 12,000 | \$0.94 | 40,000 | \$6.67 |
| LED Linear Replacement Lamps | LED 4' Linear Replacement Lamp | 35,000 | \$8.57 | 70,000 | \$13.67 | 20,000 | \$6.17 | 70,000 | \$11.96 |
| | LED 2' Linear Replacement Lamp | 35,000 | \$5.76 | 70,000 | \$13.67 | 20,000 | \$6.17 | 70,000 | \$11.96 |

| LED Category | EE Measure Description | EE Measure | | | | Baseline | | | |
|-----------------------------|--|-----------------|-------------------------|-----------------------|-------------------------------|-----------------|-------------------------|--------------------|----------------------------|
| | | Lamp Life (hrs) | Total Lamp Replace Cost | LED Driver Life (hrs) | Total LED Driver Replace Cost | Lamp Life (hrs) | Total Lamp Replace Cost | Ballast Life (hrs) | Total Ballast Replace Cost |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 35,000 | \$46.68 | 70,000 | \$40.00 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| | LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 35,000 | \$56.31 | 70,000 | \$40.00 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| | LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 35,000 | \$49.58 | 70,000 | \$40.00 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| | LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 35,000 | \$57.76 | 70,000 | \$40.00 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| | LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 35,000 | \$68.89 | 70,000 | \$40.00 | 20,000 | \$22.68 | 70,000 | \$35.00 |
| | LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 35,000 | \$43.43 | 70,000 | \$40.00 | 20,000 | \$5.67 | 70,000 | \$35.00 |
| | LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 35,000 | \$52.31 | 70,000 | \$40.00 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| | LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 35,000 | \$63.86 | 70,000 | \$40.00 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, ≤ 3000 lumens | 35,000 | \$45.01 | 70,000 | \$40.00 | 20,000 | \$5.67 | 70,000 | \$35.00 |
| | LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 35,000 | \$58.73 | 70,000 | \$40.00 | 20,000 | \$11.34 | 70,000 | \$35.00 |
| | LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 35,000 | \$73.50 | 70,000 | \$40.00 | 20,000 | \$17.01 | 70,000 | \$35.00 |
| | LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 35,000 | \$88.69 | 70,000 | \$40.00 | 30,000 | \$26.33 | 70,000 | \$60.00 |
| | LED Surface & Suspended Linear Fixture, > 7500 lumens | 35,000 | \$123.91 | 70,000 | \$40.00 | 30,000 | \$39.50 | 70,000 | \$60.00 |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, ≤ 10,000 lumens | 35,000 | \$90.03 | 70,000 | \$62.50 | 18,000 | \$64.50 | 70,000 | \$92.50 |

| LED Category | EE Measure Description | EE Measure | | | | Baseline | | | |
|------------------------------------|--|-----------------|-------------------------|-----------------------|-------------------------------|-----------------|-------------------------|--------------------|----------------------------|
| | | Lamp Life (hrs) | Total Lamp Replace Cost | LED Driver Life (hrs) | Total LED Driver Replace Cost | Lamp Life (hrs) | Total Lamp Replace Cost | Ballast Life (hrs) | Total Ballast Replace Cost |
| | LED High-Bay Fixtures, 10,001-15,000 lumens | 35,000 | \$122.59 | 70,000 | \$62.50 | 18,000 | \$86.00 | 70,000 | \$92.50 |
| | LED High-Bay Fixtures, 15,001-20,000 lumens | 35,000 | \$157.22 | 70,000 | \$62.50 | 18,000 | \$129.00 | 70,000 | \$117.50 |
| | LED High-Bay Fixtures, > 20,000 lumens | 35,000 | \$228.52 | 70,000 | \$62.50 | 18,000 | \$172.00 | 70,000 | \$142.50 |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, ≤ 2,000 lumens | 35,000 | \$37.00 | 70,000 | \$40.00 | 1,000 | \$1.23 | 40,000 | \$26.25 |
| | LED Ag Interior Fixtures, 2,001-4,000 lumens | 35,000 | \$44.96 | 70,000 | \$40.00 | 1,000 | \$1.43 | 40,000 | \$26.25 |
| | LED Ag Interior Fixtures, 4,001-6,000 lumens | 35,000 | \$63.02 | 70,000 | \$40.00 | 1,000 | \$1.62 | 40,000 | \$26.25 |
| | LED Ag Interior Fixtures, 6,001-8,000 lumens | 35,000 | \$79.78 | 70,000 | \$40.00 | 1,000 | \$1.81 | 40,000 | \$26.25 |
| | LED Ag Interior Fixtures, 8,001-12,000 lumens | 35,000 | \$119.91 | 70,000 | \$62.50 | 15,000 | \$63.00 | 40,000 | \$112.50 |
| | LED Ag Interior Fixtures, 12,001-16,000 lumens | 35,000 | \$151.89 | 70,000 | \$62.50 | 15,000 | \$68.00 | 40,000 | \$122.50 |
| | LED Ag Interior Fixtures, 16,001-20,000 lumens | 35,000 | \$184.62 | 70,000 | \$62.50 | 15,000 | \$73.00 | 40,000 | \$132.50 |
| | LED Ag Interior Fixtures, > 20,000 lumens | 35,000 | \$285.75 | 70,000 | \$62.50 | 15,000 | \$136.00 | 40,000 | \$202.50 |
| LED Exterior Fixtures | LED Exterior Fixtures, ≤ 5,000 lumens | 35,000 | \$86.92 | 70,000 | \$62.50 | 15,000 | \$58.00 | 40,000 | \$102.50 |
| | LED Exterior Fixtures, 5,001-10,000 lumens | 35,000 | \$111.81 | 70,000 | \$62.50 | 15,000 | \$63.00 | 40,000 | \$112.50 |
| | LED Exterior Fixtures, 10,001-15,000 lumens | 35,000 | \$138.32 | 70,000 | \$62.50 | 15,000 | \$68.00 | 40,000 | \$122.50 |
| | LED Exterior Fixtures, > 15,000 lumens | 35,000 | \$223.67 | 70,000 | \$62.50 | 15,000 | \$73.00 | 40,000 | \$132.50 |

MEASURE CODE:

2.6.4 LED Screw Based Omnidirectional Bulb

DESCRIPTION

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to baseline EISA incandescent, halogen, or compact fluorescent lamps.

This specific characterization provides savings assumptions for LED lamps that replace standard screw-in connections (e.g., A-Type lamp) such as interior/exterior omnidirectional bulb options.

This characterization assumes that the LED is installed in a commercial location. This is, therefore, appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the residential versus nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W 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.

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.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new LED screw-based lamps must be ENERGY STAR[®] qualified based upon the ENERGY STAR[®] specification v2.0 which will become effective on 1/2/2017 (<https://www.energystar.gov/sites/default/files/Luminaires%20V2%200%20Final.pdf>).

Qualification could also be based on the Design Light Consortium's qualified product list.²⁰¹

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent. From 2020 the baseline will begin transitioning to a CFL²⁰² based upon what is available in the market and therefore a midlife adjustment is provided.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the product is the lamp life in hours divided by operating hours per year. Depending on operating conditions (currents and temperatures) and other factors (settings and building use), LED rated life is assumed to be 50,000 hours.²⁰³

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume \$3.26 (baseline cost of \$1.80 and efficient cost of \$5.06).²⁰⁴

²⁰¹ <https://www.designlights.org/QPL>

²⁰² 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.

²⁰³ LED Fixture Component Costs & Lifetime Table found on page 372 of the IL TRM v6.0 Volume 2.

²⁰⁴ Incandescent/halogen and LED cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

LOADSHAPE

Lighting BUSExt Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Watts_{Base} = Based on lumens of LED bulb installed

Watts_{EE} = Actual wattage of LED purchased/installed. If unknown, use default provided below.²⁰⁵

| Lower Lumen Range | Upper Lumen Range | Watts _{Base} | Watts _{EE} LED | Delta Watts |
|-------------------|-------------------|-----------------------|-------------------------|-------------|
| 250 | 309 | 25 | 4.0 | 21 |
| 310 | 749 | 29 | 6.7 | 22.3 |
| 750 | 1,049 | 43 | 10.1 | 32.9 |
| 1,050 | 1,489 | 53 | 12.8 | 40.2 |
| 1,490 | 2,600 | 72 | 17.4 | 54.6 |
| 2,601 | 3,000 | 150 | 43.1 | 106.9 |
| 3,001 | 3,999 | 200 | 53.8 | 146.2 |
| 4,000 | 6,000 | 300 | 76.9 | 223.1 |

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

ISR = In-Service Rate or the percentage of units rebated that get installed

²⁰⁵ Watts_{EE} defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, Watts_{EE} is based upon the ENERGY STAR® minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx.” These assumptions should be reviewed regularly to ensure they represent the available product.

$$= 98.7\%^{206}$$

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 to a CFL equivalent in 2020 due to the EISA backstop provision (except for <310 and 2600+ lumen lamps), the annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for 43W equivalent LED lamp installed in 2016, the full savings (as calculated above in the Algorithm) should be claimed for the first four years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) should be claimed for the remainder of the measure life.²⁰⁷

| Lower Lumen Range | Upper Lumen Range | Mid Lumen Range | Watts EE | WattsBase before EISA 2020 | Delta Watts before EISA 2020 | WattsBase after EISA 2020 ²⁰⁸ | Delta Watts after EISA 2020 | Mid Life adjustment (in 2020) to first year savings |
|-------------------|-------------------|-----------------|----------|----------------------------|------------------------------|--|-----------------------------|---|
| 250 | 309 | 280 | 4.0 | 25 | 21 | 25 | 21 | 100.0% |
| 310 | 749 | 530 | 6.7 | 29 | 22.3 | 9.4 | 2.7 | 12.1% |
| 750 | 1049 | 900 | 10.1 | 43 | 32.9 | 13.4 | 3.3 | 10.0% |
| 1050 | 1489 | 1270 | 12.8 | 53 | 40.2 | 18.9 | 6.1 | 15.2% |
| 1490 | 2600 | 2045 | 17.4 | 72 | 54.6 | 24.8 | 7.4 | 13.6% |
| 2,550 | 3,000 | 2,775 | 43.1 | 150 | 106.9 | 150 | 106.9 | 100.0% |
| 3,001 | 3,999 | 3,500 | 53.8 | 200 | 146.2 | 200 | 146.2 | 100.0% |
| 4,000 | 6,000 | 5,000 | 76.9 | 300 | 223.1 | 300 | 223.1 | 100.0% |

Heating Penalty:

If electrically heated building:²⁰⁹

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

²⁰⁶ Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

²⁰⁷ These adjustments should be applied to kW and gas impacts as well.

²⁰⁸ Calculated with EISA requirement of 45lumens/watt.

²⁰⁹ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
- = 0.0001899635 for indoor lighting
- = 0.0000056160 for exterior lighting
- = 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):²¹⁰

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

Where:

- IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the falling EISA-Qualified backdrop provision, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:²¹¹

| Incandescent / Halogen | CFL | LED A-Lamp |
|------------------------|--------|------------|
| \$1.80 | \$2.20 | \$5.06 |

The present value of replacement lamps and annual levelized replacement costs using utilities’ average real discount rate of 6.91% are presented below:

| Location | PV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|-------------|------------------------------------|-------------|-------------|---|-------------|-------------|
| | 2016 - 2017 | 2017 - 2018 | 2018 - 2019 | 2016 - 2017 | 2017 - 2018 | 2018 - 2019 |
| C&I Average | \$18.66 | \$14.70 | \$10.46 | \$2.04 | \$1.60 | \$1.14 |

²¹⁰ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

²¹¹ All cost assumptions based on Cadmus “LED Incremental Cost Study: Overall Final Report,” February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

Note: incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows. If unknown building type, assume C&I Average:

| Building Type | Replacement Period (years) ²¹² | Replacement Cost |
|------------------------------|---|-----------------------|
| Large Office | 0.32 | \$1.80 ²¹³ |
| Medium Office | 0.32 | |
| Small Office | 0.35 | |
| Warehouse | 0.35 | |
| Stand-alone Retail | 0.29 | |
| Strip Mall | 0.27 | |
| Primary School | 0.29 | |
| Secondary School | 0.29 | |
| Supermarket | 0.27 | |
| Quick Service Restaurant | 0.16 | |
| Full Service Restaurant | 0.16 | |
| Hospital | 0.26 | |
| Outpatient Health Care | 0.26 | |
| Small Hotel - Building | 0.27 | |
| Large Hotel - Building | 0.27 | |
| Midrise Apartment - Building | 0.35 | |
| C&I Average | 0.30 | |

MEASURE CODE:

²¹² Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA-qualified halogen/incandescent is 1000 hours (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)).

²¹³ Incandescent/halogen cost assumptions based on Cadmus “LED Incremental Cost Study: Overall Final Report,” February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

2.6.5 T5 Fixtures and Lamps

DESCRIPTION

T5 HO lamp/ballast systems have greater lumens per watt than a typical T8 system. The smaller lamp diameter of the T5HO also increases optical control efficiency and allows for more precise control and directional distribution of lighting. These characteristics make it easier to design light fixtures that can produce equal or greater light than standard T8 or T12 systems, while using fewer watts. In addition, when lighting designers specify T5 HO lamps/ballasts, they can use fewer luminaires per project, especially for large commercial projects, thus increasing energy savings further.²¹⁴

The main markets served by T5 HO fixtures and lamps include retrofit in the commercial and nonresidential sector, specifically industrial, warehouse, and grocery facilities with higher ceiling heights that require maximum light output.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The definition of the efficient equipment is T5 HO high-bay (>15ft mounting height) fixtures with 3, 4, 6, or 8-lamp configurations.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on number of lamps in a fixture and is defined in the baseline reference table at the end of this characterization. The default baseline is assumed to be a Pulse-Start Metal Halide fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of the efficient equipment fixture is 15 years.²¹⁵

DEEMED MEASURE COST

The deemed measure cost is found in Reference Table at the end of this characterization. For retrofit applications, actual costs should be used if available, or, if not available, \$10/lamp and \$37.50/ballast can be used to account for installation labor costs.

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

²¹⁴ Lighting Research Center. T5 Fluorescent Systems. <http://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/lat5/abstract.asp>

²¹⁵ Focus on Energy Evaluation “Business Programs: Measure Life Study” Final Report, August 9, 2009, prepared by PA Consulting Group.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

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

Where:

| | |
|-----------------------|--|
| Watts _{Base} | = Custom input. If unknown, input wattage of the baseline system is dependant on new fixture configuration and found in the ‘T5HO Efficient and Baseline Wattage and Cost Assumptions’ reference table below. |
| Watts _{EE} | = Custom Input. If unknown, input wattage depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the ‘T5HO Efficient and Baseline Wattage and Cost Assumptions’ reference table below. |
| Hours | = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.8 as annual operating hours, by building type. If hours or building type are unknown, use the C&I Average value. |
| WHF _e | = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 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. = 98%. ²¹⁶ |

Heating Penalty:If electrically heated building:²¹⁷

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

| | |
|-------|---|
| IFkWh | = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value. |
|-------|---|

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

| | |
|----|---|
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0001899635 for indoor lighting |
|----|---|

²¹⁶ Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD).

²¹⁷ Negative value because this is an increase in heating consumption due to the efficient lighting.

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):

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

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8.²¹⁸ If unknown, use the C&I Average value.

DEEMED O&M COST ADJUSTMENT CALCULATION

See reference tables for different cost assumptions for lamps and ballasts. When available, actual costs and hours of use should be used.

REFERENCE TABLES

T5HO Efficient and Baseline Wattage and Cost Assumptions²¹⁹

| EE Measure Description | WattsEE | Baseline Description | WattsBASE | Incremental Cost |
|------------------------|---------|-----------------------------------|-----------|------------------|
| 3-Lamp T5 High-Bay | 176 | 200 Watt Pulse Start Metal-Halide | 227 | \$100.00 |
| 4-Lamp T5 High-Bay | 235 | 320 Watt Pulse Start Metal-Halide | 364 | \$100.00 |
| 6-Lamp T5 High-Bay | 352 | 400 Watt Pulse Start Metal-Halide | 455 | \$100.00 |
| 8-Lamp T5 High-Bay | 470 | 750 Watt Pulse Start Metal-Halide | 825 | \$100.00 |

T5 HO Component Costs and Lifetimes²²⁰

| EE Measure Description | EE Measure | | | | Baseline | | | |
|------------------------|-----------------|-----------------------------|--------------------|--------------------------------|-----------------|-----------------------------|--------------------|--------------------------------|
| | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| 3-Lamp T5 High-Bay | 30,000 | \$63.00 | 70,000 | \$87.50 | 15,000 | \$63.00 | 40,000 | \$107.50 |
| 4-Lamp T5 High-Bay | 30,000 | \$84.00 | 70,000 | \$87.50 | 20,000 | \$68.00 | 40,000 | \$117.50 |
| 6-Lamp T5 High-Bay | 30,000 | \$126.00 | 70,000 | \$112.50 | 20,000 | \$73.00 | 40,000 | \$127.50 |
| 8-Lamp T5 High-Bay | 30,000 | \$168.00 | 70,000 | \$137.50 | 20,000 | \$78.00 | 40,000 | \$137.50 |

²¹⁸ Negative value because this is an increase in heating consumption due to the efficient lighting.

²¹⁹ Reference Table adapted from Efficiency Vermont TRM, T5 Measure Savings Algorithms and Cost Assumptions, October, 2014. Refer to “T5HO-adjusted deemed costs.baselines.xlsx” for more information.

²²⁰ Costs include labor cost – see “T5HO-adjusted deemed costs.baselines.xlsx” for more information.

MEASURE CODE:

2.6.6 LED Exit Sign

This measure characterizes the savings associated with installing a new LED exit sign (or retrofit kit) in place of a CFL or incandescent exit sign in a commercial building. LED exit signs use less power (≤ 5 watts), have a significantly longer lifetime, and have less maintenance costs when compared to incandescent or CFL exit signs.²²¹

This measure applies to the following program types: RF and DI.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is an LED exit sign with an input power demand of 5 watts or less.²²²

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the existing exit sign (either a CFL or incandescent unit).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 16 years.²²³

DEEMED MEASURE COST

Actual program delivery costs should be used if available. If not, use the full cost of \$39²²⁴ for a new LED exit sign and \$25 for a retrofit kit, plus \$6.25 in labor,²²⁵ for a total measure cost of \$45.25 and \$31.25, respectively.

LOADSHAPE

Miscellaneous BUS

²²¹ ENERGY STAR® “*Save Energy, Money and Prevent Pollution with LED Exit Signs.*”

²²² ENERGY STAR® “*Program Requirements for Exit Signs Version 3.0.*” While the EPA suspended the ENERGY STAR® Exit Sign specification effective May 1, 2008, Federal requirements specify minimum efficiency standards for electrically-powered, single-faced exit signs with integral lighting sources that are equivalent to ENERGY STAR® levels for input power demand of 5 watts or less per face.

²²³ California Database for Energy Efficiency Resources (DEER) 2014 Estimated Useful Life (EUL) Table Update.

²²⁴ Cost of new LED exit sign from ENERGY STAR® Exit Signs Calculator.xlsx.

²²⁵ Assumption based on 15 minutes (including portion of travel time) and \$25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor.

 Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS²²⁶

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

Where:

Watts_{Base} = Actual wattage if known, if unknown assume the following:

| Baseline Type | Watts _{Base} |
|-----------------------------|-----------------------|
| Incandescent (dual sided) | 50W ²²⁷ |
| Incandescent (single sided) | 25W |
| CFL (dual sided) | 14W ²²⁸ |
| CFL (single sided) | 7W |

Watts_{EE} = Actual wattage if known; if unknown assume 2W for singled sided and 4W.²²⁹ for dual sided

Hours = Annual operating hours
= 8,766

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}^{230} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 2.8. If unknown, use the C&I Average value.

Other factors as defined above.

²²⁶ There is no ISR calculation. Exit signs and emergency lighting are required by federal regulations to be installed and functional in all public buildings as outlined by the U.S. Occupational Safety and Health Standards (USOSHA 1993).

²²⁷ Average incandescent single sided (5W, 10W, 15W, 20W, 25W, 34W, 40W, 50W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at:

<http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

²²⁸ Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at:

<http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

²²⁹ Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages. Available at:

<http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

²²⁹ Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: <http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

²³⁰ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, including cooling savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439

Other factors as defined above.

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated buiding (or if heating is unknown):²³¹

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each building type.

Other factors as defined above.

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.

| Component | Baseline Measure | |
|-------------------|-----------------------|---------------------------|
| | Cost | Life (yrs) |
| CFL lamp | \$8.91 ²³² | 0.63 years ²³³ |
| Incandescent lamp | \$7.39 ²³⁴ | 0.14 years ²³⁵ |

²³¹ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

²³² Includes cost of labor and new replacement bulb. Labor cost of \$6.25 based on 15 minutes (including portion of travel time) and \$25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor. Cost of new 7W CFL bulb is \$2.66, from Itron “2010-2012 WO017 Ex Ante Measure Cost Study Final Report.” Prepared for California Public Utilities Commission, May 27, 2014.

²³³ ENERGY STAR® “Save Energy, Money and Prevent Pollution with LED Exit Signs” states that CFL bulbs for exit signs typically have an average rated life of 5,000-6,000 hours. Given 24/7 run time, assume a CFL in an exit sign will require replacement every 0.63 years (5,500 hours/8,766 hours).

²³⁴ Includes cost of labor and new replacement bulb. Labor cost of \$6.25 based on 15 minutes (including portion of travel time) and \$25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor. Cost of new 29W incandescent A-lamp is \$1.14, from Itron “2010-2012 WO017 Ex Ante Measure Cost Study Final Report.” Prepared for California Public Utilities Commission, May 27, 2014.

²³⁵ ENERGY STAR® “Save Energy, Money and Prevent Pollution with LED Exit Signs” states that a typical incandescent exit sign bulb will have a rated life of 500-2,000 hours. Given 24/7 run time, assume an incandescent in an exit sign will require replacement every 0.14 years (1,250 hours/8,766 hours).

MEASURE CODE:

2.6.7 LED Specialty Lamp

DESCRIPTION

This characterization provides savings assumptions for LED directional, decorative, and globe lamps. This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the EISA requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

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.

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.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR® labeled based upon the ENERGY STAR® specification v2.0 which will become effective on 1/2/2017. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf. Qualification could also be based on the Design Light Consortium's qualified product list.²³⁶

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent. From 2020 the baseline will begin transitioning to a CFL based upon what is available in the market.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the product is the lamp life in hours divided by operating hours per year. Depending on operating conditions (currents and temperatures) and other factors (settings and building use), LED rated life is assumed to be 50,000 hours.²³⁷

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:²³⁸

²³⁶ <https://www.designlights.org/QPL>

²³⁷ LED Fixture Component Costs & Lifetime Table found on page 372 of the IL TRM v6.0 Volume 2.

²³⁸ Incandescent based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report," Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year's worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; "Energy Savings Potential of Solid-State Lighting in General Illumination Applications," Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

| Bulb Type | LED Wattage | LED | Incandescent | Incremental Cost |
|-------------|-------------|---------|--------------|------------------|
| Directional | < 20W | \$14.52 | \$6.31 | \$8.21 |
| | ≥20W | \$45.85 | | \$39.54 |
| Decorative | <15W | \$8.09 | \$3.92 | \$4.17 |
| | 15 to <25W | \$15.86 | | \$11.94 |
| | ≥25W | \$15.86 | | \$11.94 |

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Watts_{Base} = Based on bulb type and lumens of LED bulb installed. See table below.

Watts_{EE} = Actual wattage of LED purchased / installed - If unknown, use default provided below:²³⁹

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Watts _{Base} | Watts _{EE} | Delta Watts |
|-------------|-------------------|-------------------|-----------------------|---------------------|-------------|
| Directional | 250 | 349 | 25 | 5.6 | 19.4 |
| | 350 | 399 | 35 | 6.3 | 28.7 |
| | 400 | 599 | 40 | 7.5 | 32.5 |
| | 600 | 749 | 60 | 9.7 | 50.3 |
| | 750 | 999 | 75 | 12.7 | 62.3 |
| | 1000 | 1250 | 100 | 16.2 | 83.8 |
| Decorative | 70 | 89 | 10 | 1.8 | 8.2 |
| | 90 | 149 | 15 | 2.7 | 12.3 |
| | 150 | 299 | 25 | 3.2 | 21.8 |
| | 300 | 499 | 40 | 4.7 | 35.3 |

²³⁹ Watt_{EE} defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, Watt_{EE} is based upon the ENERGY STAR® minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx.” These assumptions should be reviewed regularly to ensure they represent the available product.

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Watts _{Base} | Watts _{EE} | Delta Watts |
|-----------|-------------------|-------------------|-----------------------|---------------------|-------------|
| | 500 | 699 | 60 | 6.9 | 53.1 |
| Globe | 250 | 349 | 25 | 4.1 | 20.9 |
| | 350 | 499 | 40 | 5.9 | 34.1 |
| | 500 | 574 | 60 | 7.6 | 52.4 |
| | 575 | 649 | 75 | 13.6 | 61.4 |
| | 650 | 1099 | 100 | 17.5 | 82.5 |
| | 1100 | 1300 | 150 | 13.0 | 137.0 |

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

ISR = In Service Rate or the percentage of units rebated that get installed
 = 98.7%²⁴⁰

Heating Penalty:

If electrically heated building:²⁴¹

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001899635 for indoor lighting

²⁴⁰ Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

²⁴¹ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

for measure is provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

Other factors as defined above.

NATURAL GAS SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):²⁴²

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

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M cost should be applied as follows:

| Installation Location | Replacement Period (years) ²⁴³ | Replacement Cost ²⁴⁴ |
|------------------------------|---|---|
| Large Office | 0.32 | Decorative: \$6.31 Directional: \$3.92 |
| Medium Office | 0.32 | |
| Small Office | 0.35 | |
| Warehouse | 0.35 | |
| Stand-alone Retail | 0.29 | |
| Strip Mall | 0.27 | |
| Primary School | 0.29 | |
| Secondary School | 0.29 | |
| Supermarket | 0.27 | |
| Quick Service Restaurant | 0.16 | |
| Full Service Restaurant | 0.16 | |
| Hospital | 0.26 | |
| Outpatient Health Care | 0.26 | |
| Small Hotel - Building | 0.27 | |
| Large Hotel - Building | 0.27 | |
| Midrise Apartment - Building | 0.35 | |
| C&I Average | 0.30 | |

²⁴² Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

²⁴³ Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescent 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).

²⁴⁴ Incandescent costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report,” Itron, February 28, 2014.

MEASURE CODE:

2.6.8 Lighting Power Density

DESCRIPTION

This measure entails the installation of efficient lighting systems in either new construction or during substantial renovation of commercial buildings that triggers compliance with code. This methodology applies to situations where code specifies maximum lighting power density allowances (W/ft²). Either the Building Area Method or Space by Space (not recognized by IECC 2009) method as defined in IECC 2009, 2012 or 2015, can be used for calculating the Interior Lighting Power Density.²⁴⁵ The measure consists of a design that is more efficient (has a lower lighting power density in watts/square foot) than code requires.

This measure was developed to be applicable to the following program type: 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 the building code recognized by the local jurisdiction. For illustrative purposes in this characterization, IECC 2009, 2012 and 2015, are highlighted to demonstrate the methodology.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.²⁴⁶

DEEMED MEASURE COST

The actual incremental cost over a baseline system should be collected from the customer if possible, or quantified using an alternative suitable source.

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

$$\Delta\text{kWh} = (\text{WSF}_{\text{base}} - \text{WSF}_{\text{effic}}) / 1000 * \text{SF} * \text{Hours} * \text{WHF}_e$$

Where:

²⁴⁵ 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).

²⁴⁶ Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

| | |
|----------------------|---|
| WSF _{base} | = Baseline lighting watts per square foot or linear foot as determined by building or space type. IECC example whole building analysis values are presented in the Reference Tables below. ²⁴⁷ |
| WSF _{effic} | = The actual installed lighting watts per square foot or linear foot. |
| SF | = Provided by customer based on square footage of the building area applicable to the lighting design for new building. |
| Hours | = Annual site-specific hours of operation of the lighting equipment collected from the customer or selected from the Reference Table in Section 2.8 if unavailable. |
| WHF _e | = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 2.8 for each building type. If building is not cooled, the value is 1.0. |

Heating Penalty

If electrically heated building:

$$\Delta \text{kWh}_{\text{heatpenalty}}^{248} = (\text{WSF}_{\text{base}} - \text{WSF}_{\text{effic}}) / 1000 * \text{SF} * \text{Hours} * -\text{IFkWh}$$

Where:

| | |
|-------|--|
| IFkWh | = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 2.8. If unknown, use the C&I Average value. |
|-------|--|

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

| | |
|----|---|
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001899635 for indoor lighting |
| | = 0.0000056160 for exterior lighting |
| | = 0.0001379439 for 24/7 lighting |

Other factors as defined above

NATURAL GAS ENERGY SAVINGS

$$\Delta \text{Therms} = (\text{WSF}_{\text{base}} - \text{WSF}_{\text{effic}}) / 1000 * \text{SF} * \text{Hours} * -\text{IFTherms}$$

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 2.8 for each building type. |
|----------|--|

²⁴⁷See IECC 2009, 2012 and 2015 - Reference Code documentation for additional information.

²⁴⁸Negative value because this is an increase in heating consumption due to the efficient lighting.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLESLighting Power Density Values from IECC 2009, 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

| Building Area Type ²⁴⁹ | IECC 2009 Lighting Power Density (w/ft ²) | IECC 2012 Lighting Power Density (w/ft ²) | IECC 2015 Lighting Power Density (w/ft ²) |
|-----------------------------------|---|---|---|
| Automotive Facility | 0.9 | 0.9 | 0.80 |
| Convention Center | 1.2 | 1.2 | 1.01 |
| Court House | 1.2 | 1.2 | 1.01 |
| Dining: Bar Lounge/Leisure | 1.3 | 1.3 | 1.01 |
| Dining: Cafeteria/Fast Food | 1.4 | 1.4 | 0.9 |
| Dining: Family | 1.6 | 1.6 | 0.95 |
| Dormitory | 1.0 | 1.0 | 0.57 |
| Exercise Center | 1.0 | 1.0 | 0.84 |
| Fire station | 1.0 | 0.8 | 0.67 |
| Gymnasium | 1.1 | 1.1 | 0.94 |
| Healthcare – clinic | 1.0 | 1.0 | 0.90 |
| Hospital | 1.2 | 1.2 | 1.05 |
| Hotel | 1.0 | 1.0 | 0.87 |
| Library | 1.3 | 1.3 | 1.19 |
| Manufacturing Facility | 1.3 | 1.3 | 1.17 |
| Motel | 1.0 | 1.0 | 0.87 |
| Motion Picture Theater | 1.2 | 1.2 | 0.76 |
| Multifamily | 0.7 | 0.7 | 0.51 |
| Museum | 1.1 | 1.1 | 1.02 |
| Office | 1.0 | 0.9 | 0.82 |
| Parking Garage | 0.3 | 0.3 | 0.21 |
| Penitentiary | 1.0 | 1.0 | 0.81 |
| Performing Arts Theater | 1.6 | 1.6 | 1.39 |
| Police Station | 1.0 | 1.0 | 0.87 |
| Post Office | 1.1 | 1.1 | 0.87 |
| Religious Building | 1.3 | 1.3 | 1.0 |
| Retail ²⁵⁰ | 1.5 | 1.4 | 1.26 |
| School/University | 1.2 | 1.2 | 0.87 |
| Sports Arena | 1.1 | 1.1 | 0.91 |
| Town Hall | 1.1 | 1.1 | 0.89 |
| Transportation | 1.0 | 1.0 | 0.70 |
| Warehouse | 0.8 | 0.6 | 0.66 |
| Workshop | 1.4 | 1.4 | 1.19 |

²⁴⁹ 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.

²⁵⁰ Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the small of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.

Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

COMMERCIAL ENERGY EFFICIENCY

TABLE C405.5.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft ²) |
|---|--------------------------|
| Atrium – First 40 feet in height | 0.03 per ft. ht. |
| Atrium – Above 40 feet in height | 0.02 per ft. ht. |
| Audience/seating area – permanent | |
| For auditorium | 0.9 |
| For performing arts theater | 2.6 |
| For motion picture theater | 1.2 |
| Classroom/lecture/training | 1.30 |
| Conference/meeting/multipurpose | 1.2 |
| Corridor/transition | 0.7 |
| Dining area | |
| Bar/lounge/leisure dining | 1.40 |
| Family dining area | 1.40 |
| Dressing/fitting room performing arts theater | 1.1 |
| Electrical/mechanical | 1.10 |
| Food preparation | 1.20 |
| Laboratory for classrooms | 1.3 |
| Laboratory for medical/industrial/research | 1.8 |
| Lobby | 1.10 |
| Lobby for performing arts theater | 3.3 |
| Lobby for motion picture theater | 1.0 |
| Locker room | 0.80 |
| Lounge recreation | 0.8 |
| Office – enclosed | 1.1 |
| Office – open plan | 1.0 |
| Restroom | 1.0 |
| Sales area | 1.6 ^a |
| Stairway | 0.70 |
| Storage | 0.8 |
| Workshop | 1.60 |
| Courthouse/police station/penitentiary | |
| Courtroom | 1.90 |
| Confinement cells | 1.1 |
| Judge chambers | 1.30 |
| Penitentiary audience seating | 0.5 |
| Penitentiary classroom | 1.3 |
| Penitentiary dining | 1.1 |
| BUILDING SPECIFIC SPACE-BY-SPACE TYPES | |
| Automotive – service/repair | 0.70 |
| Bank/office – banking activity area | 1.5 |
| Dormitory living quarters | 1.10 |
| Gymnasium/fitness center | |
| Fitness area | 0.9 |
| Gymnasium audience/seating | 0.40 |
| Playing area | 1.40 |

(continued)

TABLE C405.5.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft ²) |
|---|--------------------------|
| Healthcare clinic/hospital | |
| Corridors/transition | 1.00 |
| Exam/treatment | 1.70 |
| Emergency | 2.70 |
| Public and staff lounge | 0.80 |
| Medical supplies | 1.40 |
| Nursery | 0.9 |
| Nurse station | 1.00 |
| Physical therapy | 0.90 |
| Patient room | 0.70 |
| Pharmacy | 1.20 |
| Radiology/imaging | 1.3 |
| Operating room | 2.20 |
| Recovery | 1.2 |
| Lounge/recreation | 0.8 |
| Laundry – washing | 0.60 |
| Hotel | |
| Dining area | 1.30 |
| Guest rooms | 1.10 |
| Hotel lobby | 2.10 |
| Highway lodging dining | 1.20 |
| Highway lodging guest rooms | 1.10 |
| Library | |
| Stacks | 1.70 |
| Card file and cataloguing | 1.10 |
| Reading area | 1.20 |
| Manufacturing | |
| Corridors/transition | 0.40 |
| Detailed manufacturing | 1.3 |
| Equipment room | 1.0 |
| Extra high bay (> 50-foot floor-ceiling height) | 1.1 |
| High bay (25- – 50-foot floor-ceiling height) | 1.20 |
| Low bay (< 25-foot floor-ceiling height) | 1.2 |
| Museum | |
| General exhibition | 1.00 |
| Restoration | 1.70 |
| Parking garage – garage areas | 0.2 |
| Convention center | |
| Exhibit space | 1.50 |
| Audience/seating area | 0.90 |
| Fire stations | |
| Engine room | 0.80 |
| Sleeping quarters | 0.30 |
| Post office | |
| Sorting area | 0.9 |
| Religious building | |
| Fellowship hall | 0.60 |
| Audience seating | 2.40 |
| Worship pulpit/choir | 2.40 |
| Retail | |
| Dressing/fitting area | 0.9 |
| Mall concourse | 1.6 |
| Sales area | 1.6 ^a |

(continued)

**TABLE C405.5.2(2)—continued
 INTERIOR LIGHTING POWER ALLOWANCES:
 SPACE-BY-SPACE METHOD**

| BUILDING SPECIFIC SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|-------------------------------|
| Sports arena | |
| Audience seating | 0.4 |
| Court sports area – Class 4 | 0.7 |
| Court sports area – Class 3 | 1.2 |
| Court sports area – Class 2 | 1.9 |
| Court sports area – Class 1 | 3.0 |
| Ring sports area | 2.7 |
| Transportation | |
| Air/train/bus baggage area | 1.00 |
| Airport concourse | 0.60 |
| Terminal – ticket counter | 1.50 |
| Warehouse | |
| Fine material storage | 1.40 |
| Medium/bulky material | 0.60 |

Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

**TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

| COMMON SPACE TYPES* | LPD (watts/sq.ft) |
|--|--------------------------------------|
| Atrium | |
| Less than 40 feet in height | 0.03 per foot in total height |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height |
| Audience seating area | |
| In an auditorium | 0.63 |
| In a convention center | 0.82 |
| In a gymnasium | 0.65 |
| In a motion picture theater | 1.14 |
| In a penitentiary | 0.28 |
| In a performing arts theater | 2.43 |
| In a religious building | 1.53 |
| In a sports arena | 0.43 |
| Otherwise | 0.43 |
| Banking activity area | 1.01 |
| Breakroom (See Lounge/Breakroom) | |
| Classroom/lecture hall/training room | |
| In a penitentiary | 1.34 |
| Otherwise | 1.24 |
| Conference/meeting/multipurpose room | 1.23 |
| Copy/print room | 0.72 |
| Corridor | |
| In a facility for the visually impaired (and not used primarily by the staff) ^b | 0.92 |
| In a hospital | 0.79 |
| In a manufacturing facility | 0.41 |
| Otherwise | 0.66 |
| Courtroom | 1.72 |
| Computer room | 1.71 |
| Dining area | |
| In a penitentiary | 0.96 |
| In a facility for the visually impaired (and not used primarily by the staff) ^b | 1.9 |
| In bar/lounge or leisure dining | 1.07 |
| In cafeteria or fast food dining | 0.65 |
| In family dining | 0.89 |
| Otherwise | 0.65 |
| Electrical/mechanical room | 0.95 |
| Emergency vehicle garage | 0.56 |

(continued)

**TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

| COMMON SPACE TYPES* | LPD (watts/sq.ft) |
|--|--------------------------|
| Food preparation area | 1.21 |
| Guest room | 0.47 |
| Laboratory | |
| In or as a classroom | 1.43 |
| Otherwise | 1.81 |
| Laundry/washing area | 0.6 |
| Loading dock, interior | 0.47 |
| Lobby | |
| In a facility for the visually impaired (and not used primarily by the staff) ^b | 1.8 |
| For an elevator | 0.64 |
| In a hotel | 1.06 |
| In a motion picture theater | 0.59 |
| In a performing arts theater | 2.0 |
| Otherwise | 0.9 |
| Locker room | 0.75 |
| Lounge/breakroom | |
| In a healthcare facility | 0.92 |
| Otherwise | 0.73 |
| Office | |
| Enclosed | 1.11 |
| Open plan | 0.98 |
| Parking area, interior | 0.19 |
| Pharmacy area | 1.68 |
| Restroom | |
| In a facility for the visually impaired (and not used primarily by the staff) ^b | 1.21 |
| Otherwise | 0.98 |
| Sales area | 1.59 |
| Seating area, general | 0.54 |
| Stairway (See space containing stairway) | |
| Stairwell | 0.69 |
| Storage room | 0.63 |
| Vehicular maintenance area | 0.67 |
| Workshop | 1.59 |
| BUILDING TYPE SPECIFIC SPACE TYPES* | LPD (watts/sq.ft) |
| Facility for the visually impaired^b | |
| In a chapel (and not used primarily by the staff) | 2.21 |
| In a recreation room (and not used primarily by the staff) | 2.41 |
| Automotive (See Vehicular Maintenance Area above) | |
| Convention Center—exhibit space | 1.45 |
| Dormitory—living quarters | 0.38 |
| Fire Station—sleeping quarters | 0.22 |
| Gymnasium/fitness center | |
| In an exercise area | 0.72 |
| In a playing area | 1.2 |

(continued)

**TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

| BUILDING TYPE SPECIFIC SPACE TYPES ^a | LPD (watts/sq.ft) |
|--|-------------------|
| healthcare facility | |
| In an exam/treatment room | 1.66 |
| In an imaging room | 1.51 |
| In a medical supply room | 0.74 |
| In a nursery | 0.88 |
| In a nurse's station | 0.71 |
| In an operating room | 2.48 |
| In a patient room | 0.62 |
| In a physical therapy room | 0.91 |
| In a recovery room | 1.15 |
| Library | |
| In a reading area | 1.06 |
| In the stacks | 1.71 |
| Manufacturing facility | |
| In a detailed manufacturing area | 1.29 |
| In an equipment room | 0.74 |
| In an extra high bay area (greater than 50' floor-to-ceiling height) | 1.05 |
| In a high bay area (25-50' floor-to-ceiling height) | 1.23 |
| In a low bay area (less than 25' floor-to-ceiling height) | 1.19 |
| Museum | |
| In a general exhibition area | 1.05 |
| In a restoration room | 1.02 |
| Performing arts theater—dressing room | 0.61 |
| Post Office—Sorting Area | 0.94 |
| Religious buildings | |
| In a fellowship hall | 0.64 |
| In a worship/pulpit/choir area | 1.53 |
| Retail facilities | |
| In a dressing/fitting room | 0.71 |
| In a mall concourse | 1.1 |
| Sports arena—playing area | |
| For a Class I facility | 3.68 |
| For a Class II facility | 2.4 |
| For a Class III facility | 1.8 |
| For a Class IV facility | 1.2 |
| Transportation facility | |
| In a baggage/carousel area | 0.53 |
| In an airport concourse | 0.36 |
| At a terminal ticket counter | 0.8 |
| Warehouse—storage area | |
| For medium to bulky, palletized items | 0.58 |
| For smaller, hand-carried items | 0.95 |

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
 b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

The exterior lighting design will be based on the building location and the applicable “Lighting Zone” as defined in

IECC 2015 Table C405.5.2(1) which follows. This table is identical to IECC 2012 Table C405.6.2(1) and IECC 2009 Table 505.6.2(1).

**TABLE C405.5.2(1)
EXTERIOR LIGHTING ZONES**

| LIGHTING ZONE | DESCRIPTION |
|---------------|--|
| 1 | Developed areas of national parks, state parks, forest land, and rural areas |
| 2 | Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas |
| 3 | All other areas not classified as lighting zone 1, 2 or 4 |
| 4 | High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority |

The lighting power density savings will be based on reductions below the allowable design levels as specified in IECC 2009 Table 505.6.2(2), IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).

Allowable Design Levels from IECC 2009:

TABLE 505.6.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|--|---|---|---|
| Base Site Allowance (Base allowance may be used in tradable or nontradable surfaces.) | | 500W | 600W | 750W | 1300W |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.) | Uncovered Parking Areas | | | | |
| | Parking areas and drives | 0.04 W/ft ² | 0.06 W/ft ² | 0.10 W/ft ² | 0.13 W/ft ² |
| | Building Grounds | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft ² | 0.14 W/ft ² | 0.16 W/ft ² | 0.2 W/ft ² |
| | Stairways | 0.75 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² |
| | Pedestrian tunnels | 0.15 W/ft ² | 0.15 W/ft ² | 0.2 W/ft ² | 0.3 W/ft ² |
| | Building Entrances and Exits | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft ² | 0.25 W/ft ² | 0.4 W/ft ² | 0.4 W/ft ² |
| | Sales Canopies | | | | |
| | Free-standing and attached | 0.6 W/ft ² | 0.6 W/ft ² | 0.8 W/ft ² | 1.0 W/ft ² |
| | Outdoor Sales | | | | |
| Open areas (including vehicle sales lots) | 0.25 W/ft ² | 0.25 W/ft ² | 0.5 W/ft ² | 0.7 W/ft ² | |
| Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10W/linear foot | 10W/linear foot | 30 W/linear foot | |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.1 W/ft ² for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length | 0.15 W/ft ² for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length | 0.2 W/ft ² for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| | Automated teller machines and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

Allowable Design Levels from IECC 2012:

**TABLE C405.6.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

| | | LIGHTING ZONES | | | |
|---|---|--|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| Uncovered Parking Areas | | | | | |
| | Parking areas and drives | 0.04 W/ft ² | 0.06 W/ft ² | 0.10 W/ft ² | 0.13 W/ft ² |
| Building Grounds | | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft ² | 0.14 W/ft ² | 0.16 W/ft ² | 0.2 W/ft ² |
| | Stairways | 0.75 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² |
| | Pedestrian tunnels | 0.15 W/ft ² | 0.15 W/ft ² | 0.2 W/ft ² | 0.3 W/ft ² |
| Building Entrances and Exits | | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft ² | 0.25 W/ft ² | 0.4 W/ft ² | 0.4 W/ft ² |
| Sales Canopies | | | | | |
| | Free-standing and attached | 0.6 W/ft ² | 0.6 W/ft ² | 0.8 W/ft ² | 1.0 W/ft ² |
| Outdoor Sales | | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft ² | 0.25 W/ft ² | 0.5 W/ft ² | 0.7 W/ft ² |
| | Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.1 W/ft ² for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length | 0.15 W/ft ² for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length | 0.2 W/ft ² for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| | Automated teller machines and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

Allowable Design Levels from IECC 2015:

TABLE C405.5.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

| | | LIGHTING ZONES | | | |
|---|---|--|--|--|--|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.) | Uncovered Parking Areas | | | | |
| | Parking areas and drives | 0.04 W/ft ² | 0.06 W/ft ² | 0.10 W/ft ² | 0.13 W/ft ² |
| | Building Grounds | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft ² | 0.14 W/ft ² | 0.16 W/ft ² | 0.2 W/ft ² |
| | Stairways | 0.75 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² | 1.0 W/ft ² |
| | Pedestrian tunnels | 0.15 W/ft ² | 0.15 W/ft ² | 0.2 W/ft ² | 0.3 W/ft ² |
| | Building Entrances and Exits | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft ² | 0.25 W/ft ² | 0.4 W/ft ² | 0.4 W/ft ² |
| | Sales Canopies | | | | |
| | Free-standing and attached | 0.6 W/ft ² | 0.6 W/ft ² | 0.8 W/ft ² | 1.0 W/ft ² |
| | Outdoor Sales | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft ² | 0.25 W/ft ² | 0.5 W/ft ² | 0.7 W/ft ² |
| Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot | |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.075 W/ft ² of gross above-grade wall area | 0.113 W/ft ² of gross above-grade wall area | 0.15 W/ft ² of gross above-grade wall area |
| | Automated teller machines (ATM) and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area | 0.75 W/ft ² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area | 0.5 W/ft ² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².
W = watts.

MEASURE CODE:

2.6.9 Metal Halide Fixtures and Lamps

DESCRIPTION

This measure involves the installation of high efficiency pulse start metal halide fixtures and lamps in place of a standard metal halide. Pulse start metal halide luminaires produce more lumens per watt and have an improved lumen maintenance compared to standard probe start technology. Similarly, the high efficiency pulse start metal halide ballast lasts longer than a standard system due to their cooler operating temperatures.²⁵¹

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an EISA-compliant pulse start metal halide lamp and ballasts for luminaires. Under 2009 federal rulings metal halide ballasts in low-watt options (150W-500W fixtures) must be pulse start and have a minimum ballast efficiency of 88%.²⁵² Amendments made in 2014 require more stringent energy conservation standards with compliance required by February 10, 2017.²⁵³

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing bulb and fixture. If unknown assume, High Intensity Discharge (HID) Metal Halide lighting with probe start fixture and a standard \leq 400 Watt lamp.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.²⁵⁴

DEEMED MEASURE COST

As a retrofit measure, actual costs should be used. If unknown, cost is assumed to be \$267.²⁵⁵

LOADSHAPE

Lighting BUS

Ext Lighting BUS

²⁵¹ Building a Brighter Future: Your Guide to EISA-Compliant Ballast and Lamp Solutions from Philips Lighting: <http://1000bulbs.com/pdf/advance%20eisa%20brochure.pdf>

²⁵² Under EISA rulings, metal halide ballasts in low-watt options must be pulse start and have a minimum ballast efficiency of 88%. This ruling virtually eliminates the manufacture of probe start (ceramic) fixtures but some exemptions exist including significantly the 150w wet location fixtures (as rated per NEC 2002, section 410.4 (A)). These will be replaced by 150W. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations <https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9>

²⁵³ The revised 2014 efficiency standards for metal halides require that luminaires produced on or after February 10, 2017, must **not** contain a probe-start metal halide ballast. Exceptions to this ruling include, metal halide luminaires with a regulated-lag ballast that utilize an electronic ballasts which operates at 480V and those which utilize a high-frequency (\geq 1000Hz) electronic ballast. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations <https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9>

²⁵⁴ GDS Associates, *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*, June 2007, http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

²⁵⁵ Assuming cost of lamp and fixture combined per Itron, Inc. 2010-2012 WO017 Ex Ante Measure Cost Study – Final Report (*Deemed Measures*), May 27, 2014.

Miscellaneous BUS

 Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta\text{kWh} = \frac{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}}{1,000} * \text{Hours} * \text{WHF}_e * \text{ISR}$$

Where:

$\text{Watts}_{\text{Base}}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp). Value can be selected from the reference table at the end of the characterization or a custom value can be used.

Watts_{EE} = New Input wattage of EE fixture, which depends on new fixture configuration. Value can be selected from the appropriate reference table at the end of the characterization, or a custom value can be used.

Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.8. If hours or building type are unknown, use the C&I Average value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate is assumed to be 100%

Heating Penalty:

If electrically heated building:

$$\Delta\text{kWh}_{\text{heatpenalty}}^{256} = \frac{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}}{1,000} * \text{ISR} * \text{Hours} * (-\text{IFkWh})$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 2.8. If unknown, use the C&I Average value.

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

ΔkWh = as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001899635 for indoor lighting
 = 0.0000056160 for exterior lighting

²⁵⁶Negative value because this is an increase in heating consumption due to the efficient lighting.

= 0.0001379439 for 24/7 lighting

NATURAL GAS SAVINGS

$$\Delta\text{Therms}^{257} = \frac{\text{Watts}_{\text{Base}} - \text{Watts}_{\text{EE}}}{1,000} * \text{ISR} * \text{Hours} * (-\text{IFTherms})$$

Where:

IFTherms = Lighting-HVAC Interaction 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 2.8 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

No O&M adjustments apply to this measure.²⁵⁸

REFERENCE TABLES²⁵⁹

| Lamp Watt _{EE} | Efficient Fixture Ballast | Efficient System Lumen | System Watt _{EE} | Lamp Watt _{Base} | Baselines Ballast ²⁶⁰ | System Watts _{Base} | Baseline System Lumen |
|-------------------------|---------------------------|------------------------|---------------------------|---------------------------|----------------------------------|------------------------------|-----------------------|
| Pulse Start MH 150W | Pulse Start-CWA Ballast | 10500 | 185 | Probe Start MH 175W | standard C&C | 210 | 9100 |
| Pulse Start MH 175W | Pulse Start-CWA Ballast | 11200 | 208 | Probe Start MH 175W | standard C&C | 210 | 9100 |
| Pulse Start MH 200W | Pulse Start-CWA Ballast | 16800 | 232 | Probe Start MH250W | standard C&C | 295 | 13500 |
| Pulse Start MH 250W | Pulse Start-CWA Ballast | 16625 | 290 | Probe Start MH250W | standard C&C | 295 | 13500 |
| Pulse Start MH 320W | Pulse Start-CWA Ballast | 21000 | 368 | Probe Start MH400W | standard C&C | 458 | 24000 |
| Pulse Start MH350W | Pulse Start-CWA Ballast | 25200 | 400 | Probe Start MH400W | standard C&C | 458 | 24000 |
| Pulse Start MH 400W | Pulse Start-CWA Ballast | 29820 | 452 | Probe Start MH400W | standard C&C | 458 | 24000 |

MEASURE CODE:

²⁵⁷ Negative value because this is an increase in heating consumption due to the efficient lighting.

²⁵⁸ Given that probe start MH technology is becoming a technology of the past, it is assumed that upon failure they would have been replaced with pulse start technology.

²⁵⁹ Per lamp/ballast.

²⁶⁰ Standard Magnetic Core and Coil ballast systems are common for Metal Halide lamp wattages 175-400. See Panasonic “Metal Halide: Probe Start vs. Pulse Start.”

2.6.10 Occupancy Lighting Sensor Controls

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels by turning lights on or off in response to the presence (or absence) of people in a defined area. Associated energy savings depends on the building type, location area covered, type of lighting and activity, and occupancy pattern.²⁶¹

This measure relates to the installation of interior occupancy sensors on an existing lighting system. Lighting control types covered by this measure include switch-mounted, remote-mounted, and fixture-mounted. It does not cover automatic photo sensors, time clocks, and energy management systems. All sensors must be hard wired and control interior lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

It is assumed that this measure characterization applies to only those automatic controlled lighting occupancy sensors that control a minimum average wattage greater than 45W per control.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with no occupancy controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years.²⁶²

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

| Lighting control type | Cost ²⁶³ |
|--|---------------------|
| Full cost of switch (wall) mounted occupancy sensor (interior) | \$54 |
| Full cost of fixture (bi-level) mounted occupancy sensor | \$67 |
| Full cost of remote (ceiling) mounted occupancy sensor | \$105 |

LOADSHAPE

Lighting BUS

Miscellaneous BUS

²⁶¹ United States Department of the Interior. Greening the Department of Interior.

<http://www.doi.gov/archive/greening/energy/occupy.html>

²⁶² Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

²⁶³ Based on averaging typical prices quoted by online vendors. See reference table "Occupancy Sensor Reference Costs 2015.xls" for more information.

Ext Lighting BUS Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = kW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer, or use the default values presented below used;

| Lighting Control Type Interior | Default kW controlled ²⁶⁴ |
|---|--------------------------------------|
| Switch (wall) mounted occupancy sensor | 0.304 (per control) |
| Fixture-mounted occupancy sensor | 0.180 (per fixture) |
| Remote (ceiling) mounted occupancy sensor | 0.517 (per control) |

Hours = The total annual operating hours of lighting for each type of building before occupancy sensors. This number should be collected from the customer. If no data is available, the deemed average number of operating hours by building type should be used as provided by Lighting Reference Table in Section 2.8. If building type is unknown, use the C&I Average value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis or using the default values below:

| Lighting Control Type | Energy Savings Factor ²⁶⁵ |
|---|--------------------------------------|
| Switch (wall) mounted occupancy sensor | 24% |
| Fixture-mounted sensor | 24% |
| Remote (ceiling) mounted occupancy sensor | 24% |

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 2.8.

Heating Penalty:

If electrically heated building:²⁶⁶

²⁶⁴ Based on review of custom Efficiency Vermont program data of installed occupancy sensors from 2009-2014. See reference table "Updated-Occupancy-Sensor-ReferenceCosts-7-30-15.xls."

²⁶⁵ Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Page & Associates Inc. 2011.

<http://eetd.lbl.gov/publications/meta-analysis-energy-savings-lighting-controls-commercial-buildings>.

LBNL's meta study of energy savings from lighting controls in commercial buildings bases its savings analysis on over 240 actual field installations. The report found that savings are over-represented and do not filter for external factors such as building orientation, location, use, weather, blinds, commissioning, changes in behavior after controls are set, etc. As such, their value of 24% represented the best conservative estimate of occupancy controls energy savings achievable in the field today.

²⁶⁶Negative value because this is an increase in heating consumption due to the efficient lighting.

$$\Delta kWh_{heatpenalty} = kW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table 2.8.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = As calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor.
 = 0.0001899635 for indoor lighting
 = 0.0000056160 for exterior lighting

Natural Gas Energy Savings

If gas heated building (or unknown):

$$\Delta Therms = kW_{Controlled} * Hours * ESF * -IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the Lighting Reference Table in Section 2.8 by building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.6.11 Street Lighting

DESCRIPTION

This measure characterizes the savings associated with LED street lighting conversions where a LED fixture replaces a high-intensity discharge (HID) outdoor lighting system, including metal halide, high pressure sodium, and mercury vapor. LED street lights provide considerable benefits compared to HID lights, including:

- Improved nighttime visibility and safety through better color rendering, more uniform light distribution and elimination of dark areas between poles.
- Reduced direct and reflected uplight which are the primary causes of urban sky glow.
- 40-80% energy savings (dependent on incumbent lighting source).
- 50-75% street lighting maintenance savings.²⁶⁷

This measure includes LED fixture housings including cobrahead and post-top and is applicable only where utility tariffs support LED street lighting conversions.

This measure was developed to be applicable for a one-to-one RF opportunity only.²⁶⁸

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment must be an LED fixture that meets the United Illuminating Rate Schedule, alongside all other luminary performance requirements, based on site characteristics²⁶⁹ and all local, state and federal codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the existing lighting system – a metal halide, high pressure sodium, or mercury vapor outdoor lamp, ballast, and fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12.5 years.²⁷⁰

²⁶⁷ See NEEP “LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic,” January 2015, and the Municipal Solid State Street Lighting Consortium for more information <http://www1.eere.energy.gov/buildings/ssl/consortium.html>

²⁶⁸ Many light fixtures were placed in service 20-50 years ago and may no longer service their intended purpose. It is important to conduct a comprehensive assessment of lighting needs with a lighting professional when considering a LED street lighting project. LED street lighting can result in removal of lighting altogether as LED lights provide better CRI and lighting levels than existing HID lighting types. While this measure only characterizes a one-to-one replacement value, it is recommended that this measure be updated following a Missouri assessment to see where LED street lighting has resulted in the removal of street lighting to ensure additional savings calculations are captured. Recommend using Street and Parking Facility Lighting Retrofit Financial Analysis Tool developed by DOE Municipal Solid-State Street Lighting Consortium and the Federal Energy Management Program.

²⁶⁹ See DOE Municipal Solid-State Street Lighting Consortium “Model Specifications for LED Roadway Luminaires v.2.0,” July 2014.

²⁷⁰ The measure lifetime is calculated using 4,000 annual hours of use from Ameren Missouri “Light Emitting Diode (LED) Street and Area Lighting Report,” July 2013 and a typical LED streetlight lifetime of 50,000 hours from Massachusetts Department of Energy Resources “LED Streetlights: What is Your Plan? (webinar),” September 11, 2013.

DEEMED MEASURE COST

Actual measure installation cost should be used, including material and labor.²⁷¹ If the actual cost of the LED unit is unknown, use the default values for typical LED streetlight retrofits provided below.²⁷²

| Fixture Type | Light output | | | | | |
|---------------------|--------------|----------|----------------|----------|--------------|------------|
| | Low (<50W) | | Med (50W-100W) | | High (>100W) | |
| | min | max | min | max | min | max |
| Decorative/Post Top | \$350.00 | \$615.00 | \$550.00 | \$950.00 | \$750.00 | \$1,450.00 |
| Cobrahead | \$99.00 | \$225.00 | \$179.00 | \$451.00 | \$310.00 | \$720.00 |

LOADSHAPE

Ext Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS²⁷³

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

Where:

- Watts_{Base} = Actual wattage if known, if unknown assume the following nominal wattage based on technology²⁷⁴
- Metal Halide = 554W
- High Pressure Sodium = 157W
- Mercury Vapor = 228W
- Watts_{EE} = Actual wattage²⁷⁵
- Hours = Annual operating hours
= 4,000 hours²⁷⁶

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer peak savings should be claimed for street lighting, as street lights are not expected to be operational during system peak loads.

NATURAL GAS ENERGY SAVINGS

N/A

²⁷¹ Labor should include the removal of the old fixture and installation of the new fixture. Assume the typical prevailing wage as per the Annual Wage Order No. 23 published by the Missouri Department of Labor.

²⁷² LED unit costs from New York State Energy Research and Development Authority “Street Lighting in New York State: Opportunities and Challenges,” Revised January 2015.

²⁷³ There is no ISR input. Savings are per unit.

²⁷⁴ Baseline wattages are a weighted average of products evaluated in Ameren Missouri “Light Emitting Diode (LED) Street and Area Lighting Report,” July 2013. See “Street Lighting_Baseline Wattages.xlsx.”

²⁷⁵ It is important to ensure that retrofit opportunities base efficient wattage on a lumen per watt equivalence.

²⁷⁶ Ameren Missouri “Light Emitting Diode (LED) Street and Area Lighting Report,” July 2013.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Annual O&M savings are estimated at \$50/LED streetlight.²⁷⁷

MEASURE CODE:

²⁷⁷ New York State Energy Research and Development Authority “Street Lighting in New York State: Opportunities and Challenges,” Revised January 2015.

2.7 Miscellaneous

2.7.1 Laptop Computer

DESCRIPTION

This measure estimates savings for a laptop (or notebook) computer with that has been certified by ENERGY STAR® (ES) Version 6.0.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is laptop meeting the requirements set forth by ENERGY STAR® Version 6.0.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR® qualified laptop.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.²⁷⁸

DEEMED MEASURE COST²⁷⁹

The incremental cost is \$5.

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS²⁸⁰

$$\Delta kWh = \text{Hours}_{\text{idle}} * (P_{\text{idle_base}} - P_{\text{idle_eff}}) + \text{Hours}_{\text{sleep}} * (P_{\text{sleep_base}} - P_{\text{sleep_eff}}) + \text{Hours}_{\text{off}} * (P_{\text{off_base}} - P_{\text{off_eff}})$$

Where:

$\text{Hours}_{\text{idle}}$ = Annual hours the computer is on and idling. Custom input or based on usage pattern (see table below).

$P_{\text{idle_base}}$ = Power draw (kW) of baseline unit while idling. Based on computer performance level (see table below).

$P_{\text{idle_eff}}$ = Power draw (kW) of efficient unit while idling. Based on computer performance level (see table below).

²⁷⁸ Based on Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.”

²⁷⁹ 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. The small incremental cost is in alignment with Energy Star® reporting, which lists an incremental cost of \$0.

²⁸⁰ Based on the algorithms used by the Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.”

- Hours_{sleep} = Annual hours the computer is in sleep mode. Custom input or based on usage pattern (see table below).
- P_{sleep_base} = Power draw (kW) of baseline unit while in sleep mode. Based on computer performance level (see table below).
- P_{sleep_eff} = Power draw (kW) of efficient unit while in sleep mode. Based on computer performance level (see table below).
- Hours_{off} = Annual hours the computer is off. Custom input or based on usage pattern (see table below).
- P_{off_base} = Power draw (kW) of baseline unit while off. Based on computer performance level (see table below).
- P_{off_eff} = Power draw (kW) of efficient unit while off. Based on computer performance level (see table below).

Table: Default Hours of Use²⁸¹

| Use Pattern | Hours _{idle} | Hours _{sleep} | Hours _{off} |
|-------------------------------------|-----------------------|------------------------|----------------------|
| Turned off at night, sleep enabled | 803 | 1104 | 6854 |
| Turned off at night, sleep disabled | 1906 | 0 | 6854 |
| Left on at night, sleep enabled | 803 | 7957 | 0 |
| Left on at night, sleep disabled | 8760 | 0 | 0 |
| Unknown | 5853 | 439 | 2467 |

Table: Power Requirements²⁸²

| Performance Level ²⁸³ | Baseline | | | Efficient | | |
|----------------------------------|------------------------|-------------------------|-----------------------|-----------------------|------------------------|----------------------|
| | P _{idle_base} | P _{sleep_base} | P _{off_base} | P _{idle_eff} | P _{sleep_eff} | P _{off_eff} |
| Low | 0.01104 | 0.00104 | 0.000563 | 0.0064 | 0.000787 | 0.000382 |
| Medium | 0.01482 | 0.00121 | 0.000606 | 0.00861 | 0.000889 | 0.000457 |
| High | 0.01724 | 0.00134 | 0.000619 | 0.01024 | 0.00122 | 0.000522 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Energy Savings as calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439

²⁸¹ Based on Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.” “Unknown” based on data suggesting 36% of computers are shut off at night and 8% have sleep mode enabled.

²⁸² Based on Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.”

²⁸³ “Low” refers to budget or low-end models, “Medium” refers to mid-grade models and “High” refers to high-end models. For more specific performance definitions, refer to Energy Star® 6.0 Requirements.

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:

2.7.2 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 type: RF.

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 4 years.²⁸⁴

DEEMED MEASURE COST

The deemed measure cost is \$29 per networked computer, including labor.²⁸⁵

LOADSHAPE

Miscellaneous BUS

²⁸⁴ Consistent with the expected lifetimes of Energy Star® Office Equipment.

²⁸⁵ Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison

 Algorithm

CALCULATION OF ENERGY SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = kWh_{\text{savings}} * N$$

Where:

- kWh_{savings} = Annual energy savings per workstation
 = 200 kWh²⁸⁶ for desktops, 50 kWh for laptops²⁸⁷
 = If unknown, assume 161 kWh (based on 74% desktop and 26% laptop)²⁸⁸
- N = Number of desktop or laptop workstations controlled by the power management software

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Energy Savings as calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439

NATURAL GAS SAVING

NA

DEEMED O&M COST ADJUSTMENT CALCULATIONAssumed to be \$2/unit annually.²⁸⁹**MEASURE CODE:**

²⁸⁶ 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_mgmt/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).

²⁸⁷ 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.²⁸⁸ Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.²⁸⁹ 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."

2.7.3 Heat Pump Pool Heater

DESCRIPTION

This measure applies to the installation of a heat pump pool heater in place of a standard electric pool heater on an outdoor pool at a commercial location.

This measure was developed to be applicable to the following program type: 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 heat pump pool heater meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new, standard efficiency electric resistance pool heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.²⁹⁰

DEEMED MEASURE COST

The incremental equipment cost difference between an electric resistance pool heater and a heat pump pool heater is \$1,000 per unit.²⁹¹

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Q_{PoolHeating} * (1/Eff_{Base} - 1/Eff_{EE})$$

Where:

$Q_{PoolHeating}$ = Required annual heat transfer to pool water (kWh), calculated as follows:²⁹²

= For an uncovered pool: $[53.075 * (SQFT)] + 1631.1$

= For a pool that is regularly covered when not in use: $[8.079 * (SQFT)] + 1295.4$

Where SQFT is the total surface area of the pool.

²⁹⁰ Measure life is for a high-efficiency pool heater, from 2017 Michigan Energy Measures Database.

²⁹¹ Measure cost based on “The Definitive Guide to Heating Your Swimming Pool,” AquaCal, July 2013. Electric resistance pool heaters can be purchased for less than \$2,000, and heat pump pool heaters cost between \$2,000 and \$4,000.

²⁹² Based on the results of a swimming pool energy calculation tool found at <http://noanderson.com/services/swimming-pool-energy-temperature-calculator/>. Results use St. Louis weather-related assumptions and assume a pool season of May through October (per Energy Star[®] guidelines), with a water temperature of 80 degrees Fahrenheit.

Where:

Eff_{Base} = Efficiency of electric resistance pool heater
= 100%

Eff_{EE} = Efficiency (COP) of heat pump pool heater
= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Calculated value above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.7.4 Computer Server

DESCRIPTION

This measure estimates savings for a computer server with that has been certified by ENERGY STAR® (ES) Version 2.0.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is computer server meeting the requirements set forth by ENERGY STAR® Version 2.0.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR® qualified computer server.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.²⁹³

DEEMED MEASURE COST²⁹⁴

The incremental cost is \$9.80.

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS²⁹⁵

Annual energy savings are based on the rated output of the server's power supply, according to the following table:

| Power Supply Rated Output (W) | Baseline Annual Energy Consumption (kWh) | Efficient Annual Energy Consumption (kWh) | Annual Energy Savings (kWh) |
|-------------------------------|--|---|-----------------------------|
| Up to 500 | 1,221 | 742 | 479 |
| 501-1000 | 3,024 | 1,837 | 1,187 |
| 1001-1500 | 5,883 | 3,575 | 2,308 |
| 1501-2000 | 9,152 | 5,561 | 3,591 |

²⁹³ Consistent with Energy Star® computing equipment. It is important to note that lifetime doesn't necessarily reflect the expected functional lifetime of mechanical components, but rather the lifetime of operating system technology, which is generally assumed to become obsolete after a period of four years.

²⁹⁴ 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. The small incremental cost is in alignment with Energy Star® reporting, which lists an incremental cost of \$0 for all office equipment.

²⁹⁵ Based on current Energy Star® qualified product performance and assumptions drawn from the Energy Savings From Energy Star®-Qualified Servers report and Energy Star® Computer Specifications version 4.0. See "Computer Server Savings.xlsx" for additional details and methodology.

| Power Supply Rated Output (W) | Baseline Annual Energy Consumption (kWh) | Efficient Annual Energy Consumption (kWh) | Annual Energy Savings (kWh) |
|-------------------------------|--|---|-----------------------------|
| 2001-2500 | 8,667 | 5,266 | 3,401 |
| 2501-3000 | 19,633 | 11,929 | 7,704 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439

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:

2.8 Motors

2.8.1 Motors

DESCRIPTION

This measure applies to the one-for-one replacement of an old, working or failed/near failure 1-350 horsepower, constant speed, uniformly loaded HVAC fan or pumping motor with a new motor of the same rated horsepower that meets or exceeds National Electrical Manufacturers Association (NEMA) Premium efficiency levels.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new motor that meets or exceeds NEMA Premium efficiency levels.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment efficiency is the efficiency of the existing motor, or if unknown, the federal minimum required efficiency is assumed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.²⁹⁶

DEEMED MEASURE COST

Actual incremental costs should be used if available. If actual costs are unknown, use default installed cost from table below.²⁹⁷

| Motor Size (HP) | Installed Cost |
|-----------------|----------------|
| 1 | \$730 |
| 1.5 | \$725 |
| 2 | \$800 |
| 3 | \$840 |
| 5 | \$860 |
| 7.5 | \$1,165 |
| 10 | \$1,298 |
| 15 | \$2,242 |
| 20 | \$2,522 |
| 25 | \$2,873 |
| 30 | \$3,095 |
| 40 | \$3,716 |
| 50 | \$4,073 |
| 60 | \$5,128 |
| 75 | \$5,888 |
| 100 | \$7,392 |

²⁹⁶ California Database for Energy Efficiency Resources (DEER) 2014 Estimated Useful Life (EUL) Table Update.

²⁹⁷ Installed costs from 2015-2016 Demand-Side Management Plan, Xcel Energy.

| Motor Size (HP) | Installed Cost |
|-----------------|----------------|
| 125 | \$9,076 |
| 150 | \$9,401 |
| 200 | \$11,250 |
| 250 | \$13,958 |
| 300 | \$17,744 |
| 350 | \$25,653 |

LOADSHAPE

Motors BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * LF * 0.746 * (1/\eta_{Bmotor} - 1/\eta_{EEmotor}) * Hours$$

Where:

HP = Nominal horsepower (HP) of new motor
 = Actual

LF = Load Factor; Motor Load at Fan/Pump Design CFM
 = 75%²⁹⁸

0.746 = Conversion factor from HP to kWh

η_{Bmotor} = Actual efficiency of existing motor, or if unknown, use federal baseline nominal/nameplate motor efficiency as shown in table below for Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC)²⁹⁹

| Motor 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 | 3600 | 1200 | 1800 | 3600 |
| 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% |

²⁹⁸ Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. *Determining Electric Motor Load and Efficiency*, US DOE Motor Challenge, a program of the US Department of Energy, <https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf>.

²⁹⁹ For 1-200 HP motors, baseline efficiency is from NEMA MG 1 Table 12-12. For motors over 200 hp, baseline efficiency is from NEMA MG 1 Table 12-11.

| Motor Size (HP) | Open Drip Proof (ODP) # of Poles | | | Totally Enclosed Fan-Cooled (TEFC) # of Poles | | |
|-----------------|-------------------------------------|--------|--------|--|--------|--------|
| | 6 | 4 | 2 | 6 | 4 | 2 |
| | Speed (RPM) | | | Speed (RPM) | | |
| | 1200 | 1800 | 3600 | 1200 | 1800 | 3600 |
| 25 | 93.00% | 93.60% | 91.70% | 93.00% | 93.60% | 91.70% |
| 30 | 93.60% | 94.10% | 91.70% | 93.00% | 93.60% | 91.70% |
| 40 | 94.10% | 94.10% | 92.40% | 94.10% | 94.10% | 92.40% |
| 50 | 94.10% | 94.50% | 93.00% | 94.10% | 94.50% | 93.00% |
| 60 | 94.50% | 95.00% | 93.60% | 94.50% | 95.00% | 93.60% |
| 75 | 94.50% | 95.00% | 93.60% | 94.50% | 95.40% | 93.60% |
| 100 | 95.00% | 95.40% | 93.60% | 95.00% | 95.40% | 94.10% |
| 125 | 95.00% | 95.40% | 94.10% | 95.00% | 95.40% | 95.00% |
| 150 | 95.40% | 95.80% | 94.10% | 95.80% | 95.80% | 95.00% |
| 200 | 95.40% | 95.80% | 95.00% | 95.80% | 96.20% | 95.40% |
| 250 | 95.40% | 95.80% | 95.00% | 95.80% | 96.20% | 95.80% |
| 300 | 95.40% | 95.80% | 95.40% | 95.80% | 96.20% | 95.80% |
| 350 | 95.40% | 95.80% | 95.40% | 95.80% | 96.20% | 95.80% |

$\eta_{EEmotor}$ =Efficient motor nominal/nameplate motor efficiency

= Actual

Hours = Annual hours of operation for motor; see table below for HVAC motors³⁰⁰

| Building Type | Hot Water Pump Hours | Chilled Water Pump Hours | Fan Motor Run Hours |
|--------------------------|----------------------|--------------------------|---------------------|
| Large Office | 5,233 | 6,385 | 6,753 |
| Medium Office | 3,437 | 5,921 | 6,968 |
| Small Office | 3,715 | 3,774 | 6,626 |
| Warehouse | 4,587 | 1,292 | 6,263 |
| Stand-alone Retail | 4,040 | 2,713 | 6,679 |
| Strip Mall | 3,908 | 2,548 | 6,687 |
| Primary School | 4,754 | 5,160 | 5,906 |
| Secondary School | 5,594 | 5,279 | 6,702 |
| Supermarket | 4,868 | 4,255 | 6,900 |
| Quick Service Restaurant | 4,231 | 3,378 | 7,679 |
| Full Service Restaurant | 4,595 | 4,897 | 7,664 |
| Hospital | 8,760 | 8,717 | 8,760 |
| Outpatient Health Care | 8,760 | 8,689 | 8,760 |
| Small Hotel - Building | 3,533 | 7,976 | 8,760 |
| Large Hotel - Building | 5,538 | 8,308 | 8,760 |

³⁰⁰ 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 over claim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

| Building Type | Hot Water Pump Hours | Chilled Water Pump Hours | Fan Motor Run Hours |
|------------------------------|----------------------|--------------------------|---------------------|
| Midrise Apartment - Building | 5,197 | 4,347 | 8,728 |
| Nonresidential Average | 4,411 | 3,539 | 6,773 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS³⁰¹

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

³⁰¹ Since savings will be constant and without fluctuation over the period of operation, demand savings are simply the energy savings divided by the hours of operation. Demand savings are expected to coincide with peak demand period definitions, consistent with assumptions in VFD measures on HVAC pumps and fans.

2.8.2 Pool Pump

DESCRIPTION

This measure applies to the installation of a variable frequency drive (VFD) on an existing single-speed pool pump at a commercial location. VFDs save energy by reducing the speed of the pool pump motor to match the pool’s required flow rate. Additionally, VFD’s soft-starting extends motor life by reducing wear.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new VFD meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing, single-speed pool pump without a VFD or other motor control device.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.³⁰²

DEEMED MEASURE COST

Actual costs (equipment and labor) should be used if available. If actual costs are unknown, assume equipment costs of \$200/motor horsepower and labor cost of \$46.³⁰³

LOADSHAPE

Motors BUS

| Algorithm |
|-----------|
|-----------|

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 1,747 * HP$$

Where:

- 1,747 = Average annual energy savings per pool pump motor horsepower (kWh/HP)³⁰⁴
- HP = Pool pump motor horsepower
- = Custom input, actual horsepower rating of the pump motor.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

³⁰² Measure life from 2017 Michigan Energy Measures Database.

³⁰³ Costs from 2017 Michigan Energy Measures Database.

³⁰⁴ Energy savings based on monitoring performed at commercial pool facilities, from Commercial Variable Speed Pool Pump Market Characterization and Metering Study,” Southern California Edison, February 2015.

Where:

kWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8.3 Pool Pump Timer

DESCRIPTION

This measure applies to the installation of a pump timer on an existing single-speed pool pump at a commercial location. Many times, it is not necessary to run a pool's circulation pump 24 hours a day.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new pump timer meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing, single-speed pool pump without a VFD or other motor control device.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.

DEEMED MEASURE COST

Actual costs (equipment and labor) should be used if available. If actual costs are unknown, assume equipment costs of \$100.³⁰⁵

LOADSHAPE

Motors BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HRS * HP * .746$$

Where:

- | | |
|-----|---|
| HRS | = Hours Timer will shut off pump annually |
| | = Actual. |
| HP | = Pool pump motor horsepower |
| | = Custom input, actual horsepower rating of the pump motor. |

³⁰⁵ Costs from Ameren Missouri MEEIA 2016-18 TRM.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

kWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8.4 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 than 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; and
- Balancing valves on at least one load 100% open.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.³⁰⁶

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.

LOADSHAPE

Process BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (\text{HP}_{\text{motor}} * 0.746 * \text{LF} / \eta_{\text{motor}}) * \text{HOURS} * \text{ESF}$$

Where:

$$\begin{aligned} \text{HP}_{\text{motor}} &= \text{Installed nameplate motor horsepower} \\ &= \text{Actual} \end{aligned}$$

³⁰⁶ Martin, N. et al., Emerging Energy-Efficient Industrial Technologies: New York State Edition, American Council for an Energy Efficient Economy (ACEEE), March 2001 (as stated in the OH State TRM, page 269).

0.746 = Conversion factor from horse-power to kW (kW/hp)
 LF / η_{motor} = Combined as a single factor since efficiency is a function of load
 = 0.65³⁰⁷

Where:

LF = Load Factor; Ratio of the peak running load to the nameplate rating of the motor
 η_{motor} = Motor efficiency at pump operating conditions
 HOURS = Annual operating hours of the pump
 = Actual
 ESF = Energy Savings Factor; assume a value of 15%.³⁰⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Coincident Peak Factor for measure
 = 0.0001379439³⁰⁹

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

³⁰⁷ “Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings,” ACEEE 1994 Summer Study Conference, Asilomar, CA.

³⁰⁸ 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.

³⁰⁹ Based on Ameren Missouri 2016 Process Loadshape.

2.8.5 Variable Frequency Drives for Chilled Water and Hot Water Distribution Pumps

DESCRIPTION

This measure applies to VFDs installed on HVAC chilled water and hot water distribution pumps. There is a separate measure for HVAC supply and return fans. The VFD will modulate the speed of the motor when it does not need to run at full load. 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 and RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a pump motor 1-75 HP that does not have a VFD. The hydronic system that the VFD is applied to must have a variable or reduced load. Installation is to include the necessary control points and parameters (example: differential pressure, differential temperature, return water temperature) as determined by a qualified engineer.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.³¹⁰

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default measure costs are listed below for 1 to 75 HP motors.³¹¹ The average of the values below is \$179/HP.

| HP | Cost |
|----------|---------|
| 1-9 HP | \$1,874 |
| 10-19 HP | \$2,967 |
| 20-29 HP | \$4,060 |
| 30-39 HP | \$5,154 |
| 40-49 HP | \$6,247 |
| 50-59 HP | \$7,340 |
| 60-69 HP | \$8,433 |
| 70-75 HP | \$9,526 |

LOADSHAPE

Cooling BUS
Heating BUS
HVAC BUS

³¹⁰ Consistent with Ameren Missouri program assumptions.

³¹¹ Average costs observed by other Midwestern states energy efficiency programs – specific data reflects results from Iowa program costs.

 Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

BHP = System Brake Horsepower

(Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.³¹² 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% is an appropriate assumption.

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type.³¹³ When available, actual hours should be used.

| Building Type | Hot Water Pump Hours | Chilled Water Pump Hours |
|------------------------------|----------------------|--------------------------|
| Large Office | 5233 | 6385 |
| Medium Office | 3437 | 5921 |
| Small Office | 3715 | 3774 |
| Warehouse | 4587 | 1292 |
| Stand-alone Retail | 4040 | 2713 |
| Strip Mall | 3908 | 2548 |
| Primary School | 4754 | 5160 |
| Secondary School | 5594 | 5279 |
| Supermarket | 4868 | 4255 |
| Quick Service Restaurant | 4231 | 3378 |
| Full Service Restaurant | 4595 | 4897 |
| Hospital | 8760 | 8717 |
| Outpatient Health Care | 8760 | 8689 |
| Small Hotel - Building | 3533 | 7976 |
| Large Hotel - Building | 5538 | 8308 |
| Midrise Apartment - Building | 5197 | 4347 |

³¹² 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.

³¹³ 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 over claim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

| Building Type | Hot Water Pump Hours | Chilled Water Pump Hours |
|------------------------|----------------------|--------------------------|
| Nonresidential Average | 4411 | 3539 |

ESF = Energy savings factor varies by VFD application. Units are kW/HP.

| Application | ESF ³¹⁴ |
|--------------------|--------------------|
| Hot Water Pump | 0.3577 |
| Chilled Water Pump | 0.3389 |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001379439 Chilled Water Pumps

= 0.000443983 Hot Water Pumps

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

If fossil fuel impacts are expected, a custom analysis should be used to support them.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

³¹⁴ Developed from datasets produced from the Northeast Energy Efficiency Partnerships Variable Speed Drive Loadshape Project. See supporting workbook “VSD HVAC Pump Savings.xlsx” for derivation.

2.8.6 Variable Frequency Drives for HVAC Supply and Return Fans

DESCRIPTION

This measure applies to VFDs installed on HVAC supply fans and return fans. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is applicable to the following program types: TOS and RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to an HVAC fan motor that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (example: differential pressure, temperature, or volume). Savings are based on the application of VFDs to a range of baseline system conditions, including no control, inlet guide vanes, outlet guide vanes, relief dampers, and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The TOS baseline is a new motor installed without a VFD or other methods of control. The RF baseline is an existing motor operating as is. RF baselines may or may not include guide vanes, throttling valves, or other methods of control.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.³¹⁵

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.³¹⁶ The average of the values below is \$168/HP.

| HP | Cost |
|-----------|----------|
| 1-9 HP | \$1,874 |
| 10-19 HP | \$2,967 |
| 20-29 HP | \$4,060 |
| 30-39 HP | \$5,154 |
| 40-49 HP | \$6,247 |
| 50-59 HP | \$7,340 |
| 60-69 HP | \$8,433 |
| 70-79 HP | \$9,526 |
| 80-89 HP | \$10,620 |
| 90-100 HP | \$11,713 |

LOADSHAPE

HVAC BUS

³¹⁵ Consistent with Ameren Missouri program assumptions.

³¹⁶ Average costs observed by energy efficiency programs in Iowa.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS³¹⁷

$$\begin{aligned}
 kWh_{Base} &= \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{Base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Base}) \\
 kWh_{Retrofit} &= \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{base} * \sum_{30\%}^{100\%} (\%FF * PLR_{Retrofit}) \\
 \Delta kWh_{fan} &= kWh_{Base} - kWh_{Retrofit} \\
 \Delta kWh_{total} &= \Delta kWh_{fan} * (1 + IE_{energy})
 \end{aligned}$$

Where:

- kWh_{Base} = Baseline annual energy consumption (kWh/yr)
- $kWh_{Retrofit}$ = Retrofit annual energy consumption (kWh/yr)
- ΔkWh_{fan} = Fan-only annual energy savings
- ΔkWh_{total} = Total project annual energy savings
- 0.746 = Conversion factor for HP to kWh
- HP = Nominal horsepower of controlled motor
- LF = Load Factor; Motor Load at Fan Design CFM (Default = 65%)³¹⁸
- η_{motor} = Installed nominal/nameplate motor efficiency
 = Actual. If unknown, default can be assumed as a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor, with efficiency indicated in the following table:

³¹⁷ 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.

³¹⁸ Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry,” U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory.

NEMA Premium Efficiency Motors Default Efficiencies³¹⁹

| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
|---------|-----------------------|--------------|-------|------------------------------------|-------|-------|
| | # of Poles | | | # of Poles | | |
| | 6 | 4 | 2 | 6 | 4 | 2 |
| | Speed (RPM) | | | Speed (RPM) | | |
| | 1200 | 1800 Default | 3600 | 1200 | 1800 | 3600 |
| 1 | 0.825 | 0.855 | 0.770 | 0.825 | 0.855 | 0.770 |
| 1.5 | 0.865 | 0.865 | 0.840 | 0.875 | 0.865 | 0.840 |
| 2 | 0.875 | 0.865 | 0.855 | 0.885 | 0.865 | 0.855 |
| 3 | 0.885 | 0.895 | 0.855 | 0.895 | 0.895 | 0.865 |
| 5 | 0.895 | 0.895 | 0.865 | 0.895 | 0.895 | 0.885 |
| 7.5 | 0.902 | 0.910 | 0.885 | 0.910 | 0.917 | 0.895 |
| 10 | 0.917 | 0.917 | 0.895 | 0.910 | 0.917 | 0.902 |
| 15 | 0.917 | 0.930 | 0.902 | 0.917 | 0.924 | 0.910 |
| 20 | 0.924 | 0.930 | 0.910 | 0.917 | 0.930 | 0.910 |
| 25 | 0.930 | 0.936 | 0.917 | 0.930 | 0.936 | 0.917 |
| 30 | 0.936 | 0.941 | 0.917 | 0.930 | 0.936 | 0.917 |
| 40 | 0.941 | 0.941 | 0.924 | 0.941 | 0.941 | 0.924 |
| 50 | 0.941 | 0.945 | 0.930 | 0.941 | 0.945 | 0.930 |
| 60 | 0.945 | 0.950 | 0.936 | 0.945 | 0.950 | 0.936 |
| 75 | 0.945 | 0.950 | 0.936 | 0.945 | 0.954 | 0.936 |
| 100 | 0.950 | 0.954 | 0.936 | 0.950 | 0.954 | 0.941 |
| 125 | 0.950 | 0.954 | 0.941 | 0.950 | 0.954 | 0.950 |
| 150 | 0.954 | 0.958 | 0.941 | 0.958 | 0.958 | 0.950 |
| 200 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.954 |
| 250 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.958 |
| 300 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 350 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 400 | 0.958 | 0.958 | 0.958 | 0.958 | 0.962 | 0.958 |
| 450 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |
| 500 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |

RHRS_{Base} = Annual operating hours for fan motor based on building type.

Default hours are provided for HVAC applications which vary by building type.³²⁰ When available, actual hours should be used.

| Building Type | Total Fan Run Hours |
|---------------|---------------------|
| Large Office | 6753 |
| Medium Office | 6968 |
| Small Office | 6626 |

³¹⁹ 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.

³²⁰ Hours per year are estimated using the modeling results and represent the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

| Building Type | Total Fan Run Hours |
|------------------------------|---------------------|
| Warehouse | 6263 |
| Stand-alone Retail | 6679 |
| Strip Mall | 6687 |
| Primary School | 5906 |
| Secondary School | 6702 |
| Supermarket | 6900 |
| Quick Service Restaurant | 7679 |
| Full Service Restaurant | 7664 |
| Hospital | 8760 |
| Outpatient Health Care | 8760 |
| Small Hotel - Building | 8760 |
| Large Hotel - Building | 8760 |
| Midrise Apartment - Building | 8728 |
| Nonresidential Average | 6773 |

%FF = Percentage of run-time spent within a given flow fraction range³²¹

| Flow Fraction (% of design cfm) | Percent of Time at Flow Fraction |
|---------------------------------|----------------------------------|
| 0% to 10% | 0.0% |
| 10% to 20% | 1.0% |
| 20% to 30% | 5.5% |
| 30% to 40% | 15.5% |
| 40% to 50% | 22.0% |
| 50% to 60% | 25.0% |
| 60% to 70% | 19.0% |
| 70% to 80% | 8.5% |
| 80% to 90% | 3.0% |
| 90% to 100% | 0.5% |

PLR_{Base} = Part load ratio for a given flow fraction range based on the baseline flow control type (see table below)

PLR_{Retrofit} = Part load ratio for a given flow fraction range based on the retrofit flow control type (see table below)

| 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 |

³²¹ Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

| Control Type | Flow Fraction | | | | | | | | | |
|--|---------------|------|------|------|------|------|------|------|------|------|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Inlet Guide Vane, BI & Airfoil Fans | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Inlet Vane Dampers | 0.38 | 0.40 | 0.42 | 0.44 | 0.48 | 0.53 | 0.60 | 0.70 | 0.83 | 0.99 |
| Outlet Damper, FC Fans | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Eddy Current Drives | 0.17 | 0.20 | 0.25 | 0.32 | 0.41 | 0.51 | 0.63 | 0.76 | 0.90 | 1.04 |
| Inlet Guide Vane, FC Fans | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| VFD with duct static pressure controls | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.29 | 0.41 | 0.57 | 0.76 | 1.01 |
| VFD with low/no duct static pressure | 0.05 | 0.06 | 0.09 | 0.12 | 0.18 | 0.27 | 0.39 | 0.55 | 0.75 | 1.00 |

Provided below are the resultant values based upon the defaults provided above:

| Control Type | $\sum_{0\%}^{100\%} (\%FF \times PLR_{Base})$ |
|--|---|
| No Control or Bypass Damper | 1.00 |
| Discharge Dampers | 0.80 |
| Outlet Damper, BI & Airfoil Fans | 0.78 |
| Inlet Damper Box | 0.69 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.63 |
| Inlet Vane Dampers | 0.53 |
| Outlet Damper, FC Fans | 0.53 |
| Eddy Current Drives | 0.49 |
| Inlet Guide Vane, FC Fans | 0.39 |
| VFD with duct static pressure controls | 0.30 |
| VFD with low/no duct static pressure | 0.27 |

$$IE_{energy} = HVAC \text{ interactive effects factor for energy (default = 15.7\%)}^{322}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{total} * CF$$

Where:

$$\Delta kWh_{total} = \text{As calculated above.}$$

$$CF = \text{Summer peak coincidence demand (kW) to annual energy (kWh) factor} \\ = 0.000443983$$

NATURAL GAS ENERGY SAVINGS

If fossil fuel impacts are expected, a custom analysis should be used to support them.

³²² 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.9 Refrigeration

2.9.1 Commercial Solid and Glass Door Refrigerators & Freezers

DESCRIPTION

This measure applies to ENERGY STAR® vertical closed and horizontal closed refrigerators or freezers installed in a commercial kitchen. ENERGY STAR® commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new ENERGY STAR® certified vertical closed or horizontal closed, solid or glass door refrigerator or freezer meeting energy consumption requirements as determined by door type (solid or glass) and refrigerated volume (V).

ENERGY STAR® Requirements (Version 3.0, Effective October 1, 2014)

| Volume (ft ³) | Maximum Daily Energy Consumption (kWh/day) | |
|---------------------------|--|---------------------|
| | Refrigerator | Freezer |
| Vertical Closed | | |
| Solid Door | | |
| $0 < V < 15$ | $\leq 0.02V + 1.60$ | $\leq 0.25V + 1.55$ |
| $15 \leq V < 30$ | $\leq 0.09V + 0.55$ | $\leq 0.20V + 2.30$ |
| $30 \leq V < 50$ | $\leq 0.01V + 2.95$ | $\leq 0.25V + 0.80$ |
| $V \geq 50$ | $\leq 0.06V + 0.45$ | $\leq 0.14V + 6.30$ |
| Glass Door | | |
| $0 < V < 15$ | $\leq 0.10V + 1.07$ | $\leq 0.56V + 1.61$ |
| $15 \leq V < 30$ | $\leq 0.15V + 0.32$ | $\leq 0.30V + 5.50$ |
| $30 \leq V < 50$ | $\leq 0.06V + 3.02$ | $\leq 0.55V - 2.00$ |
| $V \geq 50$ | $\leq 0.08V + 2.02$ | $\leq 0.32V + 9.49$ |
| Horizontal Closed | | |
| Solid or Glass Doors | | |
| All Volumes | $\leq 0.06V + 0.60$ | $\leq 0.10V + 0.20$ |

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new vertical closed or horizontal closed, solid or glass door refrigerator or freezer that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.³²³

³²³Measure life from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator which cites reference as “FSTC research on available models, 2009”
https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator%2003-15-2016.xlsx.

DEEMED MEASURE COST

The incremental capital cost for this measure varies by size as shown in the table below:

| Measure | Incremental Cost |
|---|------------------|
| Commercial Glass Door Freezers less than 15 ft ³ | \$220 |
| Commercial Glass Door Freezers 15 to 30 ft ³ | \$950 |
| Commercial Glass Door Freezers 30 to 50 ft ³ | \$1,307 |
| Commercial Glass Door Freezers more than 50 ft ³ | \$2,300 |
| Commercial Glass Door Refrigerators less than 15 ft ³ | \$250 |
| Commercial Glass Door Refrigerators 15 to 30 ft ³ | \$500 |
| Commercial Glass Door Refrigerators 30 to 50 ft ³ | \$1,307 |
| Commercial Glass Door Refrigerators more than 50 ft ³ | \$2,300 |
| Commercial Solid Door Freezers/Refrigerators less than 15 ft ³ | \$150 |
| Commercial Solid Door Freezers/Refrigerators 15 to 30 ft ³ | \$400 |
| Commercial Solid Door Freezers/Refrigerators 30 to 50 ft ³ | \$550 |
| Commercial Solid Door Freezers/Refrigerators more than 50 ft ³ | \$700 |
| Horizontal Closed - Solid or Glass Door Refrigerator (all volumes) | \$525 |
| Horizontal Closed - Solid or Glass Door Freezer (all volumes) | \$595 |

LOADSHAPE

Refrigeration BUS

| Algorithm |
|-----------|
|-----------|

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.³²⁴

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline refrigerator or freezer

= Calculated as shown in the table below using the actual refrigerated volume (V)

| Equipment Type | kWh _{Base} ³²⁵ |
|-------------------------|------------------------------------|
| Solid Door Refrigerator | 0.10V + 2.04 |
| Glass Door Refrigerator | 0.12V + 3.34 |
| Solid Door Freezer | 0.40V + 1.38 |
| Glass Door Freezer | 0.75V + 4.10 |

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR[®] refrigerator or freezer

³²⁴ Algorithms and assumptions from ENERGY STAR[®] Commercial Kitchen Equipment Savings Calculator.

³²⁵ 10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers.

= Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V)

| Volume (ft ³) | Maximum Daily Energy Consumption (kWh/day) | |
|---------------------------|--|----------------|
| | Refrigerator | Freezer |
| Vertical Closed | | |
| Solid Door | | |
| 0 < V < 15 | ≤ 0.02V + 1.60 | ≤ 0.25V + 1.55 |
| 15 ≤ V < 30 | ≤ 0.09V + 0.55 | ≤ 0.20V + 2.30 |
| 30 ≤ V < 50 | ≤ 0.01V + 2.95 | ≤ 0.25V + 0.80 |
| V ≥ 50 | ≤ 0.06V + 0.45 | ≤ 0.14V + 6.30 |
| Glass Door | | |
| 0 < V < 15 | ≤ 0.10V + 1.07 | ≤ 0.56V + 1.61 |
| 15 ≤ V < 30 | ≤ 0.15V + 0.32 | ≤ 0.30V + 5.50 |
| 30 ≤ V < 50 | ≤ 0.06V + 3.02 | ≤ 0.55V – 2.00 |
| V ≥ 50 | ≤ 0.08V + 2.02 | ≤ 0.32V + 9.49 |
| Horizontal Closed | | |
| Solid or Glass Doors | | |
| All Volumes | ≤ 0.06V + 0.60 | ≤ 0.10V + 0.20 |

V = Refrigerated volume (ft³) calculated in accordance with the Department of Energy test procedure in 10 CFR §431.64

= Actual installed

Days = Days of refrigerator or freezer operation per year

= Custom, or if unknown assume 365.25 days per year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001357383³²⁶

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

³²⁶ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.9.2 Refrigerated Beverage Vending Machine

DESCRIPTION

This measure applies to new ENERGY STAR[®], Class A or Class B refrigerated vending machines. ENERGY STAR[®] vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR[®], Class A or Class B³²⁷ refrigerated vending machine meeting energy consumption requirements as determined by equipment type (Class A or Class B).

ENERGY STAR Requirements (Version 3.1, Effective March 1, 2013)

| Equipment Type | Maximum Daily Energy Consumption (kWh/day) |
|----------------|--|
| Class A | $\leq 0.0523V + 2.432$ |
| Class B | $\leq 0.0657V + 2.844$ |

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new or rebuilt, Class A or Class B refrigerated vending machine that is not ENERGY STAR[®] certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.³²⁸

DEEMED MEASURE COST

The incremental cost of this measure is \$140.³²⁹

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

³²⁷ Class A means a refrigerated bottled or canned beverage vending machine that is fully cooled, and is not a combination vending machine. Class B means any refrigerated bottled or canned beverage vending machine not considered to be Class A, and is not a combination vending machine. See 10 CFR §431.292 “Definitions concerning refrigerated bottled or canned beverage vending machines.”

³²⁸ Average of measure lives recognized by Ameren Missouri (10 years) and KCPL (14 years). Also consistent with Energy Star[®] commercial refrigerator lifetime.

³²⁹ Consistent with Ameren Missouri MEEIA 2016-18 and KCPL TRM assumptions.

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline vending machine
 = Calculated as shown in the table below using the actual refrigerated volume (V)

| Equipment Type | kWh_{Base}^{330} |
|----------------|--------------------|
| Class A | $0.055V + 2.56$ |
| Class B | $0.073V + 3.16$ |

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR® vending machine
 = Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V)

| Equipment Type | kWh_{EE}^{331} |
|----------------|------------------------|
| Class A | $\leq 0.0523V + 2.432$ |
| Class B | $\leq 0.0657V + 2.844$ |

V = Refrigerated volume³³² (ft³)
 = Actual installed

Days = Days of vending machine operation per year
 = 365.25 days per year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001357383³³³

MEASURE CODE:

³³⁰10 CFR §431.296 - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

³³¹ ENERGY STAR® Version 3.1 requirements for maximum daily energy consumption.

³³²V is measured by the American National Standards Institute (ANSI)/Association of Home Appliance Manufacturers (AHAM) HRF-1-2004, “Energy, Performance and Capacity of Household Refrigerators, Refrigerator-Freezers and Freezers.” Measurement of refrigerated volume must be in accordance with the methodology specified in Section 5.2, Total Refrigerated Volume (excluding subsections 5.2.2.2 through 5.2.2.4), of ANSI/AHAM HRF-1-2004.

³³³ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

2.9.3 Door Heater Controls for Cooler or Freezer

DESCRIPTION

This measure applies to door heater controls installed on commercial coolers or freezers. There are two main categories of commercially available control strategies that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates door heaters when the relative humidity in a store rises above a specific set point and turns them off when the relative humidity falls below that set point. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain set point and turns them off when the conductivity rises above that set point. Savings result from a reduction in electric energy use due to heaters not running continuously and from reduced cooling loads when heaters are off. The assumptions included within this measure assume that door heater controls which are properly designed and commissioned will achieve approximately equivalent savings, regardless of control strategy.

This measure applies to the following program type: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a door heater control installed on a commercial glass door cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a door heater without controls, installed on a commercial glass door cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.³³⁴

DEEMED MEASURE COST

Actual incremental costs should be used if available. The incremental capital cost \$151 per door.³³⁵

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{Base} * DOORS * (\%ON_{Base} - \%ON_{Control}) * Hours$$

Where:

$$kW_{Base} = \text{Per door electric energy consumption of door heater without controls}$$

³³⁴ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values,” California Public Utilities Commission, December 16, 2008.

³³⁵ Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

- = Assume 0.130 kW per door³³⁶
- DOORS = Number of doors controlled with door heater controls
- = Actual or if unknown, use 1 (a per door savings)
- % ON_{Base} = Effective run time of uncontrolled door heater
- = Actual or if unknown, use 90.7%³³⁷
- % ON_{Control} = Effective run time with anti-sweat door heater controls
- = Actual or if unknown, use 45.6%³³⁸
- Hours = Annual hours of cooler or freezer operation
- = Assume 8,766 hours per year
- BF = Cooling Bonus factor for reduction in waste heat inside of the refrigerated space.
- = 1.3 for a refrigerator (medium/high temp), 1.5 for freezers (low temp)³³⁹

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor.
- = 0.0001357383³⁴⁰

Other variables as defined above.

Savings calculated with default values as defined above.

| Door Heater Control Application | ΔkWh/door | ΔkW/door |
|---------------------------------|-----------|----------|
| Refrigerator | 668.1 | 0.0907 |
| Freezer | 770.9 | 0.1046 |

NATURAL GAS ENERGY SAVINGS

N/A

MEASURE CODE:

³³⁶ The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 75, Table 42.

³³⁷ The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 37.

³³⁸ The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 37.

³³⁹ The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

³⁴⁰ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf”

2.9.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers/Freezers

DESCRIPTION

This measure consists of 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, thereby moving the same amount of air with less energy requirements. Additionally, less waste heat is produced, resulting in a decreased refrigeration load.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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). Savings assume that efficient motors operate continuously.

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.³⁴¹

DEEMED MEASURE COST

The measure cost is assumed to be \$177 per motor for a walk in cooler and walk in freezer, including the cost of the motor plus installation.³⁴²

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association and supported by PGE workpaper PGE3PREF126. Note that climate differences across all California climate zones resulted in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Missouri. Savings found in the aforementioned source are presented in combination with savings from controllers, however for the purposes of this measure only those associated with the ECM upgrade are considered.

³⁴¹ DEER database.

³⁴² 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 the DEER database for controller (\$291).

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \text{Savings per motor} * \text{motors}$$

Where:

Savings per motor³⁴³ = 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

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

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

³⁴³ See reference workbook “ECM Savings.xlsx” for derivation.

2.9.5 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.³⁴⁴

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a strip curtain 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.³⁴⁵

DEEMED MEASURE COST

The incremental capital cost for this measure is \$10.22/sq ft of door opening.³⁴⁶

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS³⁴⁷

$$\Delta kWh = \Delta kWh/sq ft * A$$

³⁴⁴ 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 short term monitoring of over 100 walk-in units. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.

³⁴⁵ DEER 2014 Effective Useful Life.

³⁴⁶ 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.

³⁴⁷ 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) [Kaltverluste durch Kuhlraumoffnungen. Tamm W., Kalttechnik-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].

Where:

$\Delta kWh/sq\ ft$ = Average annual kWh savings per square foot of infiltration barrier. Based on application type, as indicated by the following table:³⁴⁸

| Type | Pre-Existing Curtains | Energy Savings $\Delta kWh/sq\ ft$ |
|-----------------------------|-----------------------|------------------------------------|
| 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 |

A = Doorway area. Use actual measurements, if unknown assume the following:

| 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

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
 = 0.0001357383³⁴⁹

NATURAL GAS ENERGY SAVINGS

N/A

³⁴⁸See reference file “Strip Curtain Savings Calcs.docx” for details on derivation.

³⁴⁹ 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.10 Shell

2.10.1 Windows

DESCRIPTION

Energy and demand saving are realized through the installation of windows that offer performance improvements over baseline windows. Savings may be realized from reducing air infiltration, improved insulating properties, and changes to solar heat gain through the glazed surfaces of the building.

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

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 is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of the IECC. For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing window assemblies.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012. An efficient window would have specifications not exceeding these values.

| | Climate Zones 4 & 5 |
|-------------------------|--------------------------------|
| U-Factor | |
| <i>Fixed Windows</i> | 0.38 Btu/ft ² .°F.h |
| <i>Operable Windows</i> | 0.45 Btu/ft ² .°F.h |
| SHGC | 0.40 |

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.³⁵⁰

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used, including both material and labor costs to install the windows.

In all other scenarios, the incremental cost for this measure is assumed to be \$1.50 per square foot of window area.³⁵¹

LOADSHAPE

Cooling BUS

Algorithm

³⁵⁰ Consistent with window measure lives specified by Ameren Missouri and KCP&L.

³⁵¹ Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

Heating and cooling savings are composed of three components: infiltration, conduction and solar gains. In instances where infiltration savings do not apply or are not eligible, it may be disregarded.

If central cooling, the electric energy saved in annual cooling due to the added insulation is:

$$\begin{aligned} \Delta kWh_{cooling} &= Infiltration_{cooling} + Conduction_{cooling} + Solar_{cooling} \\ &= \frac{Infiltration_{cooling} (CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})} \end{aligned}$$

CFM_{Pre} = Infiltration at natural conditions as estimated by blower door testing before window upgrade
= Actual

CFM_{Post} = Infiltration at natural conditions as estimated by blower door testing after window upgrade
= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

EFLH_{cooling} = Equivalent Full Load Hours for Cooling [hr] are provided in Section 2.7, HVAC End Use

ΔT_{AVG,cooling} = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature:

| Weather Basis (City based upon) | OA _{AVG,cooling} [°F] ³⁵² | ΔT _{AVG,cooling} [°F] |
|------------------------------------|--|-----------------------------------|
| St Louis, MO | 80.8 | 5.8 |

0.018 = Specific Heat Capacity of Air (Btu/ft³ °F)

LM = Latent Multiplier to account for latent cooling demand:³⁵³

³⁵² National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

³⁵³ The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

| Weather Basis (City based upon) | LM |
|---------------------------------|-----|
| St Louis, MO | 3.0 |

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
- = Actual

$$Conduction_{cooling} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- U_{base} = U-factor value of baseline window assembly (Btu/ft².°F.h)
- = Dependent on Weather Basis and window type. See table below for IECC 2012 requirements:
- U_{eff} = U-factor value of the efficient window assembly (Btu/ft².°F.h)
- = Actual.
- A_{window} = Area of insulated window (including visible frame and glass) (ft²)
- Other variables as defined above.

$$Solar_{cooling} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $SHGC_{base}$ = Solar Heat Gain Coefficient of the baseline window assembly (fractional)
- $SHGC_{eff}$ = Solar Heat Gain Coefficient of the efficient window assembly (fractional)
- $\Psi_{cooling}$ = Incident solar radiation during the cooling season (Btu/ft²):³⁵⁴

| Weather Basis (City based upon) | $\Psi_{cooling}$ |
|---------------------------------|------------------|
| St Louis, MO | 40996 |

Other variables as defined above.

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the window upgrade is:

$$\Delta kWh_{heating} = Infiltration_{heating} + Conduction_{heating} - Solar_{heating}$$

³⁵⁴ See “Windows SHG.xlsx” for derivation.

$$Infiltration_{heating} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(3,412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.7, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [⁰F] during heating season between outdoor air temperature and assumed 55⁰F heating base temperature

| Weather Basis (City based upon) | $OA_{AVG,heating}$ [⁰ F] ³⁵⁵ | $\Delta T_{AVG,heating}$ [⁰ F] |
|------------------------------------|--|---|
| St Louis, MO | 43.2 | 11.8 |

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system
= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

Other variables as defined above.

$$Conduction_{heating} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Variables as defined above.

$$Solar_{heating} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{heating}}{(3,412 * \eta_{heating})}$$

Where:

$\Psi_{heating}$ = Incident solar radiation during the heading season (Btu/ft²):

| Weather Basis (City based upon) | $\Psi_{cooling}$ |
|---------------------------------|------------------|
| St Louis, MO | 66592 |

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

³⁵⁵ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

$\Delta kWh_{cooling}$ = Annual electricity savings for cooling, as calculated above
 CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
 = 0.000910684

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the window assembly is calculated with the following formula.

$$\Delta Therms = Infiltration_{gasheating} + Conduction_{gasheating} - Solar_{gasheating}$$

$$Infiltration_{gasheating} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(100,000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms
 η_{heat} = Efficiency of heating system
 = Actual

Other variables as defined above.

$$Conduction_{gasheating} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

$$Solar_{gasheating} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{heating}}{(100,000 * \eta_{heat})}$$

Variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.10.2 Ceiling and Wall Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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 is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of IECC. For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012:

| ASHRAE/IECC Climate Zone 5 (A, B, C) Nonresidential | | |
|--|---------------------|----------------------------|
| | Assembly Maximum | Insulation Min. R-Value |
| Mass | U-0.078 | R-11.4 ci |
| Metal Building | U-0.052 | R-13 + R-13 ci |
| Metal Framed | U-0.064 | R-13 + R-7.5 ci |
| Wood Framed and Other | U-0.064 | R-13 + R-3.8 ci or R-20 |

| ASHRAE/IECC Climate Zone 6 (A, B, C) Nonresidential | | |
|--|---------------------|--|
| | Assembly Maximum | Insulation Min. R-Value |
| Mass | U-0.078 | R-13.1 ci |
| Metal Building | U-0.052 | R-13 + R-13 ci |
| Metal Framed | U-0.064 | R-13 + R-7.5 ci |
| Wood Framed and Other | U-0.051 | R-13 + R-7.5 ci or R-20 + R-3.8 ci |

Note: ci = continuous insulation

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E’s 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC’s Energy Efficiency Policy Manual v.2, and GDS’s Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

HVAC BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
- R_{new} = Assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the surface in square feet.
- CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.
 - = 100% if Spray Foam or External Rigid Foam
 - = 50% if studs and cavity insulation³⁵⁶
- $EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 2.7, HVAC End Use
- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

| Weather Basis (City based upon) | $OA_{AVG,cooling}$ [°F] ³⁵⁷ | $\Delta T_{AVG,cooling}$ [°F] |
|------------------------------------|---|----------------------------------|
| St Louis, MO | 80.8 | 5.8 |

³⁵⁶ Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, “Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls.”

³⁵⁷ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
- = Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.7, HVAC end use
- $\Delta T_{AVG,heating}$ = Average temperature difference [⁰F] during heating season between outdoor air temperature and assumed 55⁰F heating base temperature

| Weather Basis (City based upon) | $OA_{AVG,heating}$ [⁰ F] ³⁵⁸ | $\Delta T_{AVG,heating}$ [⁰ F] |
|------------------------------------|--|---|
| St Louis, MO | 43.2 | 11.8 |

- 3,412 = Conversion from Btu to kWh.
- $\eta_{heating}$ = Efficiency of heating system
- = Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

- $\Delta Therms$ = Gas savings calculated with equation below.
- Fe = Percentage of heating energy consumed by fans, assume 3.14%³⁵⁹
- 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

- $\Delta kWh_{cooling}$ = Annual electricity savings for cooling, as calculated above

³⁵⁸ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

³⁵⁹ F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star[®] version 3 criteria for 2% F_e . See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
 = 0.0004439830

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * \text{Area} * \text{CRF} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = Assembly heat loss coefficient with existing insulation [(hr⁰F-ft²)/Btu]
- R_{new} = Assembly heat loss coefficient with new insulation [(hr⁰F-ft²)/Btu]
- Area = Area of the surface in square feet. Assume 1000 sq ft for planning.
- EFLH_{heating} = Equivalent Full Load Hours for Heating are provided in Section 2.7, HVAC end use
- ΔT_{AVG,heating} = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- η_{heat} = Efficiency of heating system
 = Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

Measure Code: