# Volume 2: Commercial and Industrial Measures

**Ameren Missouri TRM – Volume 2: C&I Measures Revision Log**

| Revision | Date | Description |
|---|---|---|
| 1.0 | 05/30/2018 | Initial version filed for Commission approval. |
| 1.1 | 06/19/2020 | Updated version to include new measures and updates to existing measures |
| 2.0 | 10/15/2020 | Updated version to include updates to existing measures. |
| 3.0 | 9/15/2021 | Update "Deemed Tables" with PY2020 Evaluation results plus updates to existing measures (lighting, chiller, pool pump). Added EUL lookup table for lighting measures from PY19. |
| 4.0 | 9/26/2022 | Updated "Deemed Tables" with PY2021 Evaluation results and added two new measures: 2.2.2 Compressed Air Leak Repair (shifting Compressed Air Nozzle and VSD Air Compressor to 2.2.3 and 2.2.4, respecitvely) and 2.5.10 Chiller Tune-Up. |
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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 2013.[1]

| 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]

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[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 $200.[4]

**LOADSHAPE**

Loadshape – Miscellaneous BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = [(Capacity * \frac{1}{MEFbase} * Ncycles) * (\%CWbase + (\%DHWbase * \%Electric_{DHW}) + (\%Dryerbase * \%Electric_{Dryer}))] - [(Capacity * \frac{1}{MEFeff} * Ncycles) * (\%CWeff + (\%DHWeff * \%Electric_{DHW}) + (\%Dryereff * \%Electric_{Dryer}))]$$

Where:

|  |  |
|---|---|
| Capacity | = Clothes washer capacity (cubic feet) |
|  | = Actual - If capacity is unknown, assume 3.1 cubic feet [5] |
| MEFbase | = Modified Energy Factor of baseline unit |
|  | = Actual. If unknown, assume average values provided below. |
| MEFeff | = Modified Energy Factor of efficient unit |
| Ncycles | = Number of Cycles per year |
|  | = 2190[6] |
| %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) |
| %Electric_{DHW} | = Percentage of DHW savings assumed to be electric |
| %Electric_{Dryer} | = Percentage of dryer savings assumed to be electric |

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

| Efficiency Level | MEFbase and MEFee | | |
| --- | --- | --- | --- |
| | Top loading | Front Loading | Weighted Average [7] |
| Federal Standard | 1.6 | 2.0 | 1.7 |
| ENERGY STAR® | N/A | 2.2 | 2.2 |

| Efficiency Level | 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% |

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

| 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**

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

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[7] 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% |

[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.

Where:

ΔkWh = Energy Savings as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[10]

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**

$$\Delta Therms = [[(Capacity * \frac{1}{MEFbase} * Ncycles) * ((\%DHWbase * \%Natural\ GasDHW * R\_eff) + (\%Dryerbase * \%GasDryer\%Gas\_Dryer))] - [(Capacity * \frac{1}{MEFeff} * Ncycles) * ((\%DHWeff * \%GasDHW\%Natural\ Gas\_DHW * R\_eff) + (\%Dryereff * \%GasDryer\%Gas\_Dryer))]] * Therm\_convert$$

Where:

$\%Gas_{DHW}$ = Percentage of DHW savings assumed to be Natural Gas
R_eff = Recovery efficiency factor
= 1.26[11]
$\%Gas_{Dryer}$ = Percentage of dryer savings assumed to be Natural Gas
Therm_convert = Conversion factor from kWh to Therm
= 0.03412

Other factors as defined above.

| DHW fuel | $\%Gas_{DHW}$ |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |

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[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/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

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

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**

$$\Delta Water \; (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles$$

Where:

| | |
|---|---|
| WFbase | = Water Factor of baseline clothes washer |
| WFeff | = 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 [12] | 8.5 | 5.5 | 7.4 | n/a |
| ENERGY STAR® | | 4.5 | | 19,874 |

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

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[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

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**Algorithm**

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CALCULATION OF SAVINGS

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[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

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = (Load/CEFbase - Load/CEFeff) * Ncycles * \%Electric$$

Where:

| | |
|---|---|
| Load | = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard. |
| 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.[16] If product class unknown, assume electric, standard. |
| CEFeff | = CEF (lbs/kWh) of the ENERGY STAR® unit based on ENERGY STAR® requirements. [17] If product class unknown, assume electric, standard. |
| Ncycles | = Number of dryer cycles per year. Use actual data if available. If unknown, refer to the table below.[18] |
| %Electric | = 100% for electric dryers, 5% for gas dryers[19] |

| Dryer Size | Load (lbs)[20] |
|---|---|
| Standard | 8.45 |
| Compact | 3 |

| Product Class | CEFbase (lbs/kWh) |
|---|---|
| Vented Electric, Standard ($\geq$ 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[21] |

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

[17] ENERGY STAR® Clothes Dryers Key Product Criteria.
https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[18] 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.

[19] %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.

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

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

| Product Class | CEFeff (lbs/kWh) |
|---|---|
| Vented or Ventless Electric, Standard (≥ 4.4 ft3) | 3.93 |
| Vented or Ventless Electric, Compact (120V) (<4.4 ft3) | 3.80 |
| Vented Electric, Compact (240V) (< 4.4 ft3) | 3.45 |
| Ventless Electric, Compact (240V) (< 4.4 ft3) | 2.68 |
| Vented Gas | 3.48[22] |

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

Using defaults provided above:

| Product Class | ΔkWh | | |
|---|---|---|---|
| | Multifamily | 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**

$$\Delta kW = h * CF$$

Where:

ΔkWh = Energy savings as calculated above.

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

= 0.0001379439[23]

Using defaults provided above:

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

[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 | ΔkW | | |
|---|---|---|---|
| | **Multifamily** | **Laundromat** | **On-Premise Laundromat** |
| Vented Electric, Standard (≥ 4.4 ft³) | 0.0840 | 0.1160 | 0.2821 |
| Vented Electric, Compact (120V) (<4.4 ft³) | 0.0307 | 0.0424 | 0.1031 |
| Vented Electric, Compact (240V) (<4.4 ft³) | 0.0340 | 0.0469 | 0.1141 |
| Ventless Electric, Compact (240V) (<4.4 ft³) | 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.

$$\Delta Therm = \left( \frac{Load}{CEFbase} - \frac{Load}{CEFeff} \right) * Ncycles * Therm\_convert * \%Gas$$

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 units[24]

Using defaults provided above:

ΔTherms = (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

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[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.

Using defaults provided above:

| Product Class | ΔPeakTherms | | |
|---|---|---|---|
| | 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

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

Where:

$CFM_{reduced}$ = Reduced air consumption (CFM) per drain
= 3 CFM[27]

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[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."

$kW_{CFM}$     = System power demand reduction per reduced air consumption (kw/CFM), depending on the type of compressor control, see table below[28]

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

| 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 |

| 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:

$\Delta kWh$     = Electric energy savings, calculated above
CF             = Summer peak coincidence demand (kW) to annual energy (kWh) factor
               = 0.0001379439[29]

**MEASURE CODE:**

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[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."

[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 Leak Repair

**DESCRIPTION**

This measure applies to an installed air compressor that has developed leaks. Leaks in a compressed air system lead to an increase in energy use to maintain the necessary pressure in the system.

Savings are calculated by using information collected through survey and measurement of the compressed air system, including the cubic feet per minute (CFM) of the airflow of each leak using ultrasonic leak detection equipment.

**DEFINITION OF EFFICIENT EQUIPMENT**

Efficient Equipment is defined as the state of the air compressor system after leaks have been repaired. It is not necessarily the air compressor with no leaks left as some leaks may be impossible to reach or have substantial difficulty in fixing, therefore the efficient equipment is one that has all leaks repaired that have been stated to be repaired.

**DEFINITION OF BASELINE EQUIPMENT**

Baseline equipment is characterized by the condition of the compressed air system at the time of inspection before the leaks are repaired.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The effective useful life is 2 years. [30]

**DEEMED MEASURE COST**

Measure cost should include the inspection and repair cost.

**LOADSHAPE**

Air Comp BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

Where:

$CFM_{leak}$      = CFM leaving the air compressor system through leaks
         = Use actual value if known, otherwise approximate value can be found using dB and psig reading and the table below[31]

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[30] 2022 WI TRM. PA Consulting Group. Focus on Energy, Business Programs: Measure Life Study Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[31] Values extrapolated from "Compressed Air Ultrasonic Leak Detection Guide" from UE Systems. Readings compensated for atmospheric pressure and taken at 40 kHz.

kW<sub>CFM</sub>        = System power demand reduction per reduced air consumption (kw/CFM), depending on the type of compressor control, see table below[32]

Hours        = Compressed air system pressurized hours

                 = Use actual hours if known, otherwise assume values in table below, based on business operating schedule

| Digital Reading | 10 PSIG | 25 PSIG | 50 PSIG | 75 PSIG | 100 PSIG |
|---|---|---|---|---|---|
| 10 dB | 0.05 | 0.1 | 0.2 | 0.3 | 0.5 |
| 20 dB | 0.15 | 0.3 | 0.5 | 0.9 | 0.8 |
| 30 dB | 0.4 | 0.5 | 0.8 | 1.1 | 1.4 |
| 40 dB | 0.5 | 0.8 | 1.1 | 1.4 | 1.7 |
| 50 dB | 1.9 | 2 | 2.2 | 1.8 | 2 |
| 60 dB | 2.3 | 2.6 | 2.8 | 3 | 3.6 |
| 70 dB | 3 | 3.4 | 3.9 | 4.9 | 5.2 |
| 80 dB | 3.6 | 5.1 | 5.6 | 6.8 | 7.7 |
| 90 dB | 5.3 | 6.8 | 7.1 | 7.7 | 8.4 |
| 100 dB | 6 | 7.3 | 9.6 | 10 | 10.6 |

| Compressor Control Type | kW<sub>CFM</sub> |
|---|---|
| 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 |

| 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 |

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[32] 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."

**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 |
| | = 0.0001379439[33] |

**MEASURE CODE:**

---

[33] 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 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.[34]

**DEEMED MEASURE COST**

Incremental measure costs are presented in the following table.[35]

| 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**

---

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

[35] 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.

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

Where:

| | |
|---|---|
| SCFM | = Air flow through standard nozzle. |
| | = Actual rated flow at 80 psi, if known. If unknown, use CFM by orifice diameter from table below. [36, 37] |
| SCFM%Reduced | = Percent reduction in air loss per nozzle. |
| | = Estimated at 50%[38] |
| kW/CFM | = System power reduction per air demand (kW/CFM), depending on the type of air compressor; see table below[39] |
| %USE | = Percent of the compressor total operating hours that the nozzle is in use |
| | = Custom, or if unknown, assume 5%[40] |
| Hours | = Compressed air system pressurized hours |
| | = Use actual hours if known, otherwise assume values in table below. |

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

| | |
|---|---|
| SCFM | = Air flow through standard nozzle. |
| | = Actual rated flow at 80 psi, if known. If unknown, use CFM by orifice diameter from table below. [41, 42] |
| SCFM%Reduced | = Percent reduction in air loss per nozzle. |
| | = Estimated at 50%[43] |
| kW/CFM | = System power reduction per air demand (kW/CFM), depending on the type of air compressor; see table below[44] |

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[36] Review of manufacturer's information

[37] Technical Reference Manual (TRM) for Ohio Senate Bill 221,"Energy Efficiency and Conservation Program" and 09-512-GEUNC, October 15, 2009, Pgs 170-171.

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

[39] 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."

[40] 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.

[41] Review of manufacturer's information

[42] Technical Reference Manual (TRM) for Ohio Senate Bill 221,"Energy Efficiency and Conservation Program" and 09-512-GEUNC, October 15, 2009, Pgs 170-171.

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

[44] 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."

~~%USE~~   ~~= Percent of the compressor total operating hours that the nozzle is in use~~
~~= Custom, or if unknown, assume 5%[45]~~
~~Hours~~   ~~= Compressed air system pressurized hours~~
~~= Use actual hours if known, otherwise assume values in table below.~~

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

| Air Compressor Type | ΔkW/CFM |
|---|---|
| ~~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 |
| UnloadingScrew – Variable Displacement | 0.15 |
| Screw - VFD | 0.18 |

| 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

---

[45] ~~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.~~

$$= 0.0001379439^{46}$$

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

---

[46] 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."

## 2.2.4 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 5-40 hp with variable speed control.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a modulating compressor with blow down 5-40 hp

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

10 years.[47]

**DEEMED MEASURE COST**[48]

Incremental Cost (\$) = (127 x $hp_{compressor}$) + 1446

Where:

$hp_{compressor}$     = compressor motor nominal horsepower

**LOADSHAPE**

Air Comp BUS

---

**Algorithm**

---

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh$          = 0.9 x $hp_{compressor}$ x HOURS x ($CF_b - CF_e$)

Where:

---

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

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

| | |
|---|---|
| $\Delta kWh$ | = gross customer annual kWh savings for the measure |
| $hp_{compressor}$ | = compressor motor nominal horsepower |
| $0.9^{49}$ | = compressor motor nominal horsepower to full load kW conversion factor |
| HOURS | = compressor total annual hours of operation. Custom input, if unknown use the defaults based on shift structure below. |
| $CF_b$ | = baseline compressor factor [50]<br>=0.890 |
| $CF_e$ | = efficient compressor [51] [52]<br>=0.705 |

| 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**

$$\Delta k = \Delta kWh * CF$$

Where:

| | |
|---|---|
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor<br>= 0.0001379439[43] |

**MEASURE CODE:**

---

[49] 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."

[50] 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.

[51] 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.

[52] 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 | ≤ 200P+6,511 | ≥ 41 |
| | Convection Mode | ≤ 150P+5,425 | ≥ 56 |
| Electric | Steam Mode | ≤ 0.133P+0.6400 | ≥ 55 |
| | Convection Mode | ≤ 0.080P+0.4989 | ≥ 76 |

Note: P = Pan capacity as defined in Section 1.T of the Commercial Ovens Program Requirements Version 2.2.[53]

**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. [54]

**DEEMED MEASURE COST**

---

[53] Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F1495-05 standard specification.
https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx
[54] 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

The incremental capital cost for this measure is $4,300. [55]

**LOADSHAPE**
Cooking BUS

---

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Custom calculation for an electric combination oven below. [56]

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

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 |
| $FoodCooked_{Elec}$ | = 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 |
| ElecEff | = 73.2 Wh/lb |

---

[55] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.
[56] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

|  |  |
|---|---|
|  | = Cooking energy efficiency of electric combination oven |
|  | = Custom or if unknown, use values from table below |
| $\%_{Conv}$ | = 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 |
| 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 |
| $ElecIDLE_{ConvEE}$ | = 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 |
| $ElecIDLE_{SteamEE}$ | = Idle energy rate of ENERGY STAR electric combination oven in steam mode |
|  | = (0.133*P + 0.64)*1,000 |

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

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

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

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta k = \Delta kWh * CF$$

Where:

$\Delta kWh$ = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[57]

Other variables as defined above.

**NATURAL GAS ENERGY SAVINGS**

Custom calculation for a gas combination oven below:[58]

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

Where:

| | |
|---|---|
| $\Delta CookingEnergy_{ConvGas}$ | = Difference in cooking energy between baseline and efficient combination oven in convection mode<br>= $FoodCooked_{Gas}$ * ($EFOOD_{ConvGas}$ / $GasEFF_{ConvBase}$ $EFOOD_{ConvGas}$ / $GasEFF_{ConvEE}$) * %Conv |
| $\Delta CookingEnergy_{SteamGas}$ | = Difference in cooking energy between baseline and efficient combination oven in steam mode<br>= $FoodCooked_{Gas}$ * ($EFOOD_{SteamGas}$ / $GasEFF_{SteamBase}$ − $EFOOD_{SteamGas}$ / $GasEFF_{SteamEE}$) * %Steam |
| $\Delta IdleEnergy_{ConvGas}$ | = Difference in idle energy between baseline and efficient combination oven in convection mode<br>= (($GasIDLE_{ConvBase}$ * (($Hours$ – $FoodCooked_{Gas}$ / $GasPC_{ConvBase}$) * %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<br>= [($GasIDLE_{SteamBase}$ * (($Hours$ – $FoodCooked_{Gas}$ / $GasPC_{SteamBase}$) * %Steam)) - ($GasIDLE_{SteamEE}$ * (($Hours$ - $FoodCooked_{Gas}$ / $GasPC_{SteamEE}$) * %Steam))] |
| 100,000 | = Btu to therms conversion factor |
| $FoodCooked_{Gas}$ | = Food cooked per day for gas combination oven<br>= Custom, or, if unknown, use 200 lbs if P <15, 250 lbs if 15 ≤ P 30, or 400 lbs if P ≥30 |
| $EFOOD_{ConvGas}$ | = ASTM energy to food for gas combination oven in convection mode<br>= 250 Btu/lb |

---

| | |
|---|---|
| GasEff | = Cooking energy efficiency of gas combination oven |
| | = Custom or, if unknown, use values from table below |
| $EFOOD_{SteamGas}$ | = ASTM energy to food for gas combination oven in steam mode |
| | = 105 Btu/lb |
| $GasIDLE_{Base}$ | = Idle energy rate (Btu/hr) of baseline gas combination oven |
| | = Custom or, if unknown, use values from table below |
| $GasPC_{Base}$ | = Production capacity (lbs/hr) of baseline gas combination oven |
| | = Custom or, if unknown, use values from table below |
| $GasIDLE_{ConvEE}$ | = 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 |
| $GasIDLE_{SteamEE}$ | = Idle energy rate of ENERGY STAR gas combination oven in steam mode |
| | = 200*P +6,511 |

Other variables as defined above.

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

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

| Pan Capacity | Convection Mode ($GasPC_{ConvBase}$) | Steam Mode ($GasPC_{SteamBase}$) |
|---|---|---|
| < 15 | 125 | 195 |
| 15 ≤ P 30 | 176 | 211 |
| ≥30 | 392 | 579 |

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

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

**DEFINITION OF BASELINE EQUIPMENT**

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

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years.[59]

**DEEMED MEASURE COST**

Actual incremental cost for this measure should be used. If actuals are unavailable use $4,150.[60]

---

[59] 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
[60] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

**LOADSHAPE**

Cooking BUS

---

**Algorithm**

---

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric steam cooker below; otherwise use deemed value from the table that follows.[61]

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

Where:

| | |
|---|---|
| $\Delta$IdleEnergy | = Difference in idle energy between baseline and efficient steam cooker |
| | = [(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 | = Difference in cooking energy between baseline and efficient steam cooker |
| | = (FoodCooked * EFOOD/ Eff$_{Base}$) – (FoodCooked * EFOOD/ Eff$_{ESTAR}$) |
| 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 W[62] |
| 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 |
| Production$_{Base}$ | = Production capacity (lb/hr) per pan of baseline electric steam cooker |
| | = 23.3 lb/hr |
| Production$_{ESTAR}$ | = Production capacity (lb/hr) per pan of ENERGY STAR® electric steam cooker |
| | = Custom or, if unknown, use 16.7 lb/hr |
| Pans | = Pan capacity of steam cooker |
| | = Custom or, if unknown, use 6 pans |
| EFOOD | = ASTM energy to food |

---

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

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

|                 | = 30.8 Wh/lb                                                          |
|-----------------|-----------------------------------------------------------------------|
| $Eff_{Base}$    | = Cooking efficiency (%) of baseline electric steam cooker[63]        |
|                 | = 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                               |

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

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**

$$\Delta k = \Delta kWh * CF$$

Where:

| $\Delta kWh$ | = 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**

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[63] 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.
[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."

Custom calculation for a natural gas steam cooker below; otherwise use deemed value from the table that follows.[65]

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

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$_{ESTAR}$) |
| 100,000 | = Btu to therms conversion factor |
| IdleRate$_{Base}$ | = Idle energy rate (Btu/hr) of baseline gas steam cooker = 16,500 Btu/hr[66] |
| 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 |
| 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 cooker[67] = 16.5% = Cooking efficiency (%) of ENERGY STAR® gas steam cooker |
| Eff$_{ESTAR}$ | = Custom or if unknown, use 38% |

Other variables as defined above.

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

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

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

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

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

| 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.[68]  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 cooker[69]
                          = Custom or, if unknown, use 9.3 gal/hr

Other variables as defined above

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

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[68] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
[69] Water use for ENERGY STAR® steam cookers is the average of water use values provided by ENERGY STAR® for steam generator, boiler-based, and boiler-less 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.[70]

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.[71]

LOADSHAPE
Cooking BUS

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[70] 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.
[71] Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "EPA research using AutoQuotes, 2012."

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**Algorithm**

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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.[72]

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

Where:

| | |
|---|---|
| $\Delta$IdleEnergy | = Difference in idle energy between baseline and efficient fryer |
| | = (ElecIdleBase* (Hours – FoodCooked/ElecPCBase)) – ElecIdleESTAR * (Hours – FoodCooked/ElecPCESTAR)) |
| $\Delta$CookingEnergy | = Difference in cooking energy between baseline and efficient fryer |
| | = (FoodCooked * EFOOD$_{Elec}$/ ElecEff$_{Base}$) – (FoodCooked * EFOOD$_{Elec}$/ElecEff$_{ESTAR}$) |
| 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 |
| | = 167 Wh/lb |
| ElecEff$_{Base}$ | = Cooking efficiency of baseline electric fryer |
| | = 75% for standard fryers and 70% for large vat fryers |
| | = Cooking efficiency of ENERGY STAR® electric fryer |
| ElecEff$_{ESTAR}$ | = Custom or, if unknown, use 80% for both standard and large vat fryers |

Other variables as defined above

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta k = \Delta kWh * CF$$

Where:

ΔkWh      = Electric energy savings, calculated above

CF      = Summer peak coincidence demand (kW) to annual energy (kWh) factor
     = 0.0001998949[73]

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.[74]

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

Where:

| | |
|---|---|
| ΔIdleEnergy | = (GasIdle$_{Base}$* (Hours – FoodCooked/GasPC$_{Base}$)) – (GasIdle$_{ESTAR}$ * (Hours – FoodCooked/GasPC$_{ESTAR}$)) |
| ΔCookingEnergy | = (FoodCooked * EFOOD$_{Gas}$/ GasEff$_{Base}$) – (FoodCooked * EFOOD$_{Gas}$/GasEff$_{ESTAR}$) |
| 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 |
| | = Production capacity of ENERGY STAR® gas fryer |
| | = Custom or, if unknown, use 65 lb/hr for standard fryers and 110 lb/hr |
| GasPc$_{ESTAR}$ | for large vat fryers |
| EFOOD$_{Gas}$ | = ASTM energy to food |
| | = 570 Btu/lb |
| GasEff$_{Base}$ | = Cooking efficiency of baseline gas fryer |
| | = 35% for both standard and large vat fryers |
| | = Cooking efficiency of ENERGY STAR® gas fryer |
| GasEff$_{ESTAR}$ | = Custom or, if unknown, use 50% for both standard and large vat fryers |

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[73] 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."

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

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.[75]

DEEMED MEASURE COST

The incremental capital cost for this measure is $0.[76]

LOADSHAPE
Cooking BUS

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[75] 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.
[76] Measure cost from ENERGY STAR® which cites reference as "EPA research on available models using AutoQuotes, 2013."

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**Algorithm**
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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.[77]

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

Where:

| | |
|---|---|
| $\Delta IdleEnergy$ | = Difference in idle energy between baseline and efficient convection oven |
| | = (ElecIdle$_{Base}$* (Hours - FoodCooked/ElecPC$_{Base}$)) - (ElecIdle$_{ESTAR}$ * (Hours -FoodCooked/ElecPC$_{ESTAR}$)) |
| $\Delta CookingEnergy$ | = Difference in cooking energy between baseline and efficient convection oven |
| | = (FoodCooked * EFOOD$_{Elec}$/ ElecEff$_{Base}$) - (FoodCooked * EFOOD$_{Elec}$/ ElecEff$_{ESTAR}$) |
| 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 |
| | = 73.2 Wh/lb |
| ElecEff$_{Base}$ | = Cooking efficiency of baseline electric convection oven |
| | = 65% for full-size ovens and 68% for half-size ovens |

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

ElecEff$_{ESTAR}$      = Cooking efficiency of ENERGY STAR® electric convection oven

                                  = Custom or, if unknown, use 71% for full-size and half-size ovens

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta k = \Delta kWh * CF$

Where:

| | |
|---|---|
| $\Delta kWh$ | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001998949[78] |

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.[79]

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

Where:

| | |
|---|---|
| $\Delta IdleEnergy$ | = (GasIdle$_{Base}$* (Hours - FoodCooked/GasPC$_{Base}$)) - (GasIdle$_{ESTAR}$ * (Hours -FoodCooked/GasPC$_{ESTAR}$)) |
| | = (FoodCooked * EFOOD$_{Gas}$/ GasEff$_{Base}$) - (FoodCooked * |
| $\Delta CookingEnergy$ | EFOOD$_{Gas}$/ GasEff$_{ESTAR}$) |
| 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 |
| EFOOD$_{Gas}$ | = ASTM energy to food for gas convection oven |
| | = 250 Btu/lb |
| GasEff$_{Base}$ | = Cooking efficiency of baseline gas convection oven |
| | = 44% |
| | = Cooking efficiency of ENERGY STAR® gas convection oven |
| GasEff$_{ESTAR}$ | = Custom or, if unknown, use 46% |

Other variables as defined above.

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[78] 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."

[79] 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:**

### 2.3.5 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 |
| ≤ 320 W/ft$^2$ ≤ 1.00 kW | Reported | ≤ 2,650 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.[80]

DEEMED MEASURE COST

The incremental capital cost for this measure is $0 for an electric griddle and $360 for a gas griddle.[81]

LOADSHAPE

Cooking BUS

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**Algorithm**

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[80] 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
[81] 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.

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Custom calculation for an electric griddle below; otherwise use deemed value of 1,910.4 kWh.[82]

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

Where:

| | |
|---|---|
| $\Delta IdleEnergy$ | = Difference in idle energy between baseline and efficient griddle |
| | = [(ElecIdle$_{Base}$* Width * Depth) * (Hours – FoodCooked/ElecPC$_{Base}$)] – [(ElecIdle$_{ESTAR}$ * Width * Depth) * (Hours – FoodCooked/ElecPC$_{ESTAR}$)) |
| $\Delta CookingEnergy$ | = Difference in cooking energy between baseline and efficient griddle |
| | = (FoodCooked * EFOOD$_{Elec}$ / ElecEff$_{Base}$) – (FoodCooked * EFOOD$_{Elec}$ / ElecEff$_{ESTAR}$) |
| 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% |

Other variables as defined above.

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

**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[83]

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.[84]

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

Where:

| | |
|---|---|
| ΔIdleEnergy | = [GasIdle$_{Base}$* (Width * Depth) * (Hours – FoodCooked/GasPC$_{Base}$)] – [GasIdle$_{ESTAR}$ * (Width * Depth) * (Hours – FoodCooked/GasPC$_{ESTAR}$)) |
| ΔCookingEnergy | = (FoodCooked * EFOOD$_{Gas}$/ GasEff$_{Base}$) – (FoodCooked * EFOOD$_{Gas}$/ GasEff$_{ESTAR}$) |
| 100,000 | = Btu to therms conversion factor |
| GasIdle$_{Base}$ | = Idle energy rate of baseline gas griddle<br>= 3,500 Btu/hr/ft$^2$ |
| GasIdle$_{ESTAR}$ | = Idle energy rate of ENERGY STAR® gas griddle<br>= Custom or, if unknown, use 2,650 Btu/hr/ft$^2$ |
| GasPC$_{Base}$ | = Production capacity of baseline gas griddle<br>= 25 lb/hr |
| GasPC$_{ESTAR}$ | = Production capacity of ENERGY STAR® gas griddle<br>= Custom or, if unknown, use 45 lb/hr |
| EFOOD$_{Gas}$ | = ASTM energy to food<br>= 475 Btu/lb |
| GasEff$_{Base}$ | = Cooking efficiency of baseline gas griddle<br>= 32%<br>= Cooking efficiency of ENERGY STAR®  gas griddle |
| GasEff$_{ESTAR}$ | = Custom or, if unknown, use 38% |

Other variables as defined above.

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**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**

Installation of commercial kitchen demand ventilation controls that vary the ventilation based on cooking load and/or time of day. This measure applies to the following program types: RF, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

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

**DEFINITION OF BASELINE EQUIPMENT**

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

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**[85]

The expected measure life is assumed to be 15 years.

**MEASURE COST**[86]

The incremental capital cost for this measure is:

| Measure Category | Incremental Cost ($/HP) |
|---|---|
| DVC Control Retrofit | $1,991 |
| DVC Control New | $1,991 |

**LOADSHAPE**
Cooking BUS

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**Algorithm**

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## Calculation of Savings

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

**Electric Energy Savings**[87]

| Measure Name | Annual Energy Savings per Unit (kWh/HP) |
|---|---|
| DVC Control Retrofit | 4,197 |
| DVC Control New | 4,197 |

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[85] Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 4.
[86] Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 4.
[87] Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 4.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

| | |
|---|---|
| $\Delta$kWh | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001998949[88] |

**NATURAL GAS SAVINGS**

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

Where:

| | |
|---|---|
| CFM | = the average airflow reduction with ventilation controls per hood |
| | = 430 cfm/HP |
| HP | = actual if known, otherwise assume 7.75 HP[89] |
| Annual Heating Load | = Annual heating energy required to heat fan exhaust make-up air dependent on location |
| Eff(heat) | = Heating Efficiency |
| | = actual if known, otherwise assume 80%[90] |
| 100,000 | = conversion from Btu to Therm |

| Zone | Annual Heating Load (BTU/cfm) |
|---|---|
| Missouri Average[91] | 137,000 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**Measure Code:**

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[88] See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

[89] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0, Volume 2: Commercial and Industrial Measures," Section 4.2.16, Kitchen Demand Ventilation Controls; https://s3.amazonaws.com/ilsag/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

[90] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0, Volume 2: Commercial and Industrial Measures", Section 4.2.16, Kitchen Demand Ventilation Controls; https://s3.amazonaws.com/ilsag/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

[91] Used https://s3.amazonaws.com/ilsag/2020_IL-TRM_Version_8.0_dated_October-17-2019_Final_Volumes_1-4_Compiled.pdf to compare savings values by weather zone from the IL TRM to zone-specific HDD values, and determined a linear relationship between Heating Load and HDD, then applied that linear relationship to HDD values (using base 60) for MO weather stations to estimate Heating Load values for zones in Ameren Missouri territory

### 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 (ft³) | 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.[92]

**DEEMED MEASURE COST**

Actual incremental costs should be used if available. If actual costs are unknown, assume $1,783.[93]

**LOADSHAPE**

Cooking BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

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

[93] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

**ELECTRIC ENERGY SAVINGS**[94]

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

Where:

| | |
|---|---|
| IdleRate$_{Base}$ | = Idle energy rate (W) of baseline HFHC |
| | = 40 * V |
| V | = Interior volume (ft$^3$) of new HFHC |
| | = Custom |
| IdleRate$_{ESTAR}$ | = Idle energy rate (W) of ENERGY STAR® HFHC |
| | = See table below for idle energy rates based on interior volume |
| Hours | = Average daily hours of operation |
| | = Custom or, if unknown, use 15 hours per day |
| Days | = Annual days of operation |
| | = Custom or, if unknown, use 365.25 days per year |
| 1,000 | = Wh to kWh conversion factor |

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta k = \Delta kWh * CF$

Where:

| | |
|---|---|
| ΔkWh | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001998949[95] |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

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

[95] 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."

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.[96] 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 years.[97]

DEEMED MEASURE COST

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[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 PRERINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report," Feb 2007).

[97] Consistent with Ameren Missouri MEEIA 2016-18 and KCPL TRM assumptions.

When available, the actual cost of the measure should be used. If unknown, a default value of $92.90[98] may be assumed.

**LOADSHAPE**

Cooking BUS

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**Algorithm**

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## 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 Tin + 70°F temperature rise from Tin[99] |
| $T_{in}$ | = Inlet Water Temperature |
| | = Custom, otherwise assume 57.9F[100] |
| $EFF_{Elec}$ | = Efficiency of electric water heater supplying hot water to pre-rinse spray valve |
| | =Custom, otherwise assume 97%[101] |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta k = \Delta kWh * CF$

Where:

| | |
|---|---|
| $\Delta kWh$ | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001998949[102] |

### NATURAL GAS ENERGY SAVINGS

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

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

[100] 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.

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

[102] 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."

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

Where:

| | |
|---|---|
| $EFF_{Gas}$ | = Efficiency of gas water heater supplying hot water to pre-rinse spray valve |
| | = Custom, otherwise assume 80%[103] |

Other variables as described above.

### WATER IMPACT CALCULATION

$$\Delta Gallons = (FLO_{base} - FLO_{eff}) * 60 * HOURS_{day} * DAYS_{year}$$

Where:

| | |
|---|---|
| $FLO_{base}$ | = Base case flow in gallons per minute (gal/min). Use actual when appropriate if available, otherwise use values in table below. |
| $FLO_{eff}$ | = Efficient case flow in gallons per minute (gal/min). Use actual flow rate if known, otherwise use values in table below. |
| 60 | = Minutes per hour |
| $HOURS_{day}$ | = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise use values in the table below.[104] |
| $DAYS_{year}$ | = 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. |

| Parameter | Time of Sale | Retrofit, Direct Install |
|---|---|---|
| $FLO_{base}$ | 1.6 gal/min[105] | 2.23 gal/min[106] |
| $FLO_{eff}$ | 1.06 gal/min[107] | 1.06 gal/min |

| Application | HOURS$_{day}$ |
|---|---|
| Small, quick- service restaurants | 1 |
| Medium-sized casual dining restaurants | 1.5 |
| Large institutional establishments with cafeteria | 3 |

---

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

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

[105] The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. www1.eere.energy.gov/femp/pdfs/spec_prerinsesprayvavles.pdf.

[106] 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 PRERINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report," Feb 2007).

[107] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

MEASURE CODE:

## 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.[108]

#### DEEMED MEASURE COST

The incremental cost for this measure is $8.00[109] or program actual.

#### LOADSHAPE

Water Heating BUS

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### Algorithm

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#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

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[108] 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."

[109] 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).

Note these savings are *per* faucet retrofitted.[110]

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

Where:

| | |
|---|---|
| %ElectricDHW | = proportion of water heating supplied by electric resistance heating (see values in table below) |
| GPM$_{base}$ | = Average flow rate, in gallons per minute, of the baseline faucet "as-used"<br>= 1.2[111] or custom based on metering studies[112] |
| GPM$_{low}$ | = Average flow rate, in gallons per minute, of the low-flow faucet erator "as-used"<br>= 0.94[113] or custom based on metering studies[114] |
| Usage | = Estimated usage of mixed water (mixture of hot water from water heater line and cold-water line) per faucet (gallons per year)<br>= If data is available to provide a reasonable custom estimate it should be used, if not use the defaults in the table below (or substitute custom information into the calculation): |
| EPG$_{electric}$ | = Energy per gallon of mixed water used by faucet (electric water heater)<br>= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE$_{electric}$ * 3412)<br>= (8.33 * 1.0 * (90 – 57.9)) / (0.98 * 3412) = 0.0800 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 |

---

[110] 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.

[111] 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.

[112] 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.

[113] 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.

[114] 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.

$$= 90 \text{ F }^{115}$$

SupplyTemp = Assumed temperature of water entering building

$$= 57.9 \text{ F }^{116}$$

$RE_{electric}$ = Recovery efficiency of electric water heater

$$= 98\% ^{117}$$

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators

= Assumed to be 1.0

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |
| Unknown | 43%[118] |

| Building Type | Gallons HW per unit per day[119] (A) | Unit | Estimated % HW from Faucets[120] (B) | Multiplier[121] (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 Restaurant | 0.7 | meal/day | 50% | 75 | meals per faucet | 365 | 9,581 |
| Sit-Down Restaurant | 2.4 | meal/day | 50% | 36 | meals per faucet | 365 | 15,768 |
| Retail | 2 | employee | 100% | 5 | employees per faucet | 365 | 3,650 |

[115] Temperature 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.

[116] 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

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

[118] 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.

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

[120] 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.

[121] 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.

| 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 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh * CF$

Where:

$\Delta kWh$ = 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 (see table below)

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

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

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

Other variables as defined above.

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |

| Unknown | 57%[122] |
|---------|----------|

## 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. |
| 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:

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[122] 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.

### 2.4.2 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.[123]

**DEEMED MEASURE COST**

The assumed measure cost is $1,200 per pump.[124]

**LOADSHAPE**

Miscellaneous BUS

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**Algorithm**

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**CALCULATION OF ENERGY SAVINGS**

Savings shown are per pump.

**ELECTRIC ENERGY SAVINGS**

Deemed at 651 kWh.[125]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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[123] 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.

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

[125] 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.

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

Where:

$\Delta$kWh  = calculated value above on a per faucet basis

CF       = Summer peak coincidence demand (kW) to annual energy (kWh) factor
=0.0001379439

**NATURAL GAS SAVINGS**

$\Delta$Therms = 55.9 * number of dwelling units[126]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

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[126] 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:  TOSNC.

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.[127]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.[128]

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.[129]

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

For larger HPWHs, incremental capital costs are presented below based on heating capacity.[130]

| 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 |

---

[127] 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.

[128] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.

[129] 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.

[130] 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.

| >500 | $18,000.00 |
|------|-----------|

**LOADSHAPE**

Water Heating BUS

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## Algorithm

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### CALCULATION OF SAVINGS

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = ((1/EF_{BASE} – 1/EF_{EE}) * HWU_{GAL} * \gamma Water * (T_{out} – T_{in}) * 1.0 * 3{,}412) + kWh_{COOL} – kWh_{HEAT}$

$kWh_{COOL} = ((1-1/EF_{EE}) * HWU_{GAL} * \gamma Water * (T_{out} – T_{in}) * 1.0 * LF * 53\% * LM) / (COP_{COOL} * 3{,}412) * \%Cool$

$kWh_{HEAT} = ((1-1/EF_{EE}) * HWU_{GAL} * \gamma Water * (T_{out} – T_{in}) * 1.0) * LF * 43\%) / (COP_{HEAT} * 3{,}412) * \%ElectricHeat$

Where:

| | |
|---|---|
| kWh_cool | = Cooling savings from conversion of heat in building to water heat[131] |
| kWh_heat | = Heating cost from conversion of heat in building to water heat (dependent on heating fuel) |
| $EF_{BASE}$ | = Efficiency of baseline water heater according to federal standards, expressed as Energy Factor (EF) or Thermal Efficiency ($E_t$) |
| | = See table below |
| $EF_{EE}$ | = EF of heat pump water heater |
| | = Actual |
| $HWU_{GAL}$ | = Estimated annual hot water consumption (gallons) |
| | = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided below to develop an estimate. |
| $\gamma Water$ | = Specific weight of water |
| | = 8.33 pounds per gallon |
| $T_{OUT}$ | = Tank temperature |
| | = Actual, if unknown assume 125 °F [132] |
| $T_{IN}$ | = Incoming water temperature from well or municipal system |

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[131] 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.

[132] 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.

|                  |                                                                                                      |
|------------------|------------------------------------------------------------------------------------------------------|
|                  | = 57.898 °F [133]                                                                                    |
| 1.0              | = Heat capacity of water (1 Btu/lb*°F)                                                                |
| 3,412            | = Conversion factor from Btu to kWh                                                                   |
| LF               | = Location Factor                                                                                     |
|                  | = 1.0 for HPWH installation in a conditioned space                                                   |
|                  | = 0.5 for HPWH installation in an unknown location[134]                                              |
|                  | = 0.0 for installation in an unconditioned space                                                     |
| 53%              | = Portion of reduced waste heat that results in cooling savings[135]                                 |
| 43%              | = Portion of reduced waste heat that results in increased heating load[136]                          |
| LM               | = Latent multiplier to account for latent cooling demand[137]                                        |
|                  | = 3.0 for St. Louis, MO                                                                               |
| $COP_{COOL}$     | = COP of central air conditioner                                                                     |
|                  | = Actual                                                                                              |
| $COP_{HEAT}$     | = Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%* |
| %Cool            | = Percentage of buildings with central cooling                                                       |
|                  | = 100% for cooling in the home and 0% for no cooling in the home                                      |
| %ElectricHeat    | = Percentage of buildings with electric heat                                                         |
|                  | = 100% for electric heating fuel and 0% for gas heating fuel                                          |

| Equipment Type | Size Category | Federal Standard Minimum Efficiency          |
|----------------|---------------|----------------------------------------------|
| HPWH ≤12 kW    | ≤55 gallon    | EF: 0.96 – (0.0003 * rated volume in gallons) |
| HPWH >12 kW    | >120 gallon   | Et: 98%[138]                                 |

*Method 1 to estimate HWU$_{GAL}$ – Consumption per water heater capacity*

HWU$_{GAL}$ = Consumption/cap * Capacity

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[133] 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.

[134] Professional judgment.

[135] 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.

[136] 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.

[137] 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.

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

Where:

| | |
|---|---|
| Consumption/cap | = Estimate of consumption per gallon of tank capacity, dependent on Building Type (see table below)[139] |
| Capacity | = Capacity of hot water heater in gallons |
| | = Actual |

| 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 |

*Method 2 to estimate HWUGAL – Consumption by facility size*[140]

| Building Type | Gallons HW per unit per day | Unit | Units/1000 ft² | Days per year | Gallons / 1000 ft² floor area |
|---|---|---|---|---|---|
| Small Office | 1 | person | 2.3 | 250 | 575 |
| Large Office | 1 | person | 2.3 | 250 | 575 |
| Fast Food Restaurant | 0.7 | meal/day | 784.6 | 365 | 200,458 |
| Sit-Down Restaurant | 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 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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[139] 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.

[140] Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting," Lawrence Berkeley National Library, December 1995.

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

Where:

        ΔkWh   = Electric energy savings, as calculated above

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

                 = 0.0001811545[141]

**NATURAL GAS SAVINGS**

Δtherms = [ ((1-1/$EF_{EE}$) * $HWU_{GAL}$ * γWater * $T_{out}$ – $T_{in}$) * 1.0) * LF * 53%] / (ηHeat * 100,000) * %GasHeat

Where:

        ΔTherms        = Heating cost from conversion of heat in building to water heat for buildings with natural gas heat[142]

        100,000        = Conversion factor from Btu to therms

        ηHeat           = Efficiency of heating system

                     = Actual

        %GasHeat      = Percentage of buildings with gas heat

                     = 0% for Electric Heating Fuel

                     =100% for Gas Heating Fuel

        Other variables as defined above.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

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[141] 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."

[142] 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.

## 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[143] | 1067 | 1018 | 1196 | 937 | 1217 | 865 | 1118 | 1085 | 910 | 996 | 1060 | 1053 | 1164 | 986 |

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[143] 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,[144] 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 years[145] based upon equipment life only.[146]

**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. [147]

**LOADSHAPE**

Cooling BUS
Heating BUS

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

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

[146] 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.

[147] Ameren Missouri Technical Resource Manual – Effective January 1, 2018. This current value was reviewed and confirmed using PY20 program data.

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

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[148] |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kW * CF$

Where:

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

**NATURAL GAS ENERGY SAVINGS**

$\Delta Therms = SQFT * SavingsFactor * PF / (100 * AFUE_{EXIST})$

Where:

| | |
|---|---|
| SQFT | = Square footage of building controlled by thermostat |
| SavingsFactor | = 9.940 kBtu/sf-yr[149] |
| $AFUE_{EXIST}$ | = Efficiency rating of existing heating equipment (AFUE), in decimal form. |
| 100 | = Converts kBtu to therms, 1 therm = 100 kBtu |

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[148] 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.

[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.

**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,[150] 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 years[151] based upon equipment life only.[152]

**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.[153]

**LOADSHAPE**

Cooling BUS

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

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

[152] 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.

[153] 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 = SQFT * SavingsFactor * PF / EER$_{EXIST}$

Where:

| | |
|---|---|
| Sqft | = Square footage of building controlled by thermostat |
| SavingsFactor | = 0.578 kWh/sf-yr[154] |
| PF | = Persistence Factor to account for thermostat being placed on hold, reset or bypassed. |
| | = Actual if provided in program evaluation, else assume 50%[155] |
| EER$_{EXIST}$ | = Efficiency rating of existing cooling equipment EER (btu hr/W) |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kW$ * CF

Where:

| | |
|---|---|
| $\Delta$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 = SQFT * SavingsFactor * PF / (100 * AFUE$_{EXIST}$)

Where:

| | |
|---|---|
| SQFT | = Square footage of building controlled by thermostat |
| Savings Factor | = 9.940 kBtu/sf-yr[156] |

---

[154] 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).

[155] 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.pdf%20, 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.

[156] 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.

100             = Converts kBtu to therms, 1 therm = 100 kBtu
AFUE$_{EXIST}$   = Efficiency rating of existing heating equipment (AFUE), in decimal form.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

### 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 ($CO_2$) 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 $CO_2$ 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.[157]

**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

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**Algorithm**

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[157] Based on $CO_2$ 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.

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas, cooling savings are:

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

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) |

Savings factors are based on Building Type and weather zone – see tables below.[158]

| 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 |

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[158] 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 62.1and 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.

| Special Assembly Auditorium | 476 | 534 | 536 | 635 | 650 | 556 | 580 |
|---|---|---|---|---|---|---|---|

| | SF ₕₑₐₜ HP (kWh/1000 SqFt) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Building Type** | **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 |
| 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 |

| | SF ₕₑₐₜ ER (kWh/1000 SqFt) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Building Type** | **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 | 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

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

Where:

$\Delta kWh_{cooling}$ = 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 – see table below

| 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.[159]

**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:[160]

| Supply Fan Size[161] (hp) | Controller | Installation Labor | Total Retrofit Cost |
|---|---|---|---|
| 1 | $2,200 | $750 | $2,950 |
| 2 | $2,600 | $750 | $3,350 |

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[159] Consistent with other HVAC variable speed drive lifetimes.
[160] Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656. U.S. Department of Energy, July 2013.
[161] Interpolation may be used to estimate controller cost for motor sizes not listed.

| 3 | $3,500 | $750 | $4,250 |
| 5 | $4,000 | $750 | $4,750 |
| 7.5 | $4,142 | $750 | $4,892 |

**LOADSHAPE**
HVAC BUS

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**Algorithm**

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**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**

$\Delta kWh = P_{sf} * SF * Hours_{fan}$

Where:

$P_{sf}$ = Nominal horsepower of supply fan motor

SF = Fan energy savings factor[162] (kWh/hour/horsepower)
= 0.558

$Hours_{fan}$ = Annual operating hours for fan motor based on Building Type. Default hours are provided for HVAC applications by Building Type.[163] 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 |

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[162] 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.
[163] 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.

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh * CF$

Where:

$\Delta kWh$  = 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. For multiple chiller projects, 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, Table 403.2.3(7) in the case of either IECC 2012 or the IECC 2015, or Table C403.3.2(7) in the case of IECC 2018.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[164]

DEEMED MEASURE COST

The incremental capital cost for this measure is $106.23 per ton.[165]

| Water cooled, electrically operated, positive displacement (rotary screw and scroll) ($/ton) | | | | |
|---|---|---|---|---|
| Capacity (tons) | > 0.72 kW/ton | < 0.72 and > 0.68 kW/ton | < 0.68 and > 0.64 kW/ton | 0.64 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 |

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[164] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
[165] Ameren Missouri Technical Resource Manual Effective January 1, 2018.

| Water cooled, electrically operated, positive displacement (reciprocating) ($/ton) | | | |
|---|---|---|---|
| Capacity (tons) | > 0.60 kW/ton | < 0.60 and > 0.58 kW/ton | 0.58 kw/ton and less |
| < 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

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**Algorithm**

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## 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. |
| $IPLV_{EE}$[166] | = Efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[167] |
| | = 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:

| | |
|---|---|
| $\Delta kWh$ | = Annual electricity savings, as calculated above |

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[166] 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.

[167] 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/.

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

## REFERENCE TABLES

Chillers Ratings - Chillers are rated with different units based 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[a]**

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 | | AS OF 1/1/2010[c] | | | | TEST PROCEDURE[b] |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | PATH A | | PATH B | | |
| | | | FULL LOAD | IPLV | FULL LOAD | IPLV | FULL LOAD | IPLV | |
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.416 | ≥ 9.562 | ≥ 12.500 | NAd | NAd | |
| | ≥ 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 | | | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | AHRI 550/590 |
| | ≥ 75 tons and < 150 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 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[a]**

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 | | AS OF 1/1/2010[b] | | | | TEST PROCEDURE[c] |
| | | | | | PATH A | | PATH B | | |
| | | | FULL LOAD | IPLV | FULL LOAD | IPLV | FULL LOAD | IPLV | |
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.416 | ≥ 9.562 | ≥ 12.500 | NA | NA | |
| | ≥ 150 tons | EER | | | ≥ 9.562 | ≥ 12.750 | NA | NA | |
| Air cooled without condenser, electrical operated | All capacities | EER | ≥ 10.586 | ≥ 11.782 | Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements | | | | |
| Water cooled, electrically operated, reciprocating | All capacities | kW/ton | ≤ 0.837 | ≤ 0.696 | Reciprocating units shall comply with water cooled positive displacement efficiency requirements | | | | |
| Water cooled, electrically operated, positive displacement | < 75 tons | kW/ton | | | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | AHRI 550/590 |
| | ≥ 75 tons and < 150 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 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 | | | | | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.634 | ≤ 0.596 | ≤ 0.634 | ≤ 0.596 | ≤ 0.639 | ≤ 0.450 | |
| | ≥ 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[e] |
|---|---|---|---|---|---|---|---|
| | | | Path A | Path B | Path A | Path B | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15.800 IPLV | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | 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 | |
| | | | ≤ 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.

<u>2018 IECC Baseline Efficiency Values by Chiller Type and Capacity</u>

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

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

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

**MEASURE CODE:**

### 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

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 both the full load and part load 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

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.[168]

#### DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.[169] The incremental cost for all other equipment types should be determined on a site-specific basis.

#### LOADSHAPE

Cooling BUS
Heating BUS

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**Algorithm**

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#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

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

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[168] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[169] Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.

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

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

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

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

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

Annual kWh Savings$_{cool}$ = (kBtu/hr$_{cool}$) * [(1/IEER$_{base}$) – (1/IEER$_{ee}$)] * EFLH$_{cool}$

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

Where:

| | |
|---|---|
| kBtu/hr$_{cool}$ | = Capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).<br>= Actual installed |
| SEER$_{base}$ | =Seasonal Energy Efficiency Ratio of the baseline equipment<br>= 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.<br>= Actual installed |
| EFLH$_{cool}$ | = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use. |
| HSPF$_{base}$ | = Heating Seasonal Performance Factor of the baseline equipment<br>= 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.<br>= Actual installed. If rating is COP, HSPF = COP * 3.413 |
| EFLH$_{heat}$ | = Heating mode equivalent full load hours are provided in section 2.7 HVAC End Use. |
| IEER$_{base}$ | = Integrated Energy Efficiency Ratio of the baseline equipment<br>= IEER from tables below, based on the applicable IECC. |
| IEER$_{ee}$ | = Integrated Energy Efficiency Ratio of the energy efficient equipment.<br>= Actual installed |
| kBtu/hr$_{heat}$ | = Capacity of the heating equipment in kBtu per hour.<br>= Actual installed |
| 3.412 | = Btu per Wh. |
| COP$_{base}$ | = Coefficient of performance of the baseline equipment<br>= COP from tables below, based on the applicable IECC. If rating is HSPF, COP = HSPF / 3.413 |
| COPee | = Coefficient of performance of the energy efficient equipment.<br>= 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 EERc (before Jan 1, 2010) 11.0 EERc (as of Jan 1, 2010) | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.3 EERc (before Jan 1, 2010) 10.6 EERc (as of Jan 1, 2010) | AHRI 340/360 |
| | ≥ 240,000 Btu/h | Split system and single package | 9.0 EERc 9.2 IPLYc (before Jan 1, 2010) 9.5 EERc 9.2 IPLYc (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 | AHRIASHRAE 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) | |
| | ≥ 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) | AHRI 340/360 |

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) | AHRI 210/240 |
| | | 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 = [(OF) - 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[a] |
|---|---|---|---|---|---|
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER | AHRI 210/240 |
| | | | Single Packaged | 13.0 SEER | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 13.0 SEER | |
| | | | Single Packaged | 13.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[a] | 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[a] | — | 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[a] | — | 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[a] |
| --- | --- | --- | --- | --- | --- | --- |
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER[c] | 14.0 SEER[c] | AHRI 210/240 |
| | | | Single Package | 13.0 SEER[c] | 14.0 SEER[c] | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 12.0 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 10.8 EER 11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER 10.7 IEER | 10.6 EER 11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER 10.5 IEER | 10.4 EER 11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER 9.6 IEER | 9.5 EER 10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER 9.4 IEER | 9.3 EER 9.4 IEER | |
| Water to Air: Water Loop (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 12.2 EER | 12.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| Water to Air: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 18.0 EER | 18.0 EER | ISO 13256-1 |
| Brine to Air: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering water | 14.1 EER | 14.1 EER | ISO 13256-1 |
| Water to Water: WaterLoop (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | 10.6 EER | |
| Water to Water: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.3 EER | 16.3 EER | ISO 13256-2 |
| Brine to Water: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | 12.1 EER | |

*(continued)*

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

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 7.7 HSPF[c] | 8.2 HSPF[c] | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF[c] | 8.0 HSPF[c] | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | 3.3 COP | AHRI 340/360 |
| | | | 17°F db/15°F wb outdoor air | 2.25 COP | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | 3.2 COP | |
| | | | 17°F db/15°F wb outdoor air | 2.05 COP | 2.05 COP | |
| Water to Air: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.3 COP | 4.3 COP | ISO 13256-1 |
| Water to Air: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.7 COP | 3.7 COP | |
| Brine to Air: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.2 COP | 3.2 COP | |
| Water to Water: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | 3.7 COP | ISO 13256-2 |
| Water to Water: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.1 COP | 3.1 COP | |
| Brine to Water: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | 2.5 COP | |

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

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

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

c. Minimum efficiency as of January 1, 2015.

**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) - 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:

1)  Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.

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

This measure was developed to be applicable to the following program types: TOS, NC, 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.[170]

Remaining life of existing equipment is assumed to be 5 years.[171]

**DEEMED MEASURE COST**

TOS: The incremental capital cost for this equipment is estimated to be $84/ton.[172]

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[170] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007
[171] Standard assumption of one third of effective useful life.
[172] DEER 2008. This assumes that baseline shifts between IECC versions carries the same incremental costs. Values should be verified during evaluation

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.[173]

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton.[174] This cost should be discounted to present value using the utilities' discount rate.

**LOADSHAPE**

Cooling BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

**ENERGY SAVINGS**
TOS:

$\text{PTAC } \Delta kWh^{175} \quad = \Delta kWh_{cool}$

$\text{PTHP } \Delta kWh \quad = \Delta kWh_{cool} + \Delta kWh_{heat}$

$\Delta kWh_{cool} \quad = kBtu/hr_{cool} * (1/EER_{base} - 1/EER_{ee}) * EFLH_{cool}$

$\Delta kWh_{heat} \quad = kBtu/hr_{heat} / 3.412 * (1/COP_{base} - 1/COP_{ee}) * EFLH_{heat}$

EREP:

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

$\Delta kWh \quad = \Delta kWh_{cool} + \Delta kWh_{heat}$

$\Delta kWh_{cool} \quad = kBtu/hr_{cool} * (1/EER_{exist} - 1/EER_{ee}) * EFLH_{cool}$

$\Delta kWh_{heat} \quad = kBtu/hr_{heat} / 3.412 * (1/COP_{exist} - 1/COP_{ee}) * EFLH_{heat}$

*ΔkWh for remaining measure life (next 10 years)*

$\Delta kWh \quad = \Delta kWh_{cool} + \Delta kWh_{heat}$

$\Delta kWh_{cool} \quad = kBtu/hr_{cool} * (1/EER_{base} - 1/EER_{ee}) * EFLH_{cool}$

$\Delta kWh_{heat} \quad = kBtu/hr_{heat} / 3.412 * (1/COP_{base} - 1/COP_{ee}) * EFLH_{heat}$

Where:

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[173] Based on DCEO – IL PHA Efficient Living Program data.
[174] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.
[175] There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COPbase and COPee would be 1.0.

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

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

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

EER$_{exist}$ = Energy Efficiency Ratio of the existing equipment
= Actual. If unknown assume 8.1 EER[176]

EER$_{base}$ = 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.

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 following conversion from SEER to EER for calculation of peak savings:[177] $EER = (-0.02 * SEER^2) + (1.12 * SEER)$
= Actual installed

kBtu/hr$_{heat}$ = Capacity of the heating equipment in kBtu per hour.
= Actual installed

3.412 = Btu per Wh.

COP$_{exist}$ = Coefficient of performance of the existing equipment
= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP[178] 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

IECC Minimum Efficiency Requirements

| 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 |

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[176] 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.

[177] 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.

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

| 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 unit's 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. | | | |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

TOS:

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

EREP:

$\Delta$kW for remaining life of existing unit (1st 5years)

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

$\Delta$kW for remaining measure life (next 10 years)

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

Where:

$\Delta$kWH$_{cool}$  = 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:**

### 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 both the full load and part-load 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.[179]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is assumed to be $100 per ton.[180]

**LOADSHAPE**

Cooling BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

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

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

[180] 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.

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

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

Where:

| | |
|---|---|
| kBtu/hr | = Capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr) |
| SEER$_{base}$ | = 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. |
| SEER$_{ee}$ | = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed) |
| IEER$_{base}$ | = Integrated Energy Efficiency Ratio of the baseline equipment = IEER values from tables below, if applicable code is based on IECC, or custom input as necessary. |
| IEER$_{ee}$ | = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed.) |
| EFLH | = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use |

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 EERc (before Jan 1, 2010) 11.2 EERc (as of Jan 1, 2010) | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.7 EERc (before Jan 1, 2010) 11.0 EERc (as of Jan 1, 2010) | AHRI 340/360 |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Split system and single package | 9.5 EERc 9.7 IPLYc (before Jan 1, 2010) 10.0 EERc 9.7 IPLyg (as of Jan 1, 2010) | |
| | ≥ 760,000 Btu/h | Split system and single package | 9.2 EERc 9.4 IPLYc (before Jan 1, 2010) 9.7 EERc 9.4 IPLYc (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 EERc | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 11.0 EERc | AHRI 340/360 |
| | ≥ 240,000 Btu/h | Split system and single package | 11.5 EERc | |

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 Btulh 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 |
| | ≥ 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<br>12.3 IEER | 12.1 EER<br>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<br>11.7 IEER | 12.1 EER<br>12.3 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.3 EER<br>11.5 IEER | 11.9 EER<br>12.1 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.2 IEER | 12.0 EER<br>12.2 IEER | |
| | | All other | Split System and Single Package | 10.8 EER<br>11.0 IEER | 11.8 EER<br>12.0 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.1 IEER | 11.9 EER<br>12.1 IEER | |
| | | All other | Split System and Single Package | 10.8 EER<br>10.9 IEER | 12.2 EER<br>11.9 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER<br>11.1 IEER | 11.7 EER<br>11.9 IEER | |
| | | All other | Split System and Single Package | 10.8 EER<br>10.9 IEER | 11.5 EER<br>11.7 IEER | |
| Condensing units, air cooled | ≥ 135,000 Btu/h | | | 10.1 EER<br>11.4 IEER | 10.5 EER<br>14.0 IEER | AHRI 365 |
| Condensing units, water cooled | ≥ 135,000 Btu/h | | | 13.1 EER<br>13.6 IEER | 13.5 EER<br>14.0 IEER | |
| Condensing units, evaporatively cooled | ≥ 135,000 Btu/h | | | 13.1 EER<br>13.6 IEER | 13.5 EER<br>14.0 IEER | |

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

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

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

2015 IECC Minimum Efficiency Requirements

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

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

*(continued)*

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

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

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWH * CF$

Where:

$\Delta kWH$ = 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

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

**2.5.9 High Volume Low Speed Fans**

DESCRIPTION

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

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, the efficient equipment is assumed to be classified as HVLS and have a VFD.[181]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[182]

DEEMED MEASURE COST

The incremental capital cost for the fans are as follows:[183]

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

LOADSHAPE

HVAC BUS

---

**Algorithm**

---

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[184]

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

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[181] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0, Volume 2: Commercial and Industrial Measures," Section 4.1.2, High Volume Low Speed Fans.

[182] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0, Volume 2: Commercial and Industrial Measures," Section 4.1.2, High Volume Low Speed Fans.

[183] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0, Volume 2: Commercial and Industrial Measures," Section 4.1.2, High Volume Low Speed Fans.

[184] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0, Volume 2: Commercial and Industrial Measures," Section 4.1.2, High Volume Low Speed Fans.

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

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**[185]

$$\Delta kW = \text{h} * CF$$

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.000443983

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**
N/A

**MEASURE CODE:**

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[185] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 8.0, Volume 2: Commercial and Industrial Measures," Section 4.1.2, High Volume Low Speed Fans.

## 2.5.10 Chiller Tune Up

**DESCRIPTION**
This measure is the tune-up of an existing air-cooled or water-cooled electric chiller. The tune-up consists of tube cleaning, chilled and condenser water temperature adjustments, and reciprocating compressor unloading switch adjustments.

**DEFINITION OF EFFICIENT EQUIPMENT**
The efficient condition is an existing chiller post tune-up.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline condition is an existing chiller prior to receiving the tune-up.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The expected lifetime of the measure is 5 years.

**DEEMED MEASURE COST**
The incremental cost for this measure varies. Use actual cost.

**DEEMED O&M COST ADJUSTMENTS**
There are no expected O&M cost adjustments for this measure.

**BASELINE EFFICIENCY VALUES BY CHILLER TYPE AND CAPACITY**
Refer to IECC 2012 Minimum Efficiency Requirements in Reference Tables section of this measure.

**LOADSHAPE**
Cooling BUS

## Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**[186]

$$\Delta kWh = TONS * IPLV_{BASE} * EFLH * ESF$$

Where:

TONS = Chiller nominal cooling capacity in tons (= actual; 1 ton = 12,000 Btu/hr)

$IPLV_{BASE}$ = 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 within this measure section.

EFLH = Equivalent full load hours (= dependent on location and building type, see table 2.5 in Appendix H)

ESF = Energy savings factor (= 0.08)

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[186] "Indiana Technical Reference Manual Version 2.2," Page 217.

For example, energy savings for the tune-up of a 350-ton chiller with an IPLV of .540kW/Ton serving a Medium Office in St Louis is calculated as:

$$\Delta kWh = TONS * IPLV_{BASE} * EFLH * ESF = 350 * .540 * 1386 * 0.08 = 20,956 \text{ kWh}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS[187]**

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

Where:

$\Delta kWh$ = Electric energy savings, as calculated above

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

For example, demand reduction for the tune-up of the above chiller resulting in 20,956 kWh of energy savings is calculated as:

$$\Delta kW = 20,956 \text{ kWh} * 0.0009106840 = 19.08 \text{ kW}$$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Chillers Ratings - Chillers are rated with different units based 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 |

---

[187] Indiana Technical Reference Manual Version 2.2," Page 219.

| COP | = 12 / (kW/ton) / 3.412 |
| EER | = 12 / kW/ton |
| EER | = COP x 3.412 |

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity[188]

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

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 FULL LOAD | BEFORE 1/1/2010 IPLV | AS OF 1/1/2010[b] PATH A FULL LOAD | AS OF 1/1/2010[b] PATH A IPLV | AS OF 1/1/2010[b] PATH B FULL LOAD | AS OF 1/1/2010[b] PATH B IPLV | TEST PROCEDURE[c] |
|---|---|---|---|---|---|---|---|---|---|
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.416 | ≥ 9.562 | ≥ 12.500 | NA | NA | |
| | ≥ 150 tons | EER | | | ≥ 9.562 | ≥ 12.750 | NA | NA | |
| Air cooled without condenser, electrical operated | All capacities | EER | ≥ 10.586 | ≥ 11.782 | Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements | | | | |
| Water cooled, electrically operated, reciprocating | All capacities | kW/ton | ≤ 0.837 | ≤ 0.696 | Reciprocating units shall comply with water cooled positive displacement efficiency requirements | | | | AHRI 550/590 |
| Water cooled, electrically operated, positive displacement | < 75 tons | kW/ton | | | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | |
| | ≥ 75 tons and < 150 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 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 | | | | | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.634 | ≤ 0.596 | ≤ 0.634 | ≤ 0.596 | ≤ 0.639 | ≤ 0.450 | |
| | ≥ 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.

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[188] 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.

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 | |
| | | | ≥ 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 | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA[c] | ≥ 0.600 FL | NA[c] | AHRI 560 |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA[c] | ≥ 0.700 FL | NA[c] | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | |

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

**2018 IECC Baseline Efficiency Values by Chiller Type and Capacity**

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

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

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

**MEASURE CODE:**

## 2.6 Lighting

C&I Lighting Deemed Hours and Waste Heat Factors by Building Type

| Building Type | Fixture Annual Operating Hours[189] (Hours) | Waste Heat Cooling Energy Factor[190] (WHFe) | Waste Heat Electric Resistance Heating[191] (IFkWh) | Waste Heat Electric Heat Pump Heating (IFkWh) | Waste Heat Gas Heating[192] (IFTherms) |
|---|---|---|---|---|---|
| Large Office | 3170 | 1.06 | 0.32 | 0.14 | 0.014 |
| Medium Office | 3170 | 1.14 | 0.19 | 0.08 | 0.008 |
| Small Office | 2884 | 1.11 | 0.21 | 0.09 | 0.009 |
| Warehouse | 2827 | 1.04 | 0.26 | 0.11 | 0.011 |
| Stand-alone Retail | 3421 | 1.08 | 0.21 | 0.09 | 0.009 |
| Strip Mall | 3694 | 1.08 | 0.22 | 0.10 | 0.009 |
| Primary School | 3466 | 1.08 | 0.28 | 0.12 | 0.012 |
| Secondary School | 3466 | 1.14 | 0.30 | 0.13 | 0.013 |
| Supermarket | 3765 | 1.07 | 0.26 | 0.11 | 0.011 |
| Quick Service Restaurant | 6443 | 1.12 | 0.27 | 0.12 | 0.012 |
| Full Service Restaurant | 6443 | 1.11 | 0.22 | 0.10 | 0.009 |
| Hospital | 3812 | 1.11 | 0.34 | 0.15 | 0.015 |
| Outpatient Health Care | 3898 | 1.21 | 0.28 | 0.12 | 0.012 |
| Small Hotel - Building | 3713 | 1.21 | 0.22 | 0.09 | 0.009 |
| Large Hotel - Building | 3713 | 1.24 | 0.01 | 0.00 | 0.000 |
| Midrise Apartment - Building | 2876 | 1.14 | 0.44 | 0.19 | 0.019 |
| C&I Average | 3351 | 1.09 | 0.24 | 0.10 | 0.010 |

[189] Fixtures 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). These values are references in cases where the project-specific hours are unknown.

[190] 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.

[191] Electric heat penalty assumptions are based on converting the IFTherm multiplier value into 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 2.3 COP.

[192] IFTherms value is developed using computer models consistent with methodology for Waste Heat Factor for Energy.

C&I Lighting Effective Useful Life (EUL) by Equipment Category

| Measure Category | Lighting Type [1] | Effective Useful Life (EUL) [2] |
|---|---|---|
| 2.6.3 LED Bulbs and Fixtures 2.6.4 LED Screw Based Omnidirectional Bulb 2.6.7 LED Specialty Lamp | Fixture | 15 |
| | Type A & Hybrid | 10 |
| | Type B | 15 |
| | Type C | 11 |
| | Retrofit Kit | 15 |
| | HID Replacement | 15 |
| | Lamp Replacement | 10 |
| 2.6.6 LED Exit Sign | Exit Signs | 7 |
| 2.6.8 Lighting Power Density | Lighting Power Density | 15 |

Notes:

[1] Ameren Missouri maintains a table that "maps" each lighting measure code to the appropriate Lighting Type.

[2] These effective useful lives were researched by Opinion Dynamics as part of the PY19/PY20 Ameren Missouri Evaluation efforts. EUL values for each measure group were developed through a benchmarking review of TRMs and analysis of equipment specifications (e.g., lamp life) and annual operating hours from PY19/PY20 project tracking data. See Memorandum: Recommended EUL Values for Ameren Missouri Business Lighting Measures, January 6, 2021.

### 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.[193]

DEEMED MEASURE COST
Actual incremental costs should be used if available. For default values, see table below.

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

LOADSHAPE

Lighting BUS

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**Algorithm**

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CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[194]

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * WHF_e$$

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[193] KCP&L measure life assumption.
[194] The savings numbers are for the straight lamp removal measures, as well as the lamp removal and install reflector measures.

Where:

| | |
|---|---|
| Watts$_{Base}$ | = Wattage reduction of lamp removed. Custom input; otherwise, use values in the table below. |
| 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 2.6. |
| 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 2.6 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. |

| T8 Lamp Size | Wattage[195] |
|:---:|:---:|
| 8-ft T8 | 38.6 |
| 4-ft T8 | 19.4 |

Heating Penalty

If electrically heated building:[196]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

| | |
|---|---|
| IF$_{kWh}$ | = 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 2.6.  If unknown, use the C&I Average value. |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta k = \Delta kWh * CF$

Where:

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

**NATURAL GAS ENERGY SAVINGS**

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[195] 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.

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

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):[197]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$      = 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 2.6.  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:**

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

**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) |
|---|---|
| This measure relates to the installation of new equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. In general, the measure will include qualifying high-efficiency, low ballast-factor ballasts paired with high-efficiency, long- life lamps as detailed in the attached tables. High-bay applications use this system paired with qualifying high ballast factor ballasts and high performance 32 w lamps. Custom lighting designs can use qualifying low, normal or high ballast-factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the calculation of savings algorithms. | This measure relates to the replacement of existing equipment with new equipment with efficiency that exceeds that of the existing equipment. In general, the retrofit will include qualifying high efficiency low-ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. Custom lighting designs can use qualifying low, normal or high-ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the calculation of savings algorithms.

High-efficiency troffers (new/or retrofit) utilizing HPT8 technology can provide even greater savings. When used in a high-bay application, high performance T8 fixtures can provide equal light to HID high-bay fixtures, while using fewer watts; these systems typically utilize high ballast-factor ballasts, but qualifying low and normal ballast factor ballasts may be used when appropriate light levels are provided and overall wattage is reduced. |

**DEFINITION OF EFFICIENT EQUIPMENT**

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 products[198] and qualifying RWT8 products.[199]

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

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| High-efficiency troffers combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High-efficiency troffers must have a fixture efficiency of 80% or greater to qualify. High bay fixtures must have fixture efficiencies of 85% or greater. | 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. High bay fixtures will have fixture efficiencies of 85% or greater. |

**DEFINITION OF BASELINE EQUIPMENT**

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

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| The baseline is standard efficiency T8 systems that would have been installed.  The baseline for high-bay fixtures is pulse start metal halide fixtures. | The baseline is the existing system. 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. |

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

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

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| Fixture lifetime is 15 years.[200] 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 | Fixture lifetime is 15 years. Note, since the fixture lifetime is deemed at 15 years, the replacement cost of both the lamp and ballast should be incorporated into the O&M calculation. |

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[198] http://library.cee1.org/content/cee-high-performance-t8-specification
[199] http://library.cee1.org/content/reduced-wattage-t8-specification
[200] 15 years from GDS Measure Life Report, June 2007.

| per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 15 years.[201] | |

**DEEMED MEASURE COST**

Actual incremental costs should be used if available. For default values, see the reference table at the end of this characterization.

**LOADSHAPE**
Lighting BUS

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Algorithm

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = (Watts_{BASE} – Watts_{EE}) * Hour * WHF_e * ISR$

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. |
| $Watts_{EE}$ | = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures.  Value can be selected from the appropriate reference table, 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% |

| 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 |

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[201] 15 years from GDS Measure Life Report, June 2007.

Heating Penalty

If electrically heated building:[202]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

IF$_{kWh}$ = 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**

ΔkW  = ΔkWh * CF

Where:

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

**NATURAL GAS SAVINGS**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):[203]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$ = 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:

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[202] Negative value because this is an increase in heating consumption due to the efficient lighting.
[203] Negative value because this is an increase in heating consumption due to the efficient lighting.

| 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 Assumptions[204]

| EE Measure Description | Watts$_{EE}$ | 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

| 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 | N/A |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 48.0 | 2-Lamp 40w T12 | 62.0 | $55.00 | N/A |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 71.0 | 3-Lamp 40w T12 | 108.0 | $60.00 | N/A |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 98.0 | 4-Lamp 40w T12 | 144.0 | $65.00 | N/A |
| 6-Lamp Relamp/Reballast T12 to HPT8 | 142.0 | 6-Lamp 40w T12 | 216.0 | $75.00 | N/A |
| 1-Lamp Relamp/Reballast T12 to RWT8 | 21.3 | 1-Lamp 40w T12 | 31.0 | $50.00 | N/A |
| 2-Lamp Relamp/Reballast T12 to RWT8 | 42.6 | 2-Lamp 40w T12 | 62.0 | $55.00 | N/A |
| 3-Lamp Relamp/Reballast T12 to RWT8 | 63.0 | 3-Lamp 40w T12 | 108.0 | $60.00 | N/A |
| 4-Lamp Relamp/Reballast T12 to RWT8 | 88.5 | 4-Lamp 40w T12 | 144.0 | $65.00 | N/A |
| 6-Lamp Relamp/Reballast T12 to RWT8 | 126.0 | 6-Lamp 40w T12 | 216.0 | $75.00 | N/A |

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[204] 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 distributers/contractors to use 28W almost exclusively in other markets.

| | | | | | |
|---|---|---|---|---|---|
| 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 T12s that meeting EISA efficacy standards changed from 34w to 40w to meet the lumen/per watt requirement.

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

| EE Measure Description | Watts$_{EE}$ | Baseline Description | Watts$_{BASE}$ | 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 |

Ameren Missouri

| | Lamp Quantity | 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 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 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost | Baseline Description | 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.[205]

LED Fixtures and Retrofit Kits with Network Controls achieve additional savings similar to the savings described in the Occupancy Controls section.

**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**

See Lighting EUL Reference Table for EUL values by Lighting Measure Group.

**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

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[205] Design Lights Consortium Qualified Products List http://www.designlights.org/qpl.

Algorithm

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e * ISR$$

Where:

| | |
|---|---|
| Watts$_{Base}$ | = Actual 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 2.6 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 2.6 for each Building Type. If building is un-cooled, the value is 1.0. |
| ISR | = In Service Rate represents the percentage of reported lamps or fixtures that is installed and operating and varies with the program delivery approach. Use 100% for programs with direct installation and/or installation verification procedures (e.g., verification inspections for a sample of projects); use 98.7% for program delivery without installation verification.[206] The ISR may also be set to 100% if the installation verification is embedded in other evaluation adjustments. |

Note that LED Fixtures and Retrofit Kits with Network Controls achieve additional savings similar to the savings described in the Occupancy Controls section.

Heating Penalty:

If electrically heated building:[207]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

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[206] ISR is 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). These evaluation results are from a retail-based lighting program with multiple delivery channels including point-of-sale markdown, online website, coupons, and social marketing distribution.

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

IF$_{kWh}$ = 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 2.6. 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
= 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):

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$ = Lighting-HVAC Interaction Factor for gas heating impacts.[208] 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 2.6. 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.

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

**REFERENCE TABLES** [209]

LED New and Baseline Assumptions:

| LED Category | EE Measure | | | Baseline | | Incremental Cost |
|---|---|---|---|---|---|---|
| | Description | Watts$_{EE}$ | | Description | Watts$_{BASE}$ | |
| 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 |
| | 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 |

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[209] 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 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 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:[210]

| | | EE Measure | | | | Baseline | | | |
|---|---|---|---|---|---|---|---|---|---|
| **LED Category** | **EE Measure Description** | **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 | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Interior Directional | LED Track Lighting | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Wall-Wash Fixtures | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Display Case | LED Display Case Light Fixture | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Undercabinet Shelf-Mounted Task Light Fixtures | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Display Case | LED Refrigerated Case Light, Horizontal or Vertical | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Freezer Case Light, Horizontal or Vertical | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |

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[210] Costs are based on actual costs, and measure lives are based on analysis of actual lamp life and hours of use.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LED Linear Replacement Lamps Replacement | LED 4' Linear Replacement Lamp | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 2' Linear Replacement Lamp | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 2x2 Recessed Light Fixture, 3501-5000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 2x4 Recessed Light Fixture, 3000-4500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 2x4 Recessed Light Fixture, 4501-6000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 2x4 Recessed Light Fixture, 6001-7500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 1x4 Recessed Light Fixture, 1500-3000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 1x4 Recessed Light Fixture, 3001-4500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED 1x4 Recessed Light Fixture, 4501-6000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, ≤ 3000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Surface & Suspended Linear Fixture, 3001-4500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Surface & Suspended Linear Fixture, 4501-6000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Surface & Suspended Linear Fixture, 6001-7500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Surface & Suspended Linear Fixture, > 7500 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, ≤ 10,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED High-Bay Fixtures, 10,001-15,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED High-Bay Fixtures, 15,001-20,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED High-Bay Fixtures, > 20,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, ≤ 2,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 2,001-4,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 4,001-6,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 6,001-8,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 8,001-12,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 12,001-16,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, 16,001-20,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Ag Interior Fixtures, > 20,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| LED Exterior Fixtures | LED Exterior Fixtures, ≤ 5,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Exterior Fixtures, 5,001-10,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Exterior Fixtures, 10,001-15,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |
| | LED Exterior Fixtures, > 15,000 lumens | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 | $62.50 | 15,000 | $58.00 |

**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 or on the Design Light Consortium's qualified product list.[211]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent.[212] A midlife adjustment example is provided but not applied to measures installed prior to 2022.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

See Lighting EUL Reference Table for EUL values by Lighting Measure Group.

DEEMED MEASURE COST

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[211] https://www.designlights.org/QPL

[212] 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. However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

Actual incremental costs should be used if available. If unavailable, assume $3.26 (baseline cost of $1.80 and efficient cost of $5.06).[213]

## LOADSHAPE

Lighting BUS
Ext Lighting BUS
Miscellaneous BUS

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Algorithm

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## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e * ISR$$

Where:

| | |
|---|---|
| Watts$_{Base}$ | = Based on lumens of LED bulb installed |
| Watts$_{EE}$ | = Actual wattage of LED purchased/installed.  If unknown, use default provided below.[214] |
| Hours | = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.6 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 2.6. If unknown, use the C&I Average value. |
| ISR | = In-Service Rate represents the percentage of reported lamps or fixtures that is installed and operating and varies with the program delivery approach. Use 100% for programs with direct installation and/or installation verification procedures (e.g., verification inspections for a sample of projects); use 98.7% for program delivery |

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[213] 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), p.19.

[214] 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.

without installation verification. [215]  The ISR may also be set to 100% if the installation verification is embedded in other evaluation adjustments.

| 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 |

Mid-Life Baseline Adjustment Example

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.  However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

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.[216&217]

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[215] ISR is 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). These evaluation results are from a retail-based lighting program with multiple delivery channels including point-of-sale markdown, online website, coupons, and social marketing distribution.

[216] These adjustments should be applied to kW and gas impacts as well.

[217] Calculated with EISA requirement of 45lumens/watt.

| 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:[218]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

IF_{kWh}    = 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 2.6 and based upon Building Type. If unknown, use the C&I Average value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta k = \Delta kWh * CF$$

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):[219]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

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[218] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.
[219] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

IF$_{Therms}$     = 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 2.6 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:[220]

| Incandescent / Halogen | CFL | LED ALamp |
|:---:|:---:|:---:|
| $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 |

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:

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[220] All cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 (http://mahttp://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdfeeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p.19.

| Building Type | Replacement Period (years)[221] | Replacement Cost |
|---|---|---|
| Large Office | 0.32 | |
| 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 | $1.80[222] |
| 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:**

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[221] 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 Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC)).

[222] 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), p.19.

### 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 luminaries per project, especially for large commercial projects, thus increasing energy savings further.[223]

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 PulseStart Metal Halide fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of the efficient equipment fixture is 15 years.[224]

DEEMED MEASURE COST

Actual costs should be used if available. 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

---

**Algorithm**

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CALCULATION OF SAVINGS

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[223] Lighting Research Center. T5 Fluorescent Systems. http://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/lat5/abstract.asp
[224] Focus on Energy Evaluation "Business Programs: Measure Life Study" Final Report, August 9, 2009, prepared by PA Consulting Group.

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e * ISR$$

Where:

| | |
|---|---|
| Watts_{Base} | = Custom input. If unknown, input wattage of the baseline system is dependent 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 2.6 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 2.6 for each Building Type. If building is un-cooled, the value is 1.0. |
| ISR | = In Service Rate represents the percentage of reported lamps or fixtures that is installed and operating and varies with the program delivery approach. Use 100% for programs with direct installation and/or installation verification procedures (e.g., verification inspections for a sample of projects); use 98% for program delivery without installation verification.[225] The ISR may also be set to 100% if the installation verification is embedded in other evaluation adjustments. |

Heating Penalty:

If electrically heated building:[226]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

| | |
|---|---|
| IF_{kWh} | = 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 2.6. If unknown, use the C&I Average value. |

**SUMMER COINCIDENT DEMAND SAVINGS**

$$\Delta k = \Delta kWh * CF$$

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[225] Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD).
[226] Negative value because this is an increase in heating consumption due to the efficient lighting.

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): [227]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

$IF_{Therms}$        = 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 2.6. 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 Assumptions[228&229]

| EE Measure Description | Watts$_{EE}$ | Baseline Description | Watts$_{BASE}$ | 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 |

---

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

[228] Reference Table adapted from Efficiency Vermont TRM, T5 Measure Savings Algorithms and Cost Assumptions, October,

[229] Refer to "T5HO-adjusted deemed costs.baselines.xlsx" for more information.

T5 HO Component Costs and Lifetimes[230]

| 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 |

**MEASURE CODE:**

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[230] Costs include labor cost – see "T5HO-adjusted deemed costs.baselines.xlsx" for more information.

**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 compared to incandescent or CFL exit signs.[231]

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.[232]

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is the existing exit sign (either a CFL or incandescent unit).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

See Lighting EUL Reference Table for EUL values by Lighting Measure Group.

**DEEMED MEASURE COST**

Actual program delivery costs should be used if available. If not, use the full cost of $39[233] for a new LED exit sign and $25 for a retrofit kit, plus $6.25 in labor,[234] for a total measure cost of $45.25 and $31.25, respectively.

**LOADSHAPE**

Lighting BUS

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<center>Algorithm</center>

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS[235]**

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e$$

Where:

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[231] ENERGY STAR® *"Save Energy, Money and Prevent Pollution with LED Exit Signs."*

[232] 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.

[233] Cost of new LED exit sign from ENERGY STAR® Exit Signs Calculator.xlsx.

[234] 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.

[235] 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).

WattsBase    = Actual wattage if known, if unknown assume the following:

| Baseline Type | WattsBASE |
|---|---|
| Incandescent (dual sided) | 50 W [236] |
| Incandescent (single sided) | 25 W |
| CFL (dual sided) | 14 W [237] |
| CFL (single sided) | 7 W |

WattsEE    = Actual wattage if known; if unknown assume 2W for singled sided and 4W for dual sided.[238]

Hours    = Annual operating hours = 8,766

WHFe    = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.6 for each Building Type. If building is un-cooled, the value is 1.0.

## HEATING PENALTY

If electrically heated building:[239]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

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

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

Where:

$\Delta kWh$    = Electric energy savings, including cooling savings, as calculated above.

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

CF    = 0.0001899635

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[236] 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.aescinc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf
[237] Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at:
http://www.aescinc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf
[238] 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
[239] Negative value because this is an increase in heating consumption due to the efficient lighting.

**NATURAL GAS ENERGY SAVINGS**

Heating penalty if fossil fuel heated building (or if heating is unknown):[240]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$     = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.6 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[241] | Life (yrs) [242] |
| CFL lamp | $8.91 | 0.63 years |
| Incandescent lamp | $7.39 | 0.14 years |

**MEASURE CODE:**

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

[241] 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.

[242] 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).

**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. However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

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 on1/2/2017.https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V 2_0%20_Revised%20AUG-2016.pdf). Qualification could also be based on the Design Light Consortium's qualified product list.[243]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

See Lighting EUL Reference Table for EUL values by Lighting Measure Group.

DEEMED MEASURE COST

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[243] https://www.designlights.org/QPL

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:[244]

| 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

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### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e * ISR$$

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:[245]

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.6 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

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[244] 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.

[245] WattsEE 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, WattsEE 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.

Lighting Reference Table in Section 2.6. If unknown, use the C&I
Average value.

ISR       = In Service Rate represents the percentage of reported lamps or fixtures
that is installed and operating and varies with the program delivery
approach. Use 100% for programs with direct installation and/or
installation verification procedures (e.g., verification inspections for a
sample of projects); use 98.7% for program delivery without installation
verification.[246] The ISR may also be set to 100% if the installation
verification is embedded in other evaluation adjustments.

| 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 |
| | 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 |

Heating Penalty:

If electrically heated building:[247]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

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[246] 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). These evaluation results are from a retail-based lighting program with multiple delivery channels including point-of-sale markdown, online website, coupons, and social marketing distribution.

[247] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

IF$_{kWh}$    = 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 2.6 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
         = 0.0000056160 for exterior lighting
         = 0.0001379439 for 24/7 lighting

*Other factors as defined above.*

**NATURAL GAS SAVINGS**

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):[248]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$    = 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 2.6 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:

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[248] Ibid.

| Installation Location | Replacement Period (years)[249] | Replacement Cost[250] |
|---|---|---|
| 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 | |

**MEASURE CODE:**

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[249] 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).
[250] Incandescent costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report," Itron, February 28, 2014.

## 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/ft$^2$). Either the Building Area Method or Space-by-Space (not recognized by IECC 2009) method as defined in IECC 2009, 2012, 2015, 2018 can be used for calculating the Interior Lighting Power Density (LPD).[251] The measure consists of a design that has a lower LPD than code requires.

This measure was developed to be applicable to the following program types: NC and TOS. The measure is application for any project for which the project requires compliance with building code. 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 maximum 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 the maximum lighting power density that meets the building code recognized by the local jurisdiction. For illustrative purposes in this characterization, IECC 2009, 2012, 2015, and 2018, are highlighted to demonstrate the methodology.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

See Lighting EUL Reference Table for EUL values by Lighting Measure Group.

**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

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Algorithm

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**CALCULATION OF SAVINGS**

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[251] 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).

**ENERGY SAVINGS**

$$\Delta kWh = \frac{WSF_{Base} - WSF_{EE}}{1000} * SF * Hours * WHF_e$$

Where:

| | |
|---|---|
| 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.[252] |
| WSF$_{EE}$ | = 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:[253]

$$\Delta kWh_{heatpenalty} = \frac{WSF_{Base} - WSF_{EE}}{1000} * SF * Hours * (-IF_{kWH})$$

Where:

| | |
|---|---|
| IF$_{kWh}$ | = 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**

ΔkW = ΔkWh * 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.*

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[252] See IECC 2009, 2012 and 2015 - Reference Code documentation for additional information.
[253] Negative value because this is an increase in heating consumption due to the efficient lighting.

**NATURAL GAS ENERGY SAVINGS**

$$\Delta Therms = \frac{WSF_{Base} - WSF_{EE}}{1000} * SF * Hours * (-IF_{therms})$$

Where:

IF$_{Therms}$  = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. 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**

N/A

**REFERENCE TABLES**

Lighting Power Density Values from IECC 2009, 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method

| Building Area Type [254] | 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[255] | 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 |

[254] 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.

[255] 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

**TABLE C405.5.2(2)**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|---|
| Atrium – First 40 feet in height | 0.03 per ft. ht. |
| Atrium – Above 40 feet in height | 0.02 per ft. ht. |
| Audience/seating area – permanent | |
|   For auditorium | 0.9 |
|   For performing arts theater | 2.6 |
|   For motion picture theater | 1.2 |
|   Classroom/lecture/training | 1.30 |
|   Conference/meeting/multipurpose | 1.2 |
|   Corridor/transition | 0.7 |
| Dining area | |
|   Bar/lounge/leisure dining | 1.40 |
|   Family dining area | 1.40 |
| Dressing/fitting room performing arts theater | 1.1 |
| Electrical/mechanical | 1.10 |
| Food preparation | 1.20 |
| Laboratory for classrooms | 1.3 |
| Laboratory for medical/industrial/research | 1.8 |
| Lobby | 1.10 |
| Lobby for performing arts theater | 3.3 |
| Lobby for motion picture theater | 1.0 |
| Locker room | 0.80 |
| Lounge recreation | 0.8 |
| Office – enclosed | 1.1 |
| Office – open plan | 1.0 |
| Restroom | 1.0 |
| Sales area | 1.6ª |
| Stairway | 0.70 |
| Storage | 0.8 |
| Workshop | 1.60 |
| Courthouse/police station/penetentiary | |
|   Courtroom | 1.90 |
|   Confinement cells | 1.1 |
|   Judge chambers | 1.30 |
|   Penitentiary audience seating | 0.5 |
|   Penitentiary classroom | 1.3 |
|   Penitentiary dining | 1.1 |
| **BUILDING SPECIFIC SPACE-BY-SPACE TYPES** | |
| Automotive – service/repair | 0.70 |
| Bank/office – banking activity area | 1.5 |
| Dormitory living quarters | 1.10 |
| Gymnasium/fitness center | |
|   Fitness area | 0.9 |
|   Gymnasium audience/seating | 0.40 |
|   Playing area | 1.40 |

*(continued)*

**TABLE C405.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|---|
| Healthcare clinic/hospital | |
|   Corridors/transition | 1.00 |
|   Exam/treatment | 1.70 |
|   Emergency | 2.70 |
|   Public and staff lounge | 0.80 |
|   Medical supplies | 1.40 |
|   Nursery | 0.9 |
|   Nurse station | 1.00 |
|   Physical therapy | 0.90 |
|   Patient room | 0.70 |
|   Pharmacy | 1.20 |
|   Radiology/imaging | 1.3 |
|   Operating room | 2.20 |
|   Recovery | 1.2 |
|   Lounge/recreation | 0.8 |
|   Laundry – washing | 0.60 |
| Hotel | |
|   Dining area | 1.30 |
|   Guest rooms | 1.10 |
|   Hotel lobby | 2.10 |
|   Highway lodging dining | 1.20 |
|   Highway lodging guest rooms | 1.10 |
| Library | |
|   Stacks | 1.70 |
|   Card file and cataloguing | 1.10 |
|   Reading area | 1.20 |
| Manufacturing | |
|   Corridors/transition | 0.40 |
|   Detailed manufacturing | 1.3 |
|   Equipment room | 1.0 |
|   Extra high bay (> 50-foot floor-ceiling height) | 1.1 |
|   High bay (25- – 50-foot floor-ceiling height) | 1.20 |
|   Low bay (< 25-foot floor-ceiling height) | 1.2 |
| Museum | |
|   General exhibition | 1.00 |
|   Restoration | 1.70 |
| Parking garage – garage areas | 0.2 |
| Convention center | |
|   Exhibit space | 1.50 |
|   Audience/seating area | 0.90 |
| Fire stations | |
|   Engine room | 0.80 |
|   Sleeping quarters | 0.30 |
| Post office | |
|   Sorting area | 0.9 |
| Religious building | |
|   Fellowship hall | 0.60 |
|   Audience seating | 2.40 |
|   Worship pulpit/choir | 2.40 |
| Retail | |
|   Dressing/fitting area | 0.9 |
|   Mall concourse | 1.6 |
|   Sales area | 1.6ª |

*(continued)*

**TABLE C405.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| BUILDING SPECIFIC  SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|---|
| Sports arena | |
|   Audience seating | 0.4 |
|   Court sports area – Class 4 | 0.7 |
|   Court sports area – Class 3 | 1.2 |
|   Court sports area – Class 2 | 1.9 |
|   Court sports area – Class 1 | 3.0 |
|   Ring sports area | 2.7 |
| Transportation | |
|   Air/train/bus baggage area | 1.00 |
|   Airport concourse | 0.60 |
|   Terminal – ticket counter | 1.50 |
| Warehouse | |
|   Fine material storage | 1.40 |
|   Medium/bulky material | 0.60 |

Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

| COMMON SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Atrium | |
| Less than 40 feet in height | 0.03 per foot in total height |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height |
| Audience seating area | |
| In an auditorium | 0.63 |
| In a convention center | 0.82 |
| In a gymnasium | 0.65 |
| In a motion picture theater | 1.14 |
| In a penitentiary | 0.28 |
| In a performing arts theater | 2.43 |
| In a religious building | 1.53 |
| In a sports arena | 0.43 |
| Otherwise | 0.43 |
| Banking activity area | 1.01 |
| Breakroom (See Lounge/Breakroom) | |
| Classroom/lecture hall/training room | |
| In a penitentiary | 1.34 |
| Otherwise | 1.24 |
| Conference/meeting/multipurpose room | 1.23 |
| Copy/print room | 0.72 |
| Corridor | |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 0.92 |
| In a hospital | 0.79 |
| In a manufacturing facility | 0.41 |
| Otherwise | 0.66 |
| Courtroom | 1.72 |
| Computer room | 1.71 |
| Dining area | |
| In a penitentiary | 0.96 |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 1.9 |
| In bar/lounge or leisure dining | 1.07 |
| In cafeteria or fast food dining | 0.65 |
| In family dining | 0.89 |
| Otherwise | 0.65 |
| Electrical/mechanical room | 0.95 |
| Emergency vehicle garage | 0.56 |

(continued)

TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

| COMMON SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Food preparation area | 1.21 |
| Guest room | 0.47 |
| Laboratory | |
| In or as a classroom | 1.43 |
| Otherwise | 1.81 |
| Laundry/washing area | 0.6 |
| Loading dock, interior | 0.47 |
| Lobby | |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 1.8 |
| For an elevator | 0.64 |
| In a hotel | 1.06 |
| In a motion picture theater | 0.59 |
| In a performing arts theater | 2.0 |
| Otherwise | 0.9 |
| Locker room | 0.75 |
| Lounge/breakroom | |
| In a healthcare facility | 0.92 |
| Otherwise | 0.73 |
| Office | |
| Enclosed | 1.11 |
| Open plan | 0.98 |
| Parking area, interior | 0.19 |
| Pharmacy area | 1.68 |
| Restroom | |
| In a facility for the visually impaired (and not used primarily by the staff[b] | 1.21 |
| Otherwise | 0.98 |
| Sales area | 1.59 |
| Seating area, general | 0.54 |
| Stairway (See space containing stairway) | |
| Stairwell | 0.69 |
| Storage room | 0.63 |
| Vehicular maintenance area | 0.67 |
| Workshop | 1.59 |
| BUILDING TYPE SPECIFIC SPACE TYPES[a] | LPD (watts/sq.ft) |
| Facility for the visually impaired[b] | |
| In a chapel (and not used primarily by the staff) | 2.21 |
| In a recreation room (and not used primarily by the staff) | 2.41 |
| Automotive (See Vehicular Maintenance Area above) | |
| Convention Center—exhibit space | 1.45 |
| Dormitory—living quarters | 0.38 |
| Fire Station—sleeping quarters | 0.22 |
| Gymnasium/fitness center | |
| In an exercise area | 0.72 |
| In a playing area | 1.2 |

(continued)

TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD

| BUILDING TYPE SPECIFIC SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| healthcare facility | |
| In an exam/treatment room | 1.66 |
| In an imaging room | 1.51 |
| In a medical supply room | 0.74 |
| In a nursery | 0.88 |
| In a nurse's station | 0.71 |
| In an operating room | 2.48 |
| In a patient room | 0.62 |
| In a physical therapy room | 0.91 |
| In a recovery room | 1.15 |
| Library | |
| In a reading area | 1.06 |
| In the stacks | 1.71 |
| Manufacturing facility | |
| In a detailed manufacturing area | 1.29 |
| In an equipment room | 0.74 |
| In an extra high bay area (greater than 50' floor-to-ceiling height) | 1.05 |
| In a high bay area (25-50' floor-to-ceiling height) | 1.23 |
| In a low bay area (less than 25' floor-to-ceiling height) | 1.19 |
| Museum | |
| In a general exhibition area | 1.05 |
| In a restoration room | 1.02 |
| Performing arts theater—dressing room | 0.61 |
| Post Office—Sorting Area | 0.94 |
| Religious buildings | |
| In a fellowship hall | 0.64 |
| In a worship/pulpit/choir area | 1.53 |
| Retail facilities | |
| In a dressing/fitting room | 0.71 |
| In a mall concourse | 1.1 |
| Sports arena—playing area | |
| For a Class I facility | 3.68 |
| For a Class II facility | 2.4 |
| For a Class III facility | 1.8 |
| For a Class IV facility | 1.2 |
| Transportation facility | |
| In a baggage/carousel area | 0.53 |
| In an airport concourse | 0.36 |
| At a terminal ticket counter | 0.8 |
| Warehouse—storage area | |
| For medium to bulky, palletized items | 0.58 |
| For smaller, hand-carried items | 0.95 |

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

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 m$^2$.

Allowable Design Levels from IECC 2012

TABLE C405.6.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

| | | LIGHTING ZONES | | | |
|---|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| | Uncovered Parking Areas | | | | |
| | Parking areas and drives | 0.04 W/ft² | 0.06 W/ft² | 0.10 W/ft² | 0.13 W/ft² |
| | Building Grounds | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.) | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft² | 0.14 W/ft² | 0.16 W/ft² | 0.2 W/ft² |
| | Stairways | 0.75 W/ft² | 1.0 W/ft² | 1.0 W/ft² | 1.0 W/ft² |
| | Pedestrian tunnels | 0.15 W/ft² | 0.15 W/ft² | 0.2 W/ft² | 0.3 W/ft² |
| | Building Entrances and Exits | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft² | 0.25 W/ft² | 0.4 W/ft² | 0.4 W/ft² |
| | Sales Canopies | | | | |
| | Free-standing and attached | 0.6 W/ft² | 0.6 W/ft² | 0.8 W/ft² | 1.0 W/ft² |
| | Outdoor Sales | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft² | 0.25 W/ft² | 0.5 W/ft² | 0.7 W/ft² |
| | Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.1 W/ft² for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length | 0.15 W/ft² for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length | 0.2 W/ft² for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| | Automated teller machines and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

Allowable Design Levels from IECC 2015

TABLE C405.5.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

| | | LIGHTING ZONES | | | |
|---|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| **Tradable Surfaces** (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.) | *Uncovered Parking Areas* | | | | |
| | Parking areas and drives | 0.04 W/ft² | 0.06 W/ft² | 0.10 W/ft² | 0.13 W/ft² |
| | *Building Grounds* | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft² | 0.14 W/ft² | 0.16 W/ft² | 0.2 W/ft² |
| | Stairways | 0.75 W/ft² | 1.0 W/ft² | 1.0 W/ft² | 1.0 W/ft² |
| | Pedestrian tunnels | 0.15 W/ft² | 0.15 W/ft² | 0.2 W/ft² | 0.3 W/ft² |
| | *Building Entrances and Exits* | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft² | 0.25 W/ft² | 0.4 W/ft² | 0.4 W/ft² |
| | *Sales Canopies* | | | | |
| | Free-standing and attached | 0.6 W/ft² | 0.6 W/ft² | 0.8 W/ft² | 1.0 W/ft² |
| | *Outdoor Sales* | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft² | 0.25 W/ft² | 0.5 W/ft² | 0.7 W/ft² |
| | Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| **Nontradable Surfaces** (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.075 W/ft² of gross above-grade wall area | 0.113 W/ft² of gross above-grade wall area | 0.15 W/ft² of gross above-grade wall area |
| | Automated teller machines (ATM) and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².
W = watts.

**MEASURE CODE**

**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.[256]

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%.[257] Amendments made in 2014 require more stringent energy conservations standards with compliance required by February 10, 2017.[258]

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 ≤ 400 Watt lamp.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[259]

DEEMED MEASURE COST

Actual costs should be used when available. If unknown, cost is assumed to be $267.[260]

LOADSHAPE

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[256] Building a Brighter Future: Your Guide to EISA-Compliant Ballast and Lamp Solutions from Philips Lighting: http://1000bulbs.com/pdf/advance%20eisa%20brochure.pdf

[257] 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-standardsfor-metal-halide-lamp-fixtures#h-9

[258] 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 (≥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-standardsfor-metal-halide-lamp-fixtures#h-9

[259] 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.

[260] 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.

Lighting BUS
Ext Lighting BUS
Miscellaneous BUS

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Algorithm

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * WHF_e * ISR$$

Where:

| | |
|---|---|
| Watts$_{Base}$ | = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp). 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 2.6. 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:[261]

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{kWH})$$

Where:

| | |
|---|---|
| IF$_{kWh}$ | = 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. |

---

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

**SUMMER COINCIDENT DEMAND SAVINGS**

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

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 |
| | = 0.0001379439 for 24/7 lighting |

**NATURAL GAS SAVINGS** [262]

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours * ISR * (-IF_{therms})$$

Where:

IF$_{Therms}$ = 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.[263]

**REFERENCE TABLES**[264]

| Lamp Watt$_{EE}$ | Efficient Fixture Ballast | Efficient System Lumen | System Watt$_{EE}$ | Lamp Watt$_{Base}$ | Baselines Ballast[265] | 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 |

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[262] Negative value because this is an increase in heating consumption due to the efficient lighting

[263] 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.

[264] Per lamp/ballast.

[265] 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."

| 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:**

### 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.[266]

This measure relates to the installation of interior occupancy sensors on new fixtures in an existing lighting system. Lighting control types covered by this measure include 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 fixture-mounted occupancy sensors and remote mounted occupancy sensors.

**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 10 years.[267]

**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[268] |
|---|---|
| Full cost of fixture mounted occupancy sensor | $45 |
| Full cost of remote (ceiling) mounted occupancy sensor | $105 |

**LOADSHAPE**

Lighting BUS
Miscellaneous BUS
Ext Lighting BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

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[266] United States Department of the Interior. Greening the Department of Interior.
http://www.doi.gov/archive/greening/energy/occupy.html
[267] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[268] Based on averaging typical prices quoted by online vendors.

**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. |
| 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 2.6. 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: |
| 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 2.6. |

| Lighting Control Type Interior | Default kW controlled [269] |
|---|---|
| Fixture-mounted occupancy sensor | 0.138 (per fixture) |
| Remote (ceiling) mounted occupancy sensor | 0.338 (per control) |

| Lighting Control Type | Energy Savings Factor [270] |
|---|---|
| Fixture-mounted sensor | 24% |
| Remote (ceiling) mounted occupancy sensor | 24% |
| Network Connected controls | 24% |

Heating Penalty:

If electrically heated building:[271]

$$\Delta kWh_{heatpenalty} = kW_{controlled} * Hours * ESF * (-IF_{kWH})$$

Where:

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[269]Efficiency Vermont Technical Reference Manual 12.31.2018, Page 47;
https://puc.vermont.gov/sites/psbnew/files/doc_library/Vermont%20TRM%20Savings%20Verification%202018%20Version_FINAL.pdf

[270] 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.
[271] Negative value because this is an increase in heating consumption due to the efficient lighting.

IF$_{kWh}$              = 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 2.6.

## SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$\underline{\Delta}$kWh       = As calculated above

CF            = Summer peak coincidence demand (kW) to annual energy (kWh) factor.
   =  0.0001899635 for indoor lighting
   = 0.0001379439 for Miscellaneous
   = 0.0000056160 for exterior lighting

## Natural Gas Energy Savings

If gas heated building (or unknown):

$$\Delta Therms = \; kW_{controlled} * Hours * ESF * (-IF_{therms})$$

Where:

IF$_{Therms}$      = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the Lighting Reference Table in Section 2.6 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.[272]

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.[273]

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 characteristics[274] 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.[275]

DEEMED MEASURE COST

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[272] 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

[273] 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.

[274] See DOE Municipal Solid-State Street Lighting Consortium "Model Specifications for LED Roadway Luminaires v.2.0," July 2014.

[275] 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.

Actual measure installation cost should be used, including material and labor.[276] If the actual cost of the LED unit is unknown, use the default values for typical LED streetlight retrofits provided below.[277]

| Light output | | | | | | |
|---|---|---|---|---|---|---|
| | Low (<50W) | | Med (50W-100W) | | High (>100W) | |
| Fixture Type | 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

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## Algorithm

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## CALCULATION OF SAVINGS

## ELECTRIC ENERGY SAVINGS[278]

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1000} * Hours$$

Where:

| | |
|---|---|
| $Watts_{Base}$ | = Actual wattage if known, if unknown assume the following nominal wattage based on technology[279] |
| |     Metal Halide = 554W |
| |     High Pressure Sodium = 157W |
| |     Mercury Vapor = 228W |
| $Watts_{EE}$ | = Actual wattage[280] |
| Hours | = Annual operating hours |
| | = 4,000 hours[281] |

## 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

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[276] 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.

[277] LED unit costs from New York State Energy Research and Development Authority "Street Lighting in New York State: Opportunities and Challenges," Revised January 2015.

[278] There is no ISR input. Savings are per unit.

[279] 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."

[280] It is important to ensure that retrofit opportunities base efficient wattage on a lumen per watt equivalence.

[281] Ameren Missouri "Light Emitting Diode (LED) Street and Area Lighting Report," July 2013.

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Annual O&M savings are estimated at $50/LED streetlight.[282]

**MEASURE CODE:**

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[282] 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.[283]

**DEEMED MEASURE COST**[284]

The incremental cost is $5.

**LOADSHAPE**

Miscellaneous BUS

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**Algorithm**

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**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**[285]

$\Delta$kWh = Hours$_{idle}$ * (Pidle_base – Pidle_eff) + Hours$_{sleep}$ * (Psleep_base – Psleep_eff) + Hours$_{off}$ * (Poff_base –Poff_eff)

Where:

       Hours$_{idle}$    = Annual hours the computer is on and idling. Custom input or based on usage pattern (see table below).

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[283] Based on Energy Star® Office Equipment Calculator. See "Office Equipment Calculator.xlsx."

[284] 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."

[285] Based on the algorithms used by the Energy Star® Office Equipment Calculator. See "Office Equipment Calculator.xlsx."

$P_{idle\_base}$ = Power draw (kW) of baseline unit while idling. Based on computer performance level (see table below).

$P_{idle\_eff}$ = Power draw (kW) of efficient unit while idling. Based on computer performance level (see table below).

$Hours_{sleep}$ = 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 Use[286]

| 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 Requirements[287&288]

| Performance Level[283] | Baseline | | | Efficient | | |
|---|---|---|---|---|---|---|
| | Pidle_base | Psleep_base | Poff_base | Pidle_eff | Psleep_eff | Poff_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:

$\Delta kWh$ = Energy Savings as calculated above

---

[286] 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.

[287] Based on Energy Star® Office Equipment Calculator. See "Office Equipment Calculator.xlsx."

[288] "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.

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:

### 2.7.2 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.[289]

**DEEMED MEASURE COST**

The deemed measure cost is $29 per networked computer, including labor.[290]

**LOADSHAPE**

Miscellaneous BUS

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[289] Consistent with the expected lifetimes of Energy Star® Office Equipment.
[290] Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison

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### Algorithm

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**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = kWh_{savings} * N$$

Where:

| | |
|---|---|
| $kWh_{savings}$ | = Annual energy savings per workstation |
| | = 200 kWh[291] for desktops, 50 kWh for laptops[292] |
| | = If unknown, assume 161 kWh (based on 74% desktop and 26% laptop)[293] |
| N | = Number of desktop or laptop workstations controlled by the power management software |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

| | |
|---|---|
| $\Delta kWh$ | = Energy Savings as calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor |
| | = 0.0001379439 |

**NATURAL GAS SAVINGS**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Assumed to be $2/unit annually.[294]

**MEASURE CODE:**

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[291] Based on average energy savings/computer from the following sources:

South California Edison, Work Paper WPSCNROE0003 (200k Wh)

Surveyor Network Energy Manager Evaluation Report, NEEA (68, 100, and 128kWh)

Regional Technical Forum http://rtf.nwcouncil.org/measures/measure.asp?id=95 (200 kWh)

EnergySTAR® Computer Power Management Savings Calculator (~190 kWh for a mix of laptop/desktop and assuming 30% are already turned off at night) http://www.energystar.gov/ia/products/power_mgt/LowCarbonITSavingsCalc.xlsx?78c1-120e&78c1-120e Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry (330 kWh).

[292] 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.

[293] Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.

[294] 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 and 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 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.[295]

#### 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.[296]

#### LOADSHAPE

Miscellaneous BUS

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**Algorithm**

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#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Q_{PoolHeating} * \left(1/Eff_{Base} - 1/Eff_{EE}\right)$$

Where:

$Q_{PoolHeating}$ = Required annual heat transfer to pool water (kWh), calculated as follows:[297]
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.

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[295] Measure life is for a high-efficiency pool heater, from 2017 Michigan Energy Measures Database.

[296] 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.

[297] Based on the results of a swimming pool energy calculation tool found at http://noanderson.com/services/swimming-pool-energy-temperature-calculator/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.

$Eff_{Base}$ = 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:

$\Delta kWh$ = 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.[298]

**DEEMED MEASURE COST[299]**

The incremental cost is $9.80.

**LOADSHAPE**

Miscellaneous BUS

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**Algorithm**

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**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS[300]**

Annual energy savings are based on the rated output of the server's power supply, according to the following table:

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[298] 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.

[299] 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.

[300] 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) |
|---|---|---|---|
| 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 |
| 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:

$\Delta kWh$ = 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.[301]

**DEEMED MEASURE COST**

Actual incremental costs should be used if available. If actual costs are unknown, use default installed cost from table below.[302]

| 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 |

---

[301] California Database for Energy Efficiency Resources (DEER) 2014 Estimated Useful Life (EUL) Table Update.
[302] Installed costs from 2015-2016 Demand-Side Management Plan, Xcel Energy.

| Motor Size (HP) | Installed Cost |
|:---:|:---:|
| 75 | $5,888 |
| 100 | $7,392 |
| 125 | $9,076 |
| 150 | $9,401 |
| 200 | $11,250 |
| 250 | $13,958 |
| 300 | $17,744 |
| 350 | $25,653 |

**LOADSHAPE**

Motors BUS

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## 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%[303] |
| 0.746 | = Conversion factor from HP to kWh |
| $\eta_{Bmotor}$ | = Actual efficiency of existing motor, or if unknown, use federal baseline nominal/nameplate motor efficiency as shown in table below. |
| $\eta_{EEmotor}$ | = Efficient motor nominal/nameplate motor efficiency |
| | = Actual |
| Hours | = Annual hours of operation for motor; see table below for HVAC motors |

---

[303] 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.

Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC)[304]

| 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 |
| 1 | 82.50% | 85.50% | 77.00% | 82.50% | 85.50% | 77.00% |
| 1.5 | 86.50% | 86.50% | 84.00% | 87.50% | 86.50% | 84.00% |
| 2 | 87.50% | 86.50% | 85.50% | 88.50% | 86.50% | 85.50% |
| 3 | 88.50% | 89.50% | 85.50% | 89.50% | 89.50% | 86.50% |
| 5 | 89.50% | 89.50% | 86.50% | 89.50% | 89.50% | 88.50% |
| 7.5 | 90.20% | 91.00% | 88.50% | 91.00% | 91.70% | 89.50% |
| 10 | 91.70% | 91.70% | 89.50% | 91.00% | 91.70% | 90.20% |
| 15 | 91.70% | 93.00% | 90.20% | 91.70% | 92.40% | 91.00% |
| 20 | 92.40% | 93.00% | 91.00% | 91.70% | 93.00% | 91.00% |
| 25 | 93.00% | 93.60% | 91.70% | 93.00% | 93.60% | 91.70% |
| 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% |

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[304] 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.

Annual Hours of Use for HVAC Motors[305]

| 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 |
| Midrise Apartment - Building | 5,197 | 4,347 | 8,728 |
| Nonresidential Average | 4,411 | 3,539 | 6,773 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS[306]**

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

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

---

[305] 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.

[306] 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.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

**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 10 years.[307]

**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.[308]

**LOADSHAPE**

Motors BUS

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<div align="center">Algorithm</div>

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = 1,747 * HP$$

Where:

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[307] EUL set to 10 years based on 2021 comparison with other TRM values; Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

[308] Costs from 2017 Michigan Energy Measures Database.

1,747        = Average annual energy savings per pool pump motor horsepower (kWh/HP)[309]

HP        = Pool pump motor horsepower
            = Custom input, actual horsepower rating of the pump motor.

**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:**

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[309] 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.

### 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.[310]

LOADSHAPE

Motors BUS

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**Algorithm**

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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. |

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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[310] Costs from Ameren Missouri MEEIA 2016-18 TRM.

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

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.[311]

**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

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Algorithm

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**CALCULATION OF SAVINGS**

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[311] 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).

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = (HP_{motor} * 0.746 * LF / \eta_{motor}) * HOURS * ESF$$

Where:

| | |
|---|---|
| $HP_{motor}$ | = Installed nameplate motor horsepower |
| | = Actual |
| 0.746 | = Conversion factor from horsepower to kW (kW/hp) |
| $LF / \eta_{motor}$ | = Combined as a single factor since efficiency is a function of load |
| | = 0.65[312] |
| LF | = Load Factor; Ratio of the peak running load to the nameplate rating of the motor |
| $\eta_{motor}$ | = Motor efficiency at pump operating conditions |
| HOURS | = Annual operating hours of the pump |
| | =Actual |
| ESF | = Energy Savings Factor; assume a value of 15%.[313] |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

| | |
|---|---|
| CF | = Summer Coincident Peak Factor for measure |
| | = 0.0001379439[314] |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

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[312] "Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings," ACEEE 1994 Summer Study Conference, Asilomar, CA.

[313] 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.

[314] Based on Ameren Missouri 2016 Process Loadshape.

### 2.8.5 Variable Frequency Drives for Pumps and Fans on Hydronic HVAC Systems

**DESCRIPTION**

This measure applies to VFDs installed on HVAC chilled water distribution pumps, hot water distribution pumps, condenser water pumps and cooling tower fans. Back-up pumps/fans do not qualify for this measure. 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 or fan motor 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.[315]

**DEEMED MEASURE COST**

Customer-provided costs will be used when available. Default measure costs are listed below for 1 to 75 HP motors.[316]  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 |

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[315] Consistent with Ameren Missouri program assumptions.

[316] Average costs observed by other Midwestern states energy efficiency programs – specific data reflects results from Iowa program costs.

| 70-75 HP | $9,526 |
|----------|--------|
| >75 HP | $179/HP |

**LOADSHAPE**

Cooling BUS
Heating BUS
HVAC BUS

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Algorithm
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**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.[317]  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.[318] When available, actual hours should be used.

ESF    = Energy savings factor varies by VFD application.  Units are kW/HP.

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[317] 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.

[318] 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.

Annual Hours of Use for VFD Pumps and Fans

| Building Type | Heating Run Hours | Cooling Run 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 |
| Nonresidential Average | 4411 | 3539 |

ESF for VFD Pumps and Fans

| Application | ESF[319] |
|---|---|
| Hot Water Pump | 0.3577 |
| Cooling Water Pump | 0.3389 |
| Cooling Tower Fan | 0.126[320] |

**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 |
| | = 0.000910684 Cooling Water Pumps |
| | = 0.000443983 Hot Water Pumps |
| | = 0.000443983 Cooling Tower Fans |

**FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION**

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[319] 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.
[320] Based on the methodology described in the Illinois Statewide TRM for Energy Efficiency, 7th Edition (2019).

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:**

**2.8.6 Variable Frequency Drives for HVAC Supply and Return Fans**

DESCRIPTION

This measure applies to VFDs installed on HVAC supply fans and return fan. Back-up fans do not qualify for this measure. 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.[321]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.[322] 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 |

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[321] Consistent with Ameren Missouri program assumptions.
[322] Average costs observed by energy efficiency programs in Iowa.

| 90-100 HP | $11,713 |
|-----------|---------|
| >100 HP | $168/HP |

**LOADSHAPE**

HVAC BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS[323]**

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

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

$kWh_{Base} = 0.746 * HP * \frac{LF}{\eta_{moto}}) * RHRS_{base} \sum_{0.0\%}^{100\%} \left( \%FF * PLR_{Retrofit} \right)$

$kWh_{Retrofit} = 0.746 * HP * \frac{LF}{\eta_{moto}}) * RHRS_{base} \sum_{30\%}^{100\%} \left( \%FF * PLR_{Retrofit} \right)$

Where:

| | |
|---|---|
| $\Delta kWh_{fan}$ | = Fan-only annual energy savings |
| $\Delta kWh_{total}$ | = Total project annual energy savings |
| $kWh_{Base}$ | = Baseline annual energy consumption (kWh/yr) |
| $kWh_{Retrofit}$ | = Retrofit annual energy consumption (kWh/yr) |
| 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%)[324] |
| $\eta motor$ | = 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 table below. |
| $RHRS_{Base}$ | = Annual operating hours for fan motor based on Building Type. |
| %FF | = Percent of time at flow fraction |
| $PLR_{Base}$ | = 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) |

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[323] 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.

[324] 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.

$E_{energy}$ = HVAC interactive effects factor for energy (default = 15.7%)[325]

[325] 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.

NEMA Premium Efficiency Motors Default Efficiencies[326]

| 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 |

[326] 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.

Default hours are provided for HVAC applications which vary by Building Type.[327] When available, actual hours should be used.

| 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 |

| 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% |

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[327] 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.

| Control Type | Flow Fraction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| No Control or Bypass Damper | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Discharge Dampers | 0.46 | 0.55 | 0.63 | 0.70 | 0.77 | 0.83 | 0.88 | 0.93 | 0.97 | 1.00 |
| Outlet Damper, BI & Airfoil Fans | 0.53 | 0.53 | 0.57 | 0.64 | 0.72 | 0.80 | 0.89 | 0.96 | 1.02 | 1.05 |
| Inlet Damper Box | 0.56 | 0.60 | 0.62 | 0.64 | 0.66 | 0.69 | 0.74 | 0.81 | 0.92 | 1.07 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Inlet Vane Dampers | 0.38 | 0.40 | 0.42 | 0.44 | 0.48 | 0.53 | 0.60 | 0.70 | 0.83 | 0.99 |
| Outlet Damper, FC Fans | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Eddy Current Drives | 0.17 | 0.20 | 0.25 | 0.32 | 0.41 | 0.51 | 0.63 | 0.76 | 0.90 | 1.04 |
| Inlet Guide Vane, FC Fans | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| VFD with duct static pressure controls | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.29 | 0.41 | 0.57 | 0.76 | 1.01 |
| VFD with low/no duct static pressure | 0.05 | 0.06 | 0.09 | 0.12 | 0.18 | 0.27 | 0.39 | 0.55 | 0.75 | 1.00 |

Provided below 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 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

| | |
|---|---|
| $\Delta kWh_{total}$ | = As calculated above. |
| CF | = 0.000443983 |

**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:**

## 2.9 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 consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V).

ENERGY STAR® Requirements (Version 3.0, Effective October 1, 2014)

| Volume (ft³) | 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 |

**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.[328]

**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

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Algorithm

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**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Custom calculation below.[329]

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

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)

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[328] Measure 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.
[329] Algorithms and assumptions from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

kWh$_{ESTAR}$   = Maximum daily energy consumption (kWh/day) of ENERGY STAR®

                = Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V)

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

| Equipment Type | kWhBase[330] |
|---|---|
| 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 |

| Volume (ft³) | 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 |

**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

                = 0.0001357383[331]

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[330] 32510 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers.

[331] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

**NATURAL GAS ENERGY SAVINGS**

N/A

**PEAK GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:**

**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 B[332] refrigerated vending machine meeting energy consumptions 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.[333]

DEEMED MEASURE COST

The incremental cost of this measure is $140.[334]

LOADSHAPE

Refrigeration BUS

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**Algorithm**

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CALCULATION OF SAVINGS

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[332] 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."

[333] Average of measure lives recognized by Ameren Missouri (10 years) and KCPL (14 years). Also consistent with Energy Star® commercial refrigerator lifetime.

[334] Consistent with Ameren Missouri MEEIA 2016-18 and KCPL TRM assumptions.

## ELECTRIC ENERGY SAVINGS

Custom calculation below.

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

Where:

| | |
|---|---|
| $kWh_{Base}$ | = Maximum daily energy consumption (kWh/day) of baseline vending machine |
| | = Calculated as shown in the table below using the actual refrigerated volume (V) |
| $kWh_{ESTAR}$ | = 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) |
| V | = Refrigerated volume[335] (ft$^3$) |
| | = Actual installed |
| Days | = Days of vending machine operation per year |
| | = 365.25 days per year |

| Equipment Type | kWhBase [336] |
|---|---|
| Class A | 0.055V + 2.56 |
| Class B | 0.073V + 3.16 |

| Equipment Type | kWhEE[337] |
|---|---|
| Class A | ≤ 0.0523V + 2.432 |
| Class B | ≤ 0.0657V + 2.844 |

## 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 |
| | = 0.0001357383[338] |

## MEASURE CODE:

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[335] V 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.

[336] 33010 CFR §431.296 - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

[337] ENERGY STAR® Version 3.1 requirements for maximum daily energy consumption.

[338] 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.[339]

**DEEMED MEASURE COST**

Actual incremental costs should be used if available. The incremental capital cost $151 per door.[340]

**LOADSHAPE**

Refrigeration BUS

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**Algorithm**

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**CALCULATION OF SAVINGS**

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[339] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
[340] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = kW_{Base} * DOORS * (\%ON_{Base} - \%ON_{Control}) * Hours$$

Where:

| | |
|---|---|
| $kW_{Base}$ | = Per door electric energy consumption of door heater without controls |
| | = Assume 0.130 kW per door[341] |
| 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%[342] |
| $\%ON_{Control}$ | = Effective run time with anti-sweat door heater controls |
| | = Actual or if unknown, use 45.6%[343] |
| 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)[344] |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

| | |
|---|---|
| $\Delta kWh$ | = Electric energy savings, calculated above |
| CF | = Summer peak coincidence demand (kW) to annual energy (kWh) factor. |
| | = 0.0001357383[345] |

Savings calculated with default values as defined above.

| Door Heater Control Application | ΔkWh/door | ΔkW/door |
|---|---|---|
| Refrigerator | 668.1 | 0.0907 |

---

[341] 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.

[342] 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.

[343] 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.

[344] 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.

[345] Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

| Freezer | 770.9 | 0.1046 |
|---|---|---|

**NATURAL GAS ENERGY SAVINGS**

N/A

**MEASURE CODE:**

### 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.[346]

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.[347]

LOADSHAPE

Miscellaneous BUS

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**Algorithm**

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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

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[346] DEER database.

[347] 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).

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.

**ELECTRIC ENERGY SAVINGS**

ΔkWh = Savings per motor * motors

Where:

Savings per motor[348]  = based on the motor rating of the ECM motor – see table below.

motors                   = number of fan motors replaced

| 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 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

$\Delta kWh$    = 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:**

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[348] 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.[349]

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.[350]

DEEMED MEASURE COST

The incremental capital cost for this measure is $10.22/sq ft of door opening.[351]

LOADSHAPE

Refrigeration BUS

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Algorithm

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CALCULATION OF SAVINGS

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[349] 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.

[350] DEER 2014 Effective Useful Life.

[351] 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.

**ELECTRIC ENERGY SAVINGS**[352]

$$\Delta kWh = \Delta kWh/SQFT * A$$

Where:

$\Delta kWh/SQFT$ = Average annual kWh savings per square foot of infiltration barrier. Based on application type, as indicated by the table below.[353]

A = Doorway area. Use actual measurements, if unknown use the values in the table below.

| Type | Pre-Existing Curtains | Energy Savings ΔkWh/sq ft |
|------|------|------|
| Supermarket - Cooler | Yes | 37 |
| Supermarket - Cooler | No | 108 |
| Supermarket - Freezer | Yes | 119 |
| Supermarket - Freezer | No | 349 |
| Convenience Store - Cooler | Yes | 5 |
| Convenience Store - Cooler | No | 20 |
| Convenience Store - Freezer | Yes | 8 |
| Convenience Store - Freezer | No | 27 |
| Restaurant - Cooler | Yes | 8 |
| Restaurant - Cooler | No | 30 |
| Restaurant - Freezer | Yes | 34 |
| Restaurant - Freezer | No | 119 |
| Refrigerated Warehouse | Yes | 254 |
| Refrigerated Warehouse | No | 729 |

| 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:

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[352] The source algorithm from which the savings per square foot values are determined is based on Tamm's equation (an application of Bernoulli's equation) [Kalterveluste durch kuhlraumoffnungen. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144;] and the ASHRAE handbook [American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6].

[353] See reference file "Strip Curtain Savings Calcs.docx" for details on derivation.

ΔkWh　　= Electric energy savings, calculated above
CF　　　= Summer peak coincidence demand (kW) to annual energy (kWh) factor
　　　　= 0.0001357383[354]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**
N/A

**MEASURE CODE:**

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[354] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

## 2.10 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** | |
| *Fixed Windows* | 0.38 Btu/ft$^2$.°F.h |
| *Operable Windows* | 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.[355]

#### 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.[356]

#### LOADSHAPE

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[355] Consistent with window measure lives specified by Ameren Missouri and KCP&L.
[356] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

Cooling BUS

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Algorithm
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**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:

$$\Delta kWh_{cooling} = Infltration_{cooling} + Conduction_{cooling} + Solar_{cooling}$$

$$Infiltration_{Cooling} = (CFM_{PRE} - CFM_{POST}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM / (1000 * \eta_{cooling})$$

Where:

| | |
|---|---|
| $CFM_{PRE}$ | = 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 |
| $\Delta T_{AVG,cooling}$ | = Average temperature difference [$^0$F] during cooling season between outdoor air temperature and assumed $75^0$F indoor air temperature – see table below |
| 0.018 | = Specific Heat Capacity of Air (Btu/ft$^3$ °F) |
| LM | = Latent Multiplier to account for latent cooling demand [357] |
| | = 3.0 for St. Louis, MO |
| 1,000 | = Conversion from Btu to kBtu |
| | = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh) |
| $\eta_{cooling}$ | = Actual |

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[357] 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) | $OA_{AVG,cooling}$ [°F][358] | $\Delta T_{AVG,cooling}$ [°F] |
|---|---|---|
| St Louis, MO | 80.8 | 5.8 |

$Conduction_{Cooling}$ = ($U_{BASE}$ - $U_{EFF}$) * $A_{window}$ * $EFLH_{cooling}$ * $\Delta T_{AVG,cooling}$ / (1000 * $\eta_{cooling}$)

Where:

$U_{BASE}$ = U-factor value of baseline window assembly (Btu/ft$^2$.°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/ft$^2$.°F.h)

= Actual.

$A_{window}$ = Area of insulated window (including visible frame and glass) (ft$^2$)

Other variables as defined above.

$Solar_{Cooling}$ = ($SHGC_{BASE}$ – $SHGC_{EFF}$) * $A_{window}$ * $\Psi_{cooling}$ / (1000 * $\eta_{cooling}$)

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)

= Incident solar radiation during the cooling season (Btu/ft$^2$):[359]

$\Psi_{cooling}$ = 40,996 for St. Louis, MO

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:

$\Delta kWh_{heating}$ = $Infltration_{heating}$ + $Conduction_{heating}$ – $Solar_{heating}$

$Infiltration_{heating}$ = ($CFM_{PRE}$ – $CFM_{POST}$) * 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

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[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] See "Windows SHG.xlsx" for derivation.

$\Delta T_{AVG,heating}$ = Average temperature difference [$^0$F] during heating season between outdoor air temperature and assumed 55$^0$F heating base temperature

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.

| Weather Basis (City based upon) | OA$_{AVG,heating}$ [°F][360] | $\Delta T_{AVG,heating}$ [°F] |
|---|---|---|
| St Louis, MO | 43.2 | 11.8 |

$Conduction_{heating}$ = $(U_{BASE} - U_{EFF}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating} / (3{,}412 * \eta_{heating})$

Where:

Variables as defined above.

$Solar_{Heating}$ = $(SHGC_{BASE} - SHGC_{EFF}) * A_{window} * \Psi_{Heating} / (3{,}412 * \eta_{Heating})$

Where:

$\Psi_{heating}$ = Incident solar radiation during the heading season (Btu/ft$^2$)
= 66,592 for St. Louis, MO

Other variables as defined above.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:
$\Delta kWH_{cooling}$ = 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.

$\Delta Therms$ = $Infltration_{gasheat} + Conduction_{gasheat} - Solar_{gasheat}$

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[360] 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.

Infiltration$_{gasheat}$ = (CFM$_{PRE}$ – CFM$_{POST}$) * 60 * EFLH$_{heating}$ * $\Delta$T$_{AVG,heating}$ * 0.018 / (100,000 * $\eta_{heat}$)

Conduction$_{gasheat}$ = (U$_{BASE}$ – U$_{EFF}$) * A$_{window}$ * EFLH$_{heating}$ * $\Delta$T$_{AVG,heating}$ / (100,000 * $\eta_{heat}$)

Solar$_{gasheat}$ = (SHGC$_{BASE}$ – SHGC$_{EFF}$) * A$_{window}$ * $\Psi_{Heating}$ / (100,000 * $\eta_{heat}$)

Where:

|   |   |
|---|---|
| 100,000 | = Conversion from BTUs to Therms |
| $\eta_{heat}$ | = Efficiency of heating system |
|   | = Actual |

Other 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

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**Algorithm**

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**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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

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:

| | |
|---|---|
| $R_{existing}$ | = Assembly heat loss coefficient with existing insulation [(hr-$^0$F-ft$^2$)/Btu] |
| $R_{new}$ | = Assembly heat loss coefficient with new insulation [(hr-$^0$F-ft$^2$)/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 insulation[361] |
| $EFLH_{cooling}$ | = Equivalent Full Load Hours for Cooling [hr] are provided in Section 2.7, HVAC End Use |
| $\Delta T_{AVG,cooling}$ | = Average temperature difference [$^0$F] during cooling season between outdoor air temperature and assumed 75$^0$F indoor air temperature |
| 1,000 | = Conversion from Btu to kBtu |
| $\eta_{cooling}$ | = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh) |
| | = Actual |

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[361] 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."

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 [$^0$F] during heating season between outdoor air temperature and assumed $55^0$F heating base temperature

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%*

| Weather Basis (City based upon) | OAAVG,cooling [°F][362] | ΔTAVG,cooling [°F] | OAAVG,heating [°F][363] | ΔTAVG,heating [°F] |
|---|---|---|---|---|
| St Louis, MO | 80.8 | 5.8 | 43.2 | 11.8 |

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%[364]

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.

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

### NATURAL GAS SAVINGS

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[362] 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.

[363] 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.

[364] 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.

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

Where:

| | |
|---|---|
| $R_{existing}$ | = Assembly heat loss coefficient with existing insulation [(hr-$^0$F-ft$^2$)/Btu] |
| $R_{new}$ | = Assembly heat loss coefficient with new insulation [(hr-$^0$F-ft$^2$)/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 |
| $\Delta T_{AVG,heating}$ | = Average difference [$^0$F] during heating season (see above) |
| 100,000 | = Conversion from BTUs to Therms |
| $\eta_{heat}$ | = Efficiency of heating system |
| | = Actual |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**
N/A

**MEASURE CODE:**