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.

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]

[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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Efficiency Level	MEFbase		
	Top loading	Front Loading	Weighted Average[6]
Federal Standard	1.6	2.0	1.7

MEFeff = Modified Energy Factor of efficient unit

= Actual. If unknown, assume average values provided below.

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

[4] Based on Industry Data 2007 as referenced in ENERGY STAR® Commercial Clothes Washer Calculator.
[5] Based on the average clothes washer volume of all units that pass the federal standard on the California Energy Commission (CEC) database of commercial clothes washer products (accessed on 11/26/2015).
[6] Weighted average MEF of federal standard rating for front- loading and top- loading units. Baseline weighting is based upon the relative top front loading percentage of available non-ENERGY STAR® commercial products in the CEC database (accessed 11/26/2015) and ENERGY STAR® weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis.xlsx":

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

Ncycles = Number of Cycles per year

= 2190[7]

%CW = Percentage of total energy consumption for clothes washer operation (different for baseline and efficient unit – see table below)

%DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)

%Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

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

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

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%

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

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

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

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

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

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

= 0.0001379439[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

$$\Delta Therms = \left[\left[\left(Capacity * \frac{1}{IMEFbase} * Ncycles\right) * \left((\%DHWbase * \%Natural\ Gas_{DHW} * R\_eff) + (\%Dryerbase * \%Gas_{Dryer}\%Gas\_Dryer)\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left((\%DHWeff * \%Gas_{DHW}\%Natural\ Gas\_DHW * R\_eff) + (\%Dryereff * \%Gas_{Dryer}\%Gas\_Dryer)\right)\right]\right] * Therm\_convert$$

Where:

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

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

R_eff = Recovery efficiency factor

= 1.26[11]

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

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

Other factors as defined above.

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

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

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where:

WFbase = Water Factor of baseline clothes washer

Efficiency Level	WFbase		
	Top loading	Front Loading	Weighted Average[12]
Federal Standard	8.5	5.5	7.4

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	8.5	5.5	7.4	n/a
ENERGY STAR	4.5			19,874

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

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

2.1.2 Clothes Dryer

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Dryer Size	Incremental Cost[15]
Standard	$75
Compact	$105

LOADSHAPE

Loadshape - Miscellaneous BUS

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

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * \%Electric$$

Where:

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

Dryer Size	Load (lbs)[16]
Standard	8.45
Compact	3

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

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

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

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

[16] Based on ENERGY STAR® test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[17] ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis
[18] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[19] ENERGY STAR® Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[20] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

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

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

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 5% for gas dryers[22]

Using defaults provided above:

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy savings as calculated above

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

= 0.0001379439[23]

Using defaults provided above:

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

[21] NOPR analysis for DOE Commercial Clothes Washer standard. Annual use cycles of 1,074 and 1,483 for multifamily and laundromat applications, respectively. https://www.regulations.gov/document?D=EERE-2012-BT-STD-0020-0021. On-premise laundromat cycle average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

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

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

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

NATURAL GAS ENERGY SAVINGS

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

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

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

Using defaults provided above:

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

Product Class	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

Algorithm

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]

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

[25] "Measure Life Study," Energy & Resource Solutions (prepared for the Massachusetts Joint Utilities): Table 1-1, 2005.
[26] Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls.
[27] Reduced CFM consumption is based on a timer drain opening for 10 seconds every 300 seconds as the baseline. See "Industrial System Standard Deemed Saving Analysis.xls."
[28] Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See "Industrial System Standard Deemed Saving Analysis.xls."

Compressor Control Type	kW_{CFM}
Reciprocating - On/off Control	0.184
Reciprocating - Load/Unload	0.136
Screw - Load/Unload	0.152
Screw - Inlet Modulation	0.055
Screw - Inlet Modulation w/ Unloading	0.055
Screw - Variable Displacement	0.153
Screw - VFD	0.178

Hours = Compressed air system pressurized hours

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

=

= 0.0001379439[29]

MEASURE CODE:

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

2.2.2 Compressed Air Nozzle

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard air nozzle.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 15 years.[30]

DEEMED MEASURE COST

Incremental measure costs are presented in the following table.[31]

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

LOADSHAPE

Air Comp BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

SCFM = Air flow through standard nozzle.

[30] “Focus on Energy Evaluation - Business Programs: Measure Life Study,” prepared for State of Wisconsin Public Service Commission by PA Consulting Group, August 25, 2009.
[31] Costs are from EXAIR’s website and are an average of nozzles that meet the flow requirements. Models include Atto Super, Pico Super, Nano Super, Micro Super, Mini Super, Super and Large Super nozzles. www.exair.com. Accessed March 20, 2014.

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

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

SCFM%Reduced = Percent reduction in air loss per nozzle.

= Estimated at 50%[34]

kW/CFM = System power reduction per air demand (kW/CFM), depending on the type of air compressor; see table below[35]

Air Compressor Type	ΔkW/CF
Reciprocating – On/off Control	0.18
Reciprocating – Load/Unload	0.14
Screw – Load/Unload	0.15
Screw – Inlet Modulation	0.06
Screw – Inlet Modulation w/	0.06
Screw – Variable Displacement	0.15
Screw - VFD	0.18

%USE = Percent of the compressor total operating hours that the nozzle is in use

= Custom, or if unknown, assume 5%[36]

Hours = Compressed air system pressurized hours

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

---

32 Review of manufacturer’s information

33 Technical Reference Manual (TRM) for Ohio Senate Bill 221,”Energy Efficiency and Conservation Program” and 09-512-GE-UNC, October 15, 2009, Pgs 170-171.

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

35 Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See “Industrial System Standard Deemed Saving Analysis.xls.”

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

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

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, calculated above

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

=

= 0.0001379439[37]

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

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

2.2.3 VSD Air Compressor

DESCRIPTION

This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls, or variable displacement control. A baseline modulating compressor regulates output by choking off the inlet air, which is not efficient. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per US Department of Energy (DOE) data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

10 years.[38]

DEEMED MEASURE COST[39]

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

Where:

$hp_{compressor}$ = compressor motor nominal horsepower

LOADSHAPE

Air Comp BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

ΔkWh = gross customer annual kWh savings for the measure

$hp_{compressor}$ = compressor motor nominal horsepower

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

0.9[40] = compressor motor nominal horsepower to full load kW conversion factor

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

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

CF_b = baseline compressor factor[41]

=0.890

CF_e = efficient compressor[42]

=0.705

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0001379439[43]

MEASURE CODE:

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

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

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

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

2.3 Food Service

2.3.1 Combination Oven

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

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

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

Note: P = Pan capacity as defined in Section 1.T of the Commercial Ovens Program Requirements Version 2.2.[44]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

The incremental capital cost for this measure is $4,300.[46]

[44] Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification. https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf

[45] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009." https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

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

LOADSHAPE

Cooking BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric combination oven below.[47]

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

Where:

$\Delta CookingEnergy_{ConvElec}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode

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

$\Delta CookingEnergy_{SteamElec}$ = Difference in cooking energy between baseline and efficient combination oven in steam mode

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

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

= (($ElecIDLE_{ConvBase}$ * ((Hours – $FoodCooked_{Elec}$ /$ElecPC_{ConvBase}$) * $\%_{Conv}$)) - ($ElecIDLE_{ConvEE}$ * ((Hours - $FoodCooked_{Elec}$ /$ElecPC_{ConvEE}$) * $\%_{Conv}$)))

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

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

Days = Annual days of operation

= Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

Where:

$FoodCooked_{Elec}$ = Food cooked per day for electric combination oven

= Custom, or, if unknown, use 200 lbs if P <15 or 250 lbs if P ≥ 15

$EFOOD_{ConvElec}$ = ASTM energy to food for electric combination oven in convection mode

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

= 73.2 Wh/lb

ElecEff = Cooking energy efficiency of electric combination oven

= Custom or if unknown, use values from table below

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

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

= Custom or, if unknown, use 50%

$EFOOD_{SteamElec}$ = ASTM energy to food for electric combination oven in steam mode

= 30.8 Wh/lb

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

= 1 - $\%_{conv}$

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

= Custom or, if unknown, use values from table below

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

Hours = Average daily hours of operation

= Custom or, if unknown, use 12 hours per day

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

= Custom or, if unknown, use values from table below

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

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

= (0.08*P + 0.4989)*1,000

$ElecPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR electric combination oven

= Custom or, if unknown, use values from table below

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

$ElecIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR electric combination oven in steam mode

= (0.133*P + 0.64)*1,000

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[48]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a gas combination oven below:[49]

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

Where:

$\Delta CookingEnergy_{ConvGas}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode

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

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

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

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

= (($GasIDLE_{ConvBase}$ * ((Hours – $FoodCooked_{Gas}$ /$GasPC_{ConvBase}$) * $\%_{Conv}$)) - ($GasIDLE_{ConvEE}$ * ((Hours - $FoodCooked_{Gas}$ /$GasPC_{ConvEE}$) * $\%_{Conv}$)))

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

[48] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."
[49] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

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

100,000 = Btu to therms conversion factor

Where:

$FoodCooked_{Gas}$ = Food cooked per day for gas combination oven

= 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

= 250 Btu/lb

GasEff = Cooking energy efficiency of gas combination oven

= Custom or, if unknown, use values from table below

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

$EFOOD_{SteamGas}$ = 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

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

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

= Custom or, if unknown, use values from table below

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

$GasIDLE_{ConvEE}$ = 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

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

$GasIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR gas combination oven in steam mode

= 200*P +6,511

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.2 Commercial Steam Cooker

Description

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

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

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

Definition of Efficient Equipment

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

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

Pan Capacity	Electric Efficiency Requirements		Natural Gas Efficiency	
	Idle Energy Rate 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.[50]

Deemed Measure Cost

Actual incremental cost for this measure should be used. If actuals are unavailable use $4,150.[51]

Loadshape

Cooking BUS

[50] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009."
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx
[51] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

Calculation of Savings

Electric Energy Savings

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

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

Where:

ΔIdleEnergy = [(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))]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) – (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient steam cooker

ΔCookingEnergy = Difference in cooking energy between baseline and efficient steam cooker

Days = Annual days of operation

= Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

SteamMode = Time (%) in constant steam mode

= Custom or, if unknown, use 40%

$IdleRate_{Base}$ = Idle energy rate (W) of baseline electric steam cooker

= 1,100 W[53]

$IdleRate_{ESTAR}$ = Idle energy rate (W) of ENERGY STAR electric steam cooker

= Custom or, if unknown, use value from table below as determined by pan capacity

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

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

= 23.3 lb/hr

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

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

$Production_{ESTAR}$ = Production capacity (lb/hr) per pan of ENERGY STAR® electric steam cooker

= Custom or, if unknown, use 16.7 lb/hr

Pans = Pan capacity of steam cooker

= Custom or, if unknown, use 6 pans

EFOOD = ASTM energy to food

= 30.8 Wh/lb

Eff_{Base} = Cooking efficiency (%) of baseline electric steam cooker[54]

= 28%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR® electric steam cooker

= Custom or, if unknown, use 50%

Hours = Average daily hours of operation

= Custom or, if unknown, use 12 hours per day

FoodCooked = Food cooked per day (lbs)

= Custom or, if unknown, use 100 pounds

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

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

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[55]

Other variables as defined above.

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

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

NATURAL GAS ENERGY SAVINGS

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

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

Where:

ΔIdleEnergy = [(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)]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) – (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

100,000 = Btu to therms conversion factor

$IdleRate_{Base}$ = Idle energy rate (Btu/hr) of baseline gas steam cooker

= 16,500 Btu/hr[57]

$IdleRate_{ESTAR}$ = Idle energy rate (Btu/hr) of ENERGY STAR® gas steam cooker

= Custom or, if unknown, use value from table below as determined by pan capacity

Pan Capacity	$IdleRate_{ESTAR}$
3	6,250
5	10,400
6	12,500
10	12,500

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

= 23.3 lb/hr

$Production_{ESTAR}$ = Production capacity (lb/hr) per pan of ENERGY STAR® gas steam cooker

= Custom or, if unknown, use 20 lb/hr

EFOOD = ASTM energy to food

= 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker[58]

= 16.5%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR® gas steam cooker

= Custom or if unknown, use 38%

[56] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
[57] Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR® for steam generator and boiler-based cookers.
[58] Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR® for steam generator and boiler-based cookers.

Other variables as defined above.

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

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

Where:

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

= 40 gal/hr

$WaterUse_{ESTAR}$ = Water use (gal/hr) of ENERGY STAR® steam cooker[60]

= Custom or, if unknown, use 9.3 gal/hr

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

[60] Water use for ENERGY STAR® steam cookers is the average of water use values provided by ENERGY STAR® for steam generator, boiler-based, and 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.[61]

DEEMED MEASURE COST

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

[61] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009." https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.

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

LOADSHAPE

Cooking BUS**Algorithm**

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Where:

ΔIdleEnergy = ($ElecIdle_{Base}$* (Hours – FoodCooked/$ElecPC_{Base}$)) – ($ElecIdle_{ESTAR}$ * (Hours – FoodCooked/$ElecPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{Base}$) – (FoodCooked * $EFOOD_{Elec}$/$ElecEff_{ESTAR}$)

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient fryer

ΔCookingEnergy = Difference in cooking energy between baseline and efficient fryer

Days = Annual days of operation

= Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

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

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

$ElecIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® electric fryer

= Custom or, if unknown, use 1,000 W for standard fryers and 1,100 for large vat fryers

Hours = Average daily hours of operation

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

FoodCooked = Food cooked per day

= Custom or, if unknown, use 150 pounds

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

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

$ElecPC_{ESTAR}$ = Production capacity of ENERGY STAR® electric fryer

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

$EFOOD_{Elec}$ = ASTM energy to food

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

= 167 Wh/lb

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

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

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[64]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

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

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

Where:

ΔIdleEnergy = ($GasIdle_{Base}$* (Hours – FoodCooked/$GasPC_{Base}$)) – ($GasIdle_{ESTAR}$ * (Hours – FoodCooked/$GasPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{Base}$) – (FoodCooked * $EFOOD_{Gas}$/$GasEff_{ESTAR}$)

Where:

100,000 = Btu to therms conversion factor

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

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

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas fryer

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

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

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

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

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

---

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

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

$EFOOD_{Gas}$ = ASTM energy to food

= 570 Btu/lb

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

= 35% for both standard and large vat fryers

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

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

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.4 Convection Oven

Description

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

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

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

Definition of Efficient Equipment

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

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

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

The incremental capital cost for this measure is $0.[67]

[66] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009.” https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx.

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

LOADSHAPE

Cooking BUS**Algorithm**

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Where:

ΔIdleEnergy = ($ElecIdle_{Base}$* (Hours - FoodCooked/$ElecPC_{Base}$)) - ($ElecIdle_{ESTAR}$ * (Hours -FoodCooked/$ElecPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{Base}$) - (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{ESTAR}$)

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient convection oven

ΔCookingEnergy = Difference in cooking energy between baseline and efficient convection oven

Days = Annual days of operation

= Custom or, if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

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

= 2,000 W for full-size ovens and 1,030 W for half-size ovens

$ElecIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® electric convection oven

= Custom or, if unknown, use 1,600 W for full-size ovens and 1,000 W for half-size ovens

Hours = Average daily hours of operation

= Custom or, if unknown, use 12 hours per day

FoodCooked = Food cooked per day

= Custom or, if unknown, use 100 pounds

$ElecPC_{Base}$ = Production capacity of baseline electric convection oven

= 90 lb/hr for full-size ovens and 45 lb/hr for half-size ovens

$ElecPC_{ESTAR}$ = Production capacity of ENERGY STAR® electric convection oven

= Custom or, if unknown, use 90 lb/hr for full-size ovens and 50 lb/hr for half-size ovens

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

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

= 73.2 Wh/lb

$ElecEff_{Base}$ = Cooking efficiency of baseline electric convection oven

= 65% for full-size ovens and 68% for half-size ovens

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[69]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

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

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

Where:

ΔIdleEnergy = ($GasIdle_{Base}$* (Hours - FoodCooked/$GasPC_{Base}$)) - ($GasIdle_{ESTAR}$ * (Hours -FoodCooked/$GasPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{Base}$) - (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{ESTAR}$)

Where:

100,000 = Btu to therms conversion factor

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

= 15,100 Btu/hr

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas convection oven

= Custom or, if unknown, use 12,000 Btu/hr

$GasPC_{Base}$ = Production capacity of baseline gas convection oven

= 83 lb/hr

$GasPC_{ESTAR}$ = Production capacity of ENERGY STAR® gas convection oven

= Custom or, if unknown, use 86 lb/hr

---

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

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

$EFOOD_{Gas}$ = ASTM energy to food for gas convection oven

= 250 Btu/lb

$GasEff_{Base}$ = Cooking efficiency of baseline gas convection oven

= 44%

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas convection oven

= Custom or, if unknown, use 46%

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.5 Griddle

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

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

Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
Idle Energy Rate	Cooking Efficiency Consumption	Idle Energy Rate	Cooking Efficiency Consumption
≤ 320 W/ft² ≤ 1.00 kW	Reported	≤ 2,650 Btu/hr/ft² N/A	Reported

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

LOADSHAPE

Cooking BUS**Algorithm**

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

---

[71] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009." http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[72] Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "EPA research on available models using AutoQuotes, 2012." http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG.

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

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

Where:

ΔIdleEnergy	= [($ElecIdle_{Base}$* Width * Depth) * (Hours – FoodCooked/$ElecPC_{Base}$)] – [($ElecIdle_{ESTAR}$ * Width * Depth) * (Hours – FoodCooked/$ElecPC_{ESTAR}$))
ΔCookingEnergy	= (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{Base}$) – (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{ESTAR}$)

Where:

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[74]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

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

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

Where:

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

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

Where:

100,000 = Btu to therms conversion factor

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

= 3,500 Btu/hr/ft^2

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas griddle

= Custom or, if unknown, use 2,650 Btu/hr/ft^2

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

= 25 lb/hr

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

= Custom or, if unknown, use 45 lb/hr

$EFOOD_{Gas}$ = ASTM energy to food

= 475 Btu/lb

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

= 32%

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

= Custom or, if unknown, use 38%

Other variables as defined above.

---

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

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

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.3.6 Kitchen Demand Ventilation Controls

DESCRIPTION

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

This measure was developed to be applicable to the following program types: TOS and RF. For TOS applications. ASHRAE 90.1 and local codes should be applied to situations where hood exhaust rates exceed 5,000 cfm. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is kitchen ventilation system that has constant speed, continuously operating ventilation motor(s).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

$$\text{Measure Cost} = HP_{exhaust} * Cost_{HP}$$

Where:

$HP_{exhaust}$ = total rated horsepower of the exhaust motor(s)

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

Measure Category	Incremental Cost[77] , $/HP
Retrofit	$1,988
Time of Sale	$994

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

LOADSHAPE

Cooking BUS **Algorithm**

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Fan energy savings:

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

Where:

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

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

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001998949[79]

NATURAL GAS ENERGY SAVINGS

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

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

Where:

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

= custom input, or 448 cfm/HP[80] if unknown.

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

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

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

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

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

Zone	Q, Btu/cfm
St Louis	125,363

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

= actual if known, otherwise assume 80%[82]

100,000 = conversion from Btu to Therm

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

2.3.7 Hot Food Holding Cabinet

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new ENERGY STAR® electric HFHC meeting idle energy rate limits as determined by product interior volume.

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

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Actual incremental costs should be used if available. If actual costs are unknown, assume $1,783.[84]

LOADSHAPE

Cooking BUS

[83] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Calculator, which cites reference as "FSTC research on available models, 2009."
[84] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below.[85]

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

$IdleRate_{Base}$ = Idle energy rate (W) of baseline HFHC

= 40 * V

Where:

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

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

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

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[86]

Other variables as defined above.

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

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

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.3.8 Pre-Rinse Spray Valve

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the new or replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute.

DEFINITION OF BASELINE EQUIPMENT

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

Time of Sale	Retrofit, Direct Install
The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.	Actual existing flow rates should be used when possible. If unknown, baseline can be assumed to be 2.23 gallons per minute.[87] If existing pre-rinse spray valve flow rate is unknown, then existing pre-rinse spray valve must have been installed prior to 2006. The Energy Policy Act of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. However, field data shows that not all nozzles in use have been replaced with the newer flow rate nozzle. Products predating this standard can use up to five gallons per minute.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years[88]

DEEMED MEASURE COST

When available, the actual cost of the measure should be used. If unknown, a default value of $92.90[89] may be assumed.

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

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

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

LOADSHAPE

Cooking BUS**Algorithm**

CALCULATION OF ENERGY SAVINGS

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

ΔkWH = ΔGallons * 8.33 * 1 * (Tout - Tin) * (1/EFF_Elec) /3,413

Where:

ΔGallons	= 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
Tout	= Water Heater Outlet Water Temperature
	= Custom, otherwise assume Tin + 70°F temperature rise from Tin[90]
Tin	= Inlet Water Temperature
	= Custom, otherwise assume 57.9F[91]
EFF_Elec	= Efficiency of electric water heater supplying hot water to pre-rinse spray valve
	=Custom, otherwise assume 97%[92]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

NATURAL GAS ENERGY SAVINGS

ΔTherms = ΔGallons * 8.33 * 1 * (Tout - Tin) * (1/EFF_Gas) /100,000

Where (new variables only):

EFF_Gas	= Efficiency of gas water heater supplying hot water to pre-rinse spray valve
	= Custom, otherwise assume 80%[94]

[90] 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.

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

[92] 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.

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

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

WATER IMPACT CALCULATION

$$\Delta Gallons = (FLObase - FLOeff) * 60 * HOURSday * DAYSyear$$

Where:

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

Time of Sale	Retrofit, Direct Install
1.6 gal/min[95]	2.23 gal/min[96]

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

Time of Sale	Retrofit, Direct Install
1.06 gal/min[97]	1.06 gal/min[98]

60 = Minutes per hour

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

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

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

MEASURE CODE:

[95] 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.

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

[97] 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.

[98] 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.

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

2.4 Hot Water

2.4.1 Low Flow Faucet Aerator

DESCRIPTION

This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, or motel. For multifamily or senior housing, the residential low flow faucet aerator should be used.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an energy efficient faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

The incremental cost for this measure is $8[101] or program actual

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted.[102]

$$\Delta kWh = \%ElectricDHW * ((GPM\_base - GPM\_low)/GPM\_base) * Usage * EPG\_electric * ISR$$

Where:

[100] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf."

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

[102] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.

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

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	43%[103]

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

= 1.2[104] or custom based on metering studies[105]

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

= 0.94[106] or custom based on metering studies[107]

Usage = Estimated usage of mixed water (mixture of hot water from water heater line and cold-water line) per faucet (gallons per year)

= If data is available to provide a reasonable custom estimate it should be used, if not use the following defaults (or substitute custom information in to the calculation):

Building Type	Gallons hot water per unit per day[108] (A)	Unit	Estimated % hot water from Faucets[109] (B)	Multiplier[110] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Rest	0.7	meal/day	50%	75	meals per faucet	365	9,581
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365	15,768

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

[104] Representative baseline flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. This accounts for all throttling and differences from rated flow rates. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use.

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

[106] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low-flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

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

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

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

[110] Based on review of the Illinois plumbing code (Employees and students per faucet). Retail, grocery, warehouse and health are estimates. Meals per faucet estimated as 4 bathroom and 3 kitchen faucets and average meals per day of 250 (based on California study above) – 250/7 = 36. Fast food assumption estimated.

Building Type	Gallons hot water per unit per day[108] (A)	Unit	Estimated % hot water from Faucets[109] (B)	Multiplier[110] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Retail	2	employee	100%	5	employees per faucet	365	3,650
Grocery	2	employee	100%	5	employees per faucet	365	3,650
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365	16,425
Motel	20	room	25%	1	faucet per room	365	1,825
Hotel	14	room	25%	1	faucet per room	365	1,278
Other	1	employee	100%	20	employees per faucet	250	5,000

EPG_electric = Energy per gallon of mixed water used by faucet (electric water heater)

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

= (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

= 90F[111]

SupplyTemp = Assumed temperature of water entering building

= 57.9F[112]

RE_electric = Recovery efficiency of electric water heater

= 98%[113]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators

=Assumed to be 1.0

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh * CF

[111]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.
[112] Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061
[113] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

Where:

ΔkWh = calculated value above on a per faucet basis

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

= 0.0001811545FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

ΔTherms = %FossilDHW * ((GPM_base - GPM_low)/GPM_base) * Usage * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	57%[114]

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

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

= 0.00772 Therm/gal

Where:

RE_gas = Recovery efficiency of gas water heater

` = 67%[115]

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

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES USED FOR GPM ASSUMPTIONS

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

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

[115] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

2	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
3	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
4	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

MEASURE CODE:

2.4.2 Circulator Pump

DESCRIPTION

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

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

DEFINITION OF EFFICIENT EQUIPMENT

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure category is an existing, un-controlled recirculation pump on a gas-fired Central Domestic Hot Water System.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years.[116]

DEEMED MEASURE COST

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

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh.[118]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

[116] Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water.* Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

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

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

ΔkWh = calculated value above on a per faucet basis

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

= 0.0001379439

NATURAL GAS SAVINGS

ΔTherms = 55.9 * number of dwelling units[119]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

2.4.3 Heat Pump Water Heater

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

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

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

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

[120] Federal standards for ≤55 gallon and ≤12 kW storage water heaters are from 10 CFR §430.32(d). Federal standards for >120 gallon and>12 kW storage water heaters are from 10 CFR §431.110. Since the federal standard effectively requires a heat pump water heater for residential electric storage water heaters >55 gallons and ≤120 gallons, this measure excludes those units.
[121] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.
[122] Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report," Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I_August2016.xls" for more information.
[123] Costs for larger heat pump water heaters are from 2017 Michigan Energy Measures Database.xlsx and are based on heat pump water heaters with a COP ≥3.0.

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

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

= See table below

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

EF_{EE} = EF of heat pump water heater

= Actual

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per water heater capacity

= Consumption/cap * Capacity

Where:

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

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

[125] Based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2003) consumption data for West North Central (removed outliers of 1,000 kBtu/hr or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and "Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting," Lawrence Berkeley National Library, December 1995. VEIC considers these values to be relatively conservative estimates that may benefit from future evaluation.

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

Capacity = Capacity of hot water heater in gallons

= Actual

2. Consumption by facility size[126]

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

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= Actual, if unknown assume 125°F[127]

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

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

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

= 57.898°F[128]

1.0 = Heat capacity of water (1 Btu/lb*°F)

3,412 = Conversion factor from Btu to kWh

kWh_cool = Cooling savings from conversion of heat in building to water heat[129]

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

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location[130]

= 0.0 for installation in an unconditioned space

53% = Portion of reduced waste heat that results in cooling savings[131]

COP_{COOL} = COP of central air conditioner

= Actual

LM = Latent multiplier to account for latent cooling demand:[132]

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

%Cool = Percentage of buildings with central cooling

Home	%Cool
Cooling	100%
No Cooling	0%

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

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

130 Professional judgment.

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

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

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

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

Where:

43% = Portion of reduced waste heat that results in increased heating load[133]

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

%ElectricHeat = Percentage of buildings with electric heat

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%

Summer Coincident Peak Demand Savings

$$\Delta kW = kWh * CF$$

Where:

kWh = Electric energy savings, as calculated above

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

= 0.0001811545[134]

Natural Gas Savings

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

Where:

ΔTherms = Heating cost from conversion of heat in building to water heat for buildings with natural gas heat[135]

100,000 = Conversion factor from Btu to therms

ηHeat = Efficiency of heating system

[133] Based on 157 days where HDD 60>0, divided by 365.25. HDD days determined from TMY data with a base temp of 60°F.

[134] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Water Heating. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

[135] This is the additional energy consumption required to replace the heat removed from the building during the heating season by the heat pump water heater. The variable kWh_heating (electric resistance) is that additional heating energy for a building with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance building to the MMBtu required in a natural gas heated building, applying the relative efficiencies.

= Actual

%GasHeat = Percentage of buildings with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5 HVAC

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

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

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

2.5.1 Small Commercial Learning Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new programmable thermostat for reduced cooling and heating energy consumption through temperature set-back during unoccupied or reduced demand times as well as automatic adjustments based on occupancy patterns and various independent variables such as weather. This measure is limited to small businesses as defined by programs,[137] as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for learning thermostats installed in multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature set-points according to various independent variables without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a learning thermostat is assumed to be 10 years[138] based upon equipment life only.[139]

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be $224.[140]

LOADSHAPE

Cooling BUS

Heating BUS

[137] The square footage of the small office prototype building modeled in is 7,500 sf.
[138] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
[139] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer-term impacts should be assessed.
[140] 2012 Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

eff	= Efficiency of HVAC unit
	= Actual; If not available, assume 10 SEER
$EFLH_{COOL}$	= Effective Full Load Cooling Hours
	= Actual; If not available, refer to section 2.7 HVAC
$Btuh_{COOL}$	= Cooling System Capacity
	= Actual
ESF_{COOL}	= Cooling energy savings factor
	= Assume 0.139[141]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

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

NATURAL GAS ENERGY SAVINGS

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

Where:

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

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

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

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.5.2 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new programmable thermostat for reduced heating and cooling energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs,[143] as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature set-points according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years[144] based upon equipment life only.[145]

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be $181.[146]

LOADSHAPE

Cooling BUS

[143] The square footage of the small office prototype building modeled in is 7,500 sf.
[144] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
[145] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer-term impacts should be assessed.
[146] Based upon Nicor, Illinois Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013. If Missouri average costs are available, they should be used.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Sqft = Square footage of building controlled by thermostat

EER(exist) = Efficiency rating of existing cooling equipment EER (btu hr/W)

Savings Factor = 0.578 kWh/sf-yr[147]

PF = Persistence Factor to account for thermostat being placed on hold, reset or bypassed.

= Actual if provided in program evaluation, else assume 50% [148]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = Electric energy savings, as calculated above

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

= 0.0009106840

NATURAL GAS ENERGY SAVINGS

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

Where:

Sqft = Square footage of building controlled by thermostat

AFUE (exist) = Efficiency rating of existing heating equipment (AFUE), in decimal form.

100 = Converts kBtu to therms, 1 therm = 100 kBtu

---

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

[148] This factor is based on consideration of the findings from a number of evaluations, including Sachs et al, *"Field Evaluation of Programmable Thermostats,"* US DOE Building Technologies Program, December 2012, p35; "low proportion of households that ended up using thermostat-enabled energy saving settings" http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/field_eval_thermostats.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.

Savings Factor = 9.940 kBtu/sf-yr[149]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

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

2.5.3 Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) automatically adjusts building ventilation rates based on occupancy. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (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.[150]

DEEMED MEASURE COST

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

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas, cooling savings are:

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

[150] 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.

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

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

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

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

Where:

$SQFT_{cond}$ = Square footage of conditioned space commissioned with DCV

$SF_{cooling}$ = Cooling Savings Factor, including cooling and fan energy savings

$SF_{Heat\ HP}$ = Heating Savings factor for facilities heated by Heat Pump (HP)

$SF_{Heat\ ER}$ = Heating Savings factor for facilities heated by Electric Resistance (ER)

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

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

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

[151] Energy savings factors were calculated using weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given weather zone in Missouri. Original energy savings for DCV were developed for Illinois utilizing standards, inputs and approaches as set forth by ASHRAE 62.1and 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.

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

Building Type	SF $_{Heat\ ER}$ (kWh/1000 SqFt)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis, MO	Kansas City, MO	Average/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

$$\Delta kW = kWhcooling * CF$$

Where:

kWhcooling = Electric energy savings, as calculated above

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

= 0.0009106840

NATURAL GAS SAVINGS

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

Where:

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.4 Advanced Roof Top Unit (RTU) Controls

DESCRIPTION

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

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

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

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

LOADSHAPE

HVAC BUS **Algorithm**

CALCULATION OF SAVINGS

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

ELECTRIC ENERGY SAVINGS

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

Where:

P_{sf} = Nominal horsepower of supply fan motor

SF = Fan energy savings factor[155] (kWh/hour/horsepower)

= 0.558

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

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

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

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = As calculated above.

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

= 0.0004439830

NATURAL GAS ENERGY SAVINGS

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.5.5 Electric Chiller

DESCRIPTION

This measure involves the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs), for which a custom analysis should be used to establish savings.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

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

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

[157] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
[158] Ameren Missouri Technical Resource Manual Effective January 1, 2018.

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

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWH = TONS * ((IPLVbase) - (IPLVee)) * EFLH$$

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, Convertion Values' and 'Baseline Efficiency Values by Chiller Type' and Capacity in the Reference Tables section.

$IPLV_{ee}$[159] = Efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[160]

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWH = Annual electricity savings, as calculated above

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

= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

[159] Integrated Part Load Value is a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency, it is expressed in terms of IPLV here.
[160] Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetI.org. http://www.ahrinet.org/.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES

Chillers Ratings- Chillers are rated with different units depending on equipment type as shown below

Equipment Type	Unit
Air cooled, electrically operated	EER
Water cooled, electrically operated, positive displacement (reciprocating)	kW/ton
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	kW/ton

In order to convert chiller equipment ratings to IPLV the following relationships are provided

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

Baseline Efficiency Values by Chiller Type and Capacity:

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

2009 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE 503.2.3(7)
WATER CHILLING PACKAGES, EFFICIENCY REQUIREMENTS[a]

			BEFORE 1/1/2010		AS OF 1/1/2010[c]				
					PATH A		PATH B		
EQUIPMENT TYPE	SIZE CATEGORY	UNITS	FULL LOAD	IPLV	FULL LOAD	IPLV	FULL LOAD	IPLV	TEST PROCEDURE[b]
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NAd	NAd	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NAd	NAd	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units must comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NRe	≥ 0.600	NRe	NAd	NAd	AHRI 560
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 low-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.

<u>2012 IECC Baseline Efficiency Values by Chiller Type and Capacity</u>

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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010[b]				TEST PROCEDURE[c]
					PATH A		PATH B		
			FULL LOAD	IPLV	FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA	NA	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA	NA	

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.
NA = Not applicable, not to be used for compliance; NR = No requirement.

a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.

b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.

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

<u>2015 IECC Baseline Efficiency Values by Chiller Type and Capacity</u>

TABLE C403.2.3(7)
WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS[a, b, d]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[c]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/ 590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15.800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 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.

MEASURE CODE:

2.5.6 Heat Pump Systems

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

LOADSHAPE

Cooling BUSHeating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

$$\text{Annual kWh Savings}_{cool} = (kBtu/hr_{cool}) * [(1/SEERbase) – (1/SEERee)] * EFLH_{cool}$$

$$\text{Annual kWh Savings}_{heat} = (kBtu/hr_{heat}) * [(1/HSPFbase) – (1/HSPFee)] * EFLH_{heat}$$

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

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

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

$\text{Annual kWh Savings}_{cool} = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * EFLH_{cool}$

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

Where:

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

= Actual installed

SEERbase =Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER from tables below, if applicable code is based onIECC, or custom input as necessary.

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

= Actual installed

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

HSPFbase = Heating Seasonal Performance Factor of the baseline equipment

= HSPF from tables below, if applicable code is based on IECC, or custom input as necessary.

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

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

$EFLH_{heat}$ = Heating mode equivalent full load hours are provided in section 2.7 HVAC End Use.

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER from tables below, based on the applicable IECC. For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[163]

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

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the conversion from SEER to EER as provided above.

= Actual installed

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

= Actual installed

3.412 = Btu per Wh.

COPbase = Coefficient of performance of the baseline equipment

[163] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

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

COPee = Coefficient of performance of the energy efficient equipment.

= Actual installed

Minimum Efficiency Requirements: 2009 IECC

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

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]	TEST PROCEDURE[a]
Air cooled, (Cooling mode)	< 65,000 *Btu/h*[d]	Split system	13.0 SEER	*AHRI210/240*
		Single package	13.0 SEER	
	≥ 65,000 *Btu/h* and < 135,000 *Btu/h*	Split system and single package	10.1 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)	AHRI210/240
		Single package	7.0 HSPF (before Jan 23, 2010) 7.4 HSPF (as of Jan 23,2010)	
Water source (Heating mode)	< 135,000 Btu/h (Cooling capacity)	68°F entering water	4.2 COP	AHRI/ASHRAE 13256-1
Groundwater source (Heating mode)	< 135,000 Btu/h (Cooling capacity)	50°F entering water	3.6 COP	AHRI/ASHRAE 13256-1
Ground source (Heating mode)	< 135,000 Btu/h (Cooling capacity)	32°F entering water	3.1 COP	AHRI/ASHRAE 13256-1

For SI: °C = [(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[b]	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	

(continued)

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

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

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

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

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

Minimum Efficiency Requirements: 2015 IECC

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

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

(continued)

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

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

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

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

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

c. Minimum efficiency as of January 1, 2015.

Summer Coincident Peak Demand Savings

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

Where:

ΔkWH = Annual cooling electricity savings, as calculated above

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

= 0.0009106840

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

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

DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year-round to heat or cool. In warm weather, it efficiently captures heat from inside a space and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into a space, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

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

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

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

DEEMED MEASURE COST

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

EREP: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume $1,047 per ton.[167]

---

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

[165] Standard assumption of one third of effective useful life.

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

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

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

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

ENERGY SAVINGS

TOS:

PTAC ΔkWh[169] = Annual kWh $Savings_{cool}$

PTHP ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool})$ * [(1/EERbase) – (1/EERee)] * $EFLH_{cool}$

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

EREP:

ΔkWh for remaining life of existing unit (1st 5years) = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool})$ * [(1/EERexist) – (1/EERee)] * $EFLH_{cool}$

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

ΔkWh for remaining measure life (next 10 years) = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = $(kBtu/hr_{cool})$ * [(1/EERbase) – (1/EERee)] * $EFLH_{cool}$

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

Where:

$kBtu/hr_{cool}$ = 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

EERexist = Energy Efficiency Ratio of the existing equipment

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

= Actual. If unknown assume 8.1 EER[170]

EERbase = Energy Efficiency Ratio of the baseline equipment.

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

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

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

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

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

= Actual installed

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

= Actual installed

3.412 = Btu per Wh.

COPexist = Coefficient of performance of the existing equipment

[170] Estimated using the IECC building energy code up until year 2003 (p107; https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf) and assuming a 1 ton unit; EER = 10 – (0.16 * 12,000/1,000) = 8.1.
[171] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP[172] for PTHPs.

COPbase = Coefficient of performance of the baseline equipment; see table above for values.

COPee = Coefficient of performance of the energy efficient equipment.

= Actual installed

SUMMER COINCIDENT PEAK DEMAND SAVINGS

TOS:

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

EREP:

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

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

ΔkW for remaining measure life (next 10 years)

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

Where:

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

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

= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[172] 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.

2.5.8 Single-Package and Split System Unitary Air Conditioner

DESCRIPTION

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiencies can save considerable amounts of energy. This measure could apply to the replacement of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively cooled air conditioner that exceeds the energy efficiency requirements specified by the building code applicable to local jurisdiction. This may be a version of the 2009, 2012 or 2015 IECC or ASHRAE 90.1 standard.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

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

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

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

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

Where:

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

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

kBtu/hr = Capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr)

SEERbase = Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER values from tables below, if applicable code is based on IECC, or custom input as necessary.

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

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER values from tables below, if applicable code is based on IECC, or custom input as necessary. (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[175] $EER = (-0.02 * SEER^2) + (1.12 * SEER)$)

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above).

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 2.7 HVAC End Use

[175] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

<u>2009 IECC Minimum Efficiency Requirements</u>

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.

<u>2012 IECC Minimum Efficiency Requirements</u>

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

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

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, evaporatively cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.1 IEER	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER	10.5 EER 14.0 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	

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

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

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

2015 IECC Minimum Efficiency Requirements

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

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

(continued)

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

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWH = Annual electricity savings, as calculated above

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

= 0.0009106840

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

Measure Code:

2.6 Lighting

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

[176]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).

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

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

[179] Electric heat penalty assumptions are based on converting the IFTherm multiplier value in to kWh and then applying relative heating system efficiencies. The gas efficiency was assumed to be 80% AFUE, electric resistance is assumed to be 100%, Heat Pump is assumed to be 2.3COP.

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

2.6.1 Fluorescent Delamping

DESCRIPTION

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

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations.

This measure was developed to be applicable to RF.

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years.[181]

DEEMED MEASURE COST

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

LOADSHAPE

Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[182]

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

Where:

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

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

T8 Lamp Size	Wattage[183]
8-ft T8	38.6
4-ft T8	19.4

$Watts_{EE}$ = 0

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

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

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

Heating Penalty[184]

If electrically heated building:

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

Where:

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0001899635

NATURAL GAS ENERGY SAVINGS[185]

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

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

Where:

[183] Default wattage reduction is based on averaging the savings from moving from a 2 to 1, 3 to 2 and 4 to 3 lamp fixture, as provided in the Standard Performance Contract Procedures Manual: Appendix B: Table of Standard Fixture Wattages (http://www.sce.com/NR/rdonlyres/7A3455F0-A337-439B-9607-10A016D32D4B/0/spc_B_Std_Fixture_Watts.pdf).
An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor that can be expected when delamping fixtures with parallel ballasts. See "Delamping calculation.xlsx" for details.

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

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

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

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.6.2 High Performance and Reduced Wattage T8 Fixtures and Lamps

DESCRIPTION

This measure applies to High Performance T8 (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the "Reduced Wattage T8 lamps" or RWT8 lamps that result in re-lamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

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

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

The measure applies to all commercial HPT8 installations excluding new construction and major renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for the different types of installations. Whenever possible, actual costs and hours of use should be utilized for savings calculations. Default new and baseline assumptions have been provided in the reference tables. Default component costs and lifetimes have been provided for O&M calculations. Please see the Definition Table to determine applicability for each program. HPT8 configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
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[186] and qualifying RWT8 products.[187]

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

Time of Sale (TOS)	Retrofit (RF) and Direct Install (DI)
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. There will be a baseline shift applied to all T12 in 2020, at which point it is assumed no remaining T12 products will remain in operation.

Deemed Lifetime of Efficient Equipment

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

[186] http://library.cee1.org/content/cee-high-performance-t8-specification
[187] http://library.cee1.org/content/reduced-wattage-t8-specification

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

DEEMED MEASURE COST

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

LOADSHAPE

Lighting BUS Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

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

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

[188] 15 years from GDS Measure Life Report, June 2007.
[189] 15 years from GDS Measure Life Report, June 2007.

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

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 2.8. If hours or building type are unknown, use the C&I Average value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate is assumed to be 100%

Heating Penalty

If electrically heated building:

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

Where:

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

Midlife Adjustment

A midlife savings adjustment should be applied to retrofit projects in 2020 to account for the baseline lamp replacement assumption changing from a T12 to 100% Standard T8 by 2020.[191] The savings adjustment is calculated as follows, and is provided in the HP/RW T8 Reference Table below:

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

Where:

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

$Watts_{Base}$ = Input wattage of the T12 baseline

SUMMER COINCIDENT DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

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

= 0.0001899635

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

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

NATURAL GAS SAVINGS

ΔTherms[192] = ((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See Reference Tables for O&M values;

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

REFERENCE TABLES

A-1: Time of Sale: HPT8 and RWT8 New and Baseline Assumptions[193]

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

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

[193] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. See "HPT8 TRM Reference Tables.xlsx" for more information and specific product links. Currently, 25WT8 are not considered under this measure as their lower light trade off and limitations on temperature and dimming have caused most distributers/contractors to use 28W almost exclusively in other markets.

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

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

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

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

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

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

EE Measure Description	$Watts_{EE}$	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				Baseline			
EE Measure Description	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
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				Baseline			
EE Measure Description	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
1-Lamp Relamp/Reballast T12 to HPT8	1	24,000	$8.17	70,000	$52.50	20,000	$5.87	40,000	$35.00
2-Lamp Relamp/Reballast T12 to HPT8	2	24,000	$16.34	70,000	$52.50	20,000	$11.74	40,000	$35.00
3-Lamp Relamp/Reballast T12 to HPT8	3	24,000	$24.51	70,000	$52.50	20,000	$17.61	40,000	$35.00
4-Lamp Relamp/Reballast T12 to HPT8	4	24,000	$32.68	70,000	$52.50	20,000	$23.48	40,000	$35.00
6-Lamp Relamp/Reballast T12 to HPT8	6	24,000	$49.02	70,000	$105.00	20,000	$35.22	40,000	$35.00
1-Lamp Relamp/Reballast T12 to RWT8	1	18,000	$8.17	70,000	$52.50	20,000	$5.87	40,000	$35.00
2-Lamp Relamp/Reballast T12 to RWT8	2	18,000	$16.34	70,000	$52.50	20,000	$11.74	40,000	$35.00
3-Lamp Relamp/Reballast T12 to RWT8	3	18,000	$24.51	70,000	$52.50	20,000	$17.61	40,000	$35.00
4-Lamp Relamp/Reballast T12 to RWT8	4	18,000	$32.68	70,000	$52.50	20,000	$23.48	40,000	$35.00
6-Lamp Relamp/Reballast T12 to RWT8	6	18,000	$49.02	70,000	$105.00	20,000	$35.22	40,000	$35.00
1-Lamp Relamp/Reballast T8 to HPT8	1	24,000	$8.17	70,000	$52.50	20,000	$5.67	70,000	$35.00

EE Measure Description	Lamp Quantity	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
2-Lamp Relamp/Reballast T8 to HPT8	2	24,000	$16.34	70,000	$52.50	20,000	$11.34	70,000	$35.00
3-Lamp Relamp/Reballast T8 to HPT8	3	24,000	$24.51	70,000	$52.50	20,000	$17.01	70,000	$35.00
4-Lamp Relamp/Reballast T8 to HPT8	4	24,000	$32.68	70,000	$52.50	20,000	$22.68	70,000	$35.00
6-Lamp Relamp/Reballast T8 to HPT8	6	24,000	$49.02	70,000	$105.00	20,000	$34.02	70,000	$35.00
1-Lamp Relamp/Reballast T8 to RWT8	1	18,000	$8.17	70,000	$52.50	20,000	$5.67	70,000	$35.00
2-Lamp Relamp/Reballast T8 to RWT8	2	18,000	$16.34	70,000	$52.50	20,000	$11.34	70,000	$35.00
3-Lamp Relamp/Reballast T8 to RWT8	3	18,000	$24.51	70,000	$52.50	20,000	$17.01	70,000	$35.00
4-Lamp Relamp/Reballast T8 to RWT8	4	18,000	$32.68	70,000	$52.50	20,000	$22.68	70,000	$35.00
6-Lamp Relamp/Reballast T8 to RWT8	6	18,000	$49.02	70,000	$105.00	20,000	$34.02	70,000	$35.00

B-3: High Bay HPT8 Component Costs and Lifetime

EE Measure					Baseline				
EE Measure Description	Lamp Life (hrs)	Total Lamp Replaceme nt Cost	Ballas t Life (hrs)	Total Ballast Replaceme nt Cost	Baseline Description	Lamp Life (hrs)	Total Lamp Replaceme nt Cost	Ballas t Life (hrs)	Total Ballast Replaceme nt Cost
4-Lamp HPT8 w/ High-BF Ballast High-Bay	24000	$46.68	70000	$47.50	200 Watt Pulse Start Metal-Halide	12000	$35.67	40000	$110.25
					250 Watt Metal Halide	10000	$27.67	40000	$114.50
6-Lamp HPT8 w/ High-BF Ballast High-Bay	24000	$70.02	70000	$47.50	320 Watt Pulse Start Metal-Halide	20000	$78.67	40000	$131.85
					400 Watt Metal-Halide	20000	$23.67	40000	$136.50
8-Lamp HPT8 w/ High-BF Ballast High-Bay	24000	$93.36	70000	$47.50	Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH	20000	$23.67	40000	$131.85

MEASURE CODE:

2.6.3 LED Bulbs and Fixtures

DESCRIPTION

The installation of Light-Emitting Diode (LED) lighting systems have comparable luminosity to incandescent bulbs and equivalent fluorescent lamps at significantly less wattage, lower heat, and with significantly longer lifetimes.

This measure provides savings assumptions for a variety of efficient lighting fixtures including internal and external LED fixtures, recess (troffer), canopy, and pole fixtures as well as refrigerator and display case lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, all LED fixtures are assumed to be ENERGY STAR® labeled or on the Design Light Consortium qualifying fixture list.[194]

DEFINITION OF BASELINE EQUIPMENT

For TOS and RF installations, the baselines efficiency case is project specific and is determined using actual fixture types and counts from the existing space. The existing fluorescent fixture end connectors and ballasts must be completely removed to qualify.

Where the installation technology is not known, the assumed baselines condition for an outdoor pole/arm, wall-mounted, garage/canopy fixture and high-bay luminaire with a high intensity discharge light source is a metal halide fixture. Deemed fixture wattages are provided in reference tables at the end of this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Lifetime is the life of the product at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "LED component Costs and Lifetime." The analysis period is the same as the lifetime, capped at 15 years.[195]

DEEMED MEASURE COST

Actual incremental costs should be used if available. For default values, refer to the reference tables below.

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

---

[194] Design Lights Consortium Qualified Products List http://www.designlights.org/qpl.
[195] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed. If unknown, use default provided in "LED New and Baseline Assumptions."

Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.8. by building type. If hours or building type are unknown, use the C&I Average value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate is assumed to be 98.7% for Time of Sale and 100% for Retrofit.[196]

Heating Penalty:

If electrically heated building:

$$\Delta kWhheatpenalty = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts;[197] this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

Mid Life Adjustment:

A midlife savings adjustment should be applied to any retrofit measure using a T12 baseline. The adjustment should occur in 2020 to account for the baseline lamp replacement assumption changing from a T12 to 100% Standard T8 by 2020.[198] The savings adjustment is calculated as follows:

$$\% \, Adjustment = \left(\frac{Watts_{\text{T8base}} - Watts_{\text{EE}}}{Watts_{\text{T12 Base}} - Watts_{\text{EE}}}\right)$$

Where:

WattsT8 Base = Input wattage of the existing system based on 100% T8 fixture.

WattsT12 Base = Input wattage of the existing T12 system.

[196] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015 and consistent with other program ISR in neighboring states (Illinois and Iowa).

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0001899635 for indoor lighting

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

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

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

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts.[199] This factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

REFERENCE TABLES[200]

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

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

[200] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE "Energy Savings Potential of Solid-State Lighting in General Illumination Applications," Table A.1. See "LED Lighting Systems TRM Reference Tables.xlsx" for more information and specific product links.

LED Category	EE Measure		Baseline		Incremental Cost
	Description	$Watts_{EE}$	Description	$Watts_{BASE}$	
	LED Undercabinet Shelf-Mounted Task Light Fixtures	7.1 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	$11/ft
	LED Refrigerated Case Light, Horizontal or Vertical	7.6 / ft	5'T8	15.2 / ft	$11/ft
	LED Freezer Case Light, Horizontal or Vertical	7.7 / ft	6'T12HO	18.7 / ft	$11/ft
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	18.7	Lamp Only 32w T8	32.0	$24
	LED 2' Linear Replacement Lamp	9.7	Lamp Only 17w T8	17.0	$13
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	34.1	2-Lamp 32w T8 (BF < 0.89)	57.0	$48
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	42.8	3-Lamp 32w T8 (BF < 0.88)	84.5	$91
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	37.9	2-Lamp 32w T8 (BF < 0.89)	57.0	$62
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	54.3	3-Lamp 32w T8 (BF < 0.88)	84.5	$99
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	72.7	4-Lamp 32w T8 (BF < 0.88)	112.6	$150
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	18.1	1-Lamp 32w T8 (BF <0.91)	29.1	$36
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	39.6	2-Lamp 32w T8 (BF < 0.89)	57.0	$76
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	53.1	3-Lamp 32w T8 (BF < 0.88)	84.5	$130
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	19.7	1-Lamp 32w T8 (BF <0.91)	29.1	$54
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	37.8	2-Lamp 32w T8 (BF < 0.89)	57.0	$104
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	55.9	3-Lamp 32w T8 (BF < 0.88)	84.5	$158
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	62.6	T5HO 2L-F54T5HO - 4'	120.0	$215
	LED Surface & Suspended Linear Fixture, > 7500 lumens	95.4	T5HO 3L-F54T5HO - 4'	180.0	$374
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	90.3	3-Lamp T8HO Low-Bay	157.0	$191
	LED High-Bay Fixtures, 10,001-15,000 lumens	127.5	4-Lamp T8HO High-Bay	196.0	$331
	LED High-Bay Fixtures, 15,001-20,000 lumens	191.0	6-Lamp T8HO High-Bay	294.0	$482
	LED High-Bay Fixtures, > 20,000 lumens	249.7	8-Lamp T8HO High-Bay	392.0	$818
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	17.0	25% 73 Watt EISA Inc, 75% 1L T8	42.0	$33

LED Category	EE Measure		Baseline		Incremental Cost
	Description	$Watts_{EE}$	Description	$Watts_{BASE}$	
	LED Ag Interior Fixtures, 2,001-4,000 lumens	27.8	25% 146 Watt EISA Inc, 75% 2L T8	81.0	$54
	LED Ag Interior Fixtures, 4,001-6,000 lumens	51.2	25% 217 Watt EISA Inc, 75% 3L T8	121.0	$125
	LED Ag Interior Fixtures, 6,001-8,000 lumens	71.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	$190
	LED Ag Interior Fixtures, 8,001-12,000 lumens	103.5	200W Pulse Start Metal Halide	227.3	$298
	LED Ag Interior Fixtures, 12,001-16,000 lumens	143.8	320W Pulse Start Metal Halide	363.6	$450
	LED Ag Interior Fixtures, 16,001-20,000 lumens	183.3	350W Pulse Start Metal Halide	397.7	$595
	LED Ag Interior Fixtures, > 20,000 lumens	305.0	(2) 320W Pulse Start Metal Halide	727.3	$998
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	42.6	100W Metal Halide	113.6	$190
	LED Exterior Fixtures, 5,001-10,000 lumens	68.2	175W Pulse Start Metal Halide	198.9	$287
	LED Exterior Fixtures, 10,001-15,000 lumens	122.5	250W Pulse Start Metal Halide	284.1	$391
	LED Exterior Fixtures, > 15,000 lumens	215.0	400W Pulse Start Metal Halide	454.5	$793

LED Component Costs and Lifetimes:

		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	35,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Interior Directional	LED Track Lighting	35,000	$39.00	70,000	$47.50	2,500	$12.71	40,000	$11.00
	LED Wall-Wash Fixtures	35,000	$39.00	70,000	$47.50	2,500	$9.17	40,000	$27.00
LED Display Case	LED Display Case Light Fixture	35,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	35,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	35,000	$8.63/ft	70,000	$9.50/ft	15,000	$1.13	40,000	$8.00
	LED Freezer Case Light, Horizontal or Vertical	35,000	$7.88/ft	70,000	$7.92/ft	12,000	$0.94	40,000	$6.67
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	35,000	$8.57	70,000	$13.67	20,000	$6.17	70,000	$11.96
	LED 2' Linear Replacement Lamp	35,000	$5.76	70,000	$13.67	20,000	$6.17	70,000	$11.96

		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 Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	35,000	$46.68	70,000	$40.00	20,000	$11.34	70,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	35,000	$56.31	70,000	$40.00	20,000	$17.01	70,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	35,000	$49.58	70,000	$40.00	20,000	$11.34	70,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	35,000	$57.76	70,000	$40.00	20,000	$17.01	70,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	35,000	$68.89	70,000	$40.00	20,000	$22.68	70,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	35,000	$43.43	70,000	$40.00	20,000	$5.67	70,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	35,000	$52.31	70,000	$40.00	20,000	$11.34	70,000	$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	35,000	$63.86	70,000	$40.00	20,000	$17.01	70,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	35,000	$45.01	70,000	$40.00	20,000	$5.67	70,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	35,000	$58.73	70,000	$40.00	20,000	$11.34	70,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	35,000	$73.50	70,000	$40.00	20,000	$17.01	70,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	35,000	$88.69	70,000	$40.00	30,000	$26.33	70,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	35,000	$123.91	70,000	$40.00	30,000	$39.50	70,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	35,000	$90.03	70,000	$62.50	18,000	$64.50	70,000	$92.50

		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 High-Bay Fixtures, 10,001-15,000 lumens	35,000	$122.59	70,000	$62.50	18,000	$86.00	70,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	35,000	$157.22	70,000	$62.50	18,000	$129.00	70,000	$117.50
	LED High-Bay Fixtures, > 20,000 lumens	35,000	$228.52	70,000	$62.50	18,000	$172.00	70,000	$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	35,000	$37.00	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	35,000	$44.96	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	35,000	$63.02	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	35,000	$79.78	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	35,000	$119.91	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	35,000	$151.89	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	35,000	$184.62	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	35,000	$285.75	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	35,000	$86.92	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	35,000	$111.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	35,000	$138.32	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Exterior Fixtures, > 15,000 lumens	35,000	$223.67	70,000	$62.50	15,000	$73.00	40,000	$132.50

MEASURE CODE:

2.6.4 LED Screw Based Omnidirectional Bulb

Description

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to baseline EISA incandescent, halogen, or compact fluorescent lamps.

This specific characterization provides savings assumptions for LED lamps that replace standard screw-in connections (e.g., A-Type lamp) such as interior/exterior omnidirectional bulb options.

This characterization assumes that the LED is installed in a commercial location. This is, therefore, appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the residential versus nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new LED screw-based lamps must be ENERGY STAR® qualified based upon the ENERGY STAR® specification v2.0 which will become effective on 1/2/2017 (https://www.energystar.gov/sites/default/files/Luminaires%20V2%200%20Final.pdf). Qualification could also be based or on the Design Light Consortium's qualified product list.[201]

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent. From 2020 the baseline will begin transitioning to a CFL[202] based upon what is available in the market and therefore a midlife adjustment is provided.

Deemed Lifetime of Efficient Equipment

The lifetime of the product is the lamp life in hours divided by operating hours per year. Depending on operating conditions (currents and temperatures) and other factors (settings and building use), LED rated life is assumed to be 50,000 hours. [203]

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume $3.26 (baseline cost of $1.80 and efficient cost of $5.06).[204]

[201] https://www.designlights.org/QPL
[202] A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL.
[203] LED Fixture Component Costs & Lifetime Table found on page 372 of the IL TRM v6.0 Volume 2.
[204] Incandescent/halogen and LED cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p.19.

LOADSHAPE

Lighting BUSExt Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed

$Watts_{EE}$ = Actual wattage of LED purchased/installed. If unknown, use default provided below.[205]

Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$ LED	Delta Watts
250	309	25	4.0	21
310	749	29	6.7	22.3
750	1,049	43	10.1	32.9
1,050	1,489	53	12.8	40.2
1,490	2,600	72	17.4	54.6
2,601	3,000	150	43.1	106.9
3,001	3,999	200	53.8	146.2
4,000	6,000	300	76.9	223.1

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

ISR = In-Service Rate or the percentage of units rebated that get installed

[205] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, $Watts_{EE}$ is based upon the ENERGY STAR® minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at "cerified-light-bulbs-2015-06-18.xlsx." These assumptions should be reviewed regularly to ensure they represent the available product.

= 98.7%[206]

Mid-Life Baseline Adjustment

During the lifetime of a standard omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes to a CFL equivalent in 2020 due to the EISA backstop provision (except for <310 and 2600+ lumen lamps), the annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for 43W equivalent LED lamp installed in 2016, the full savings (as calculated above in the Algorithm) should be claimed for the first four years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) should be claimed for the remainder of the measure life.[207]

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	Watts EE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020[208]	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
250	309	280	4.0	25	21	25	21	100.0%
310	749	530	6.7	29	22.3	9.4	2.7	12.1%
750	1049	900	10.1	43	32.9	13.4	3.3	10.0%
1050	1489	1270	12.8	53	40.2	18.9	6.1	15.2%
1490	2600	2045	17.4	72	54.6	24.8	7.4	13.6%
2,550	3,000	2,775	43.1	150	106.9	150	106.9	100.0%
3,001	3,999	3,500	53.8	200	146.2	200	146.2	100.0%
4,000	6,000	5,000	76.9	300	223.1	300	223.1	100.0%

Heating Penalty:

If electrically heated building:[209]

$$\Delta kWhheatpenalty = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

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

[206] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).
[207] These adjustments should be applied to kW and gas impacts as well.
[208] Calculated with EISA requirement of 45lumens/watt.
[209] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0001899635 for indoor lighting

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown): [210]

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

Where:

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the falling EISA-Qualified backdrop provision, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:[211]

Incandescent / Halogen	CFL	LED A-Lamp
$1.80	$2.20	$5.06

The present value of replacement lamps and annual levelized replacement costs using utilities' average real discount rate of 6.91% are presented below:

Location	PV of replacement costs for period			Levelized annual replacement cost savings		
	2016 - 2017	2017 - 2018	2018 - 2019	2016 - 2017	2017 - 2018	2018 - 2019
C&I Average	$18.66	$14.70	$10.46	$2.04	$1.60	$1.14

[210] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.
[211] All cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p.19.

Note: incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows. If unknown building type, assume C&I Average:

Building Type	Replacement Period (years)[212]	Replacement Cost
Large Office	0.32	$1.80[213]
Medium Office	0.32	
Small Office	0.35	
Warehouse	0.35	
Stand-alone Retail	0.29	
Strip Mall	0.27	
Primary School	0.29	
Secondary School	0.29	
Supermarket	0.27	
Quick Service Restaurant	0.16	
Full Service Restaurant	0.16	
Hospital	0.26	
Outpatient Health Care	0.26	
Small Hotel - Building	0.27	
Large Hotel - Building	0.27	
Midrise Apartment - Building	0.35	
C&I Average	0.30	

MEASURE CODE:

[212] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA-qualified halogen/incandescent is 1000 hours (manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC)).

[213] Incandescent/halogen cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), 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.[214]

The main markets served by T5 HO fixtures and lamps include retrofit in the commercial and nonresidential sector, specifically industrial, warehouse, and grocery facilities with higher ceiling heights that require maximum light output.

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

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

Definition of Efficient Equipment

The definition of the efficient equipment is T5 HO high-bay (>15ft mounting height) fixtures with 3, 4, 6, or 8-lamp configurations.

Definition of Baseline Equipment

The definition of baseline equipment varies based on number of lamps in a fixture and is defined in the baseline reference table at the end of this characterization. The default baseline is assumed to be a Pulse-Start Metal Halide fixture.

Deemed Lifetime of Efficient Equipment

The deemed lifetime of the efficient equipment fixture is 15 years.[215]

Deemed Measure Cost

The deemed measure cost is found in Reference Table at the end of this characterization. For retrofit applications, actual costs should be used if available, or, if not available, $10/lamp and $37.50/ballast can be used to account for installation labor costs.

Loadshape

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Custom input. If unknown, input wattage of the baseline system is dependant on new fixture configuration and found in the 'T5HO Efficient and Baseline Wattage and Cost Assumptions' reference table below.

$Watts_{EE}$ = Custom Input. If unknown, input wattage depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the 'T5HO Efficient and Baseline Wattage and Cost Assumptions' reference table below.

Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.8 as annual operating hours, by building type. If hours or building type are unknown, use the C&I Average value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

= 98%.[216]

<u>Heating Penalty:</u>

If electrically heated building:[217]

$$\Delta kWhheatpenalty = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (-IFkWh)$$

Where:

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

SUMMER COINCIDENT DEMAND SAVINGS

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

Where:

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

= 0.0001899635 for indoor lighting

[216] Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD).

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

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

NATURAL GAS ENERGY SAVINGS

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

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

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.8.[218] If unknown, use the C&I Average value.

DEEMED O&M COST ADJUSTMENT CALCULATION

See reference tables for different cost assumptions for lamps and ballasts. When available, actual costs and hours of use should be used.

REFERENCE TABLES

T5HO Efficient and Baseline Wattage and Cost Assumptions[219]

EE Measure Description	WattsEE	Baseline Description	WattsBASE	Incremental Cost
3-Lamp T5 High-Bay	176	200 Watt Pulse Start Metal-Halide	227	$100.00
4-Lamp T5 High-Bay	235	320 Watt Pulse Start Metal-Halide	364	$100.00
6-Lamp T5 High-Bay	352	400 Watt Pulse Start Metal-Halide	455	$100.00
8-Lamp T5 High-Bay	470	750 Watt Pulse Start Metal-Halide	825	$100.00

T5 HO Component Costs and Lifetimes[220]

	EE Measure				Baseline			
EE Measure Description	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
3-Lamp T5 High-Bay	30,000	$63.00	70,000	$87.50	15,000	$63.00	40,000	$107.50
4-Lamp T5 High-Bay	30,000	$84.00	70,000	$87.50	20,000	$68.00	40,000	$117.50
6-Lamp T5 High-Bay	30,000	$126.00	70,000	$112.50	20,000	$73.00	40,000	$127.50
8-Lamp T5 High-Bay	30,000	$168.00	70,000	$137.50	20,000	$78.00	40,000	$137.50

[218] Negative value because this is an increase in heating consumption due to the efficient lighting.
[219] Reference Table adapted from Efficiency Vermont TRM, T5 Measure Savings Algorithms and Cost Assumptions, October, 2014. Refer to "T5HO-adjusted deemed costs.baselines.xlsx" for more information.
[220] Costs include labor cost – see "T5HO-adjusted deemed costs.baselines.xlsx" for more information.

MEASURE CODE:

2.6.6 LED Exit Sign

This measure characterizes the savings associated with installing a new LED exit sign (or retrofit kit) in place of a CFL or incandescent exit sign in a commercial building. LED exit signs use less power (≤ 5 watts), have a significantly longer lifetime, and have less maintenance costs when compared to incandescent or CFL exit signs.[221]

This measure applies to the following program types: RF and DI.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is an LED exit sign with an input power demand of 5 watts or less.[222]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 16 years.[223]

DEEMED MEASURE COST

Actual program delivery costs should be used if available. If not, use the full cost of $39[224] for a new LED exit sign and $25 for a retrofit kit, plus $6.25 in labor,[225] for a total measure cost of $45.25 and $31.25, respectively.

LOADSHAPE

Miscellaneous BUS

[221] ENERGY STAR® "*Save Energy, Money and Prevent Pollution with LED Exit Signs*."
[222] ENERGY STAR ® "*Program Requirements for Exit Signs Version 3.0.*" While the EPA suspended the ENERGY STAR® Exit Sign specification effective May 1, 2008, Federal requirements specify minimum efficiency standards for electrically-powered, single-faced exit signs with integral lighting sources that are equivalent to ENERGY STAR® levels for input power demand of 5 watts or less per face.
[223] California Database for Energy Efficiency Resources (DEER) 2014 Estimated Useful Life (EUL) Table Update.
[224] Cost of new LED exit sign from ENERGY STAR® Exit Signs Calculator.xlsx.
[225] Assumption based on 15 minutes (including portion of travel time) and $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [226]

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

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

Baseline Type	$Watts_{Base}$
Incandescent (dual sided)	50W[227]
Incandescent (single sided)	25W
CFL (dual sided)	14W[228]
CFL (single sided)	7W

$Watts_{EE}$ = Actual wattage if known; if unknown assume 2W for singled sided and 4W.[229]for dual sided

Hours = Annual operating hours

= 8,766

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{230} = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * Hours * (-IFkWh)$$

Where:

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

Other factors as defined above.

---

[226] There is no ISR calculation. Exit signs and emergency lighting are required by federal regulations to be installed and functional in all public buildings as outlined by the U.S. Occupational Safety and Health Standards (USOSHA 1993).

[227] Average incandescent single sided (5W, 10W, 15W, 20W, 25W, 34W, 40W, 50W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[228] Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[229] Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[229] Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, including cooling savings, as calculated above.

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

= 0.0001379439

Other factors as defined above.

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated buiding (or if heating is unknown):[231]

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

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each building type.

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M cost adjustment savings should be calculated using the following component costs and lifetimes.

Component	Baseline Measure	
	Cost	Life (yrs)
CFL lamp	$8.91[232]	0.63 years[233]
Incandescent lamp	$7.39[234]	0.14 years[235]

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

[232] Includes cost of labor and new replacement bulb. Labor cost of $6.25 based on 15 minutes (including portion of travel time) and $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor. Cost of new 7W CFL bulb is $2.66, from Itron "2010-2012 WO017 Ex Ante Measure Cost Study Final Report." Prepared for California Public Utilities Commission, May 27, 2014.

[233] ENERGY STAR® "Save Energy, Money and Prevent Pollution with LED Exit Signs" states that CFL bulbs for exit signs typically have an average rated life of 5,000-6,000 hours. Given 24/7 run time, assume a CFL in an exit sign will require replacement every 0.63 years (5,500 hours/8,766 hours).

[234] Includes cost of labor and new replacement bulb. Labor cost of $6.25 based on 15 minutes (including portion of travel time) and $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor. Cost of new 29W incandescent A-lamp is $1.14, from Itron "2010-2012 WO017 Ex Ante Measure Cost Study Final Report." Prepared for California Public Utilities Commission, May 27, 2014.

[235] ENERGY STAR® "*Save Energy, Money and Prevent Pollution with LED Exit Signs*" states that a typical incandescent exit sign bulb will have a rated life of 500-2,000 hours. Given 24/7 run time, assume an incandescent in an exit sign will require replacement every 0.14 years (1,250 hours/8,766 hours).

MEASURE CODE:

2.6.7 LED Specialty Lamp

Description

This characterization provides savings assumptions for LED directional, decorative, and globe lamps. This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the EISA requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR® labeled based upon the ENERGY STAR® specification v2.0 which will become effective on1/2/2017.https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf). Qualification could also be based on the Design Light Consortium's qualified product list.[236]

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent. From 2020 the baseline will begin transitioning to a CFL based upon what is available in the market.

Deemed Lifetime of Efficient Equipment

The lifetime of the product is the lamp life in hours divided by operating hours per year. Depending on operating conditions (currents and temperatures) and other factors (settings and building use), LED rated life is assumed to be 50,000 hours.[237]

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:[238]

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

[237] LED Fixture Component Costs & Lifetime Table found on page 372 of the IL TRM v6.0 Volume 2.

[238] Incandescent based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report," Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year's worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; "Energy Savings Potential of Solid-State Lighting in General Illumination Applications," Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

Bulb Type	LED Wattage	LED	Incandescent	Incremental Cost
Directional	< 20W	$14.52	$6.31	$8.21
	≥20W	$45.85		$39.54
Decorative	<15W	$8.09	$3.92	$4.17
	15 to <25W	$15.86		$11.94
	≥25W	$15.86		$11.94

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Based on bulb type and lumens of LED bulb installed. See table below.

$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:[239]

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$	Delta Watts
Directional	250	349	25	5.6	19.4
	350	399	35	6.3	28.7
	400	599	40	7.5	32.5
	600	749	60	9.7	50.3
	750	999	75	12.7	62.3
	1000	1250	100	16.2	83.8
Decorative	70	89	10	1.8	8.2
	90	149	15	2.7	12.3
	150	299	25	3.2	21.8
	300	499	40	4.7	35.3

[239] $Watts_{EE}$ 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.

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$	Delta Watts
	500	699	60	6.9	53.1
Globe	250	349	25	4.1	20.9
	350	499	40	5.9	34.1
	500	574	60	7.6	52.4
	575	649	75	13.6	61.4
	650	1099	100	17.5	82.5
	1100	1300	150	13.0	137.0

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Lighting Reference Table in Section 2.8. If unknown, use the C&I Average value.

ISR = In Service Rate or the percentage of units rebated that get installed

= 98.7%[240]

Heating Penalty:

If electrically heated building:[241]

$$\Delta kWhheatpenalty = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0001899635 for indoor lighting

[240] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

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

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

for measure is provided in the Lighting Reference Table in Section 2.8 and based upon building type. If unknown, use the C&I Average value.

Other factors as defined above.

NATURAL GAS SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):[242]

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

Where:

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

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M cost should be applied as follows:

Installation Location	Replacement Period (years)[243]	Replacement Cost[244]
Large Office	0.32	Decorative: $6.31 Directional: $3.92
Medium Office	0.32	
Small Office	0.35	
Warehouse	0.35	
Stand-alone Retail	0.29	
Strip Mall	0.27	
Primary School	0.29	
Secondary School	0.29	
Supermarket	0.27	
Quick Service Restaurant	0.16	
Full Service Restaurant	0.16	
Hospital	0.26	
Outpatient Health Care	0.26	
Small Hotel - Building	0.27	
Large Hotel - Building	0.27	
Midrise Apartment - Building	0.35	
C&I Average	0.30	

[242] Results in a negative value because this is an increase in heating consumption due to the efficient lighting.
[243] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescent is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).
[244] Incandescent costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report," Itron, February 28, 2014.

MEASURE CODE:

2.6.8 Lighting Power Density

DESCRIPTION

This measure entails the installation of efficient lighting systems in either new construction or during substantial renovation of commercial buildings that triggers compliance with code. This methodology applies to situations where code specifies maximum lighting power density allowances (W/ft^2). Either the Building Area Method or Space by Space (not recognized by IECC 2009) method as defined in IECC 2009, 2012 or 2015, can be used for calculating the Interior Lighting Power Density.[245] The measure consists of a design that is more efficient (has a lower lighting power density in watts/square foot) than code requires.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the lighting system must be more efficient than the baseline energy code lighting power density in watts/square foot for either the interior space or exterior space.

DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a lighting power density that meets the building code recognized by the local jurisdiction. For illustrative purposes in this characterization, IECC 2009, 2012 and 2015, are highlighted to demonstrate the methodology.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[246]

DEEMED MEASURE COST

The actual incremental cost over a baseline system should be collected from the customer if possible, or quantified using an alternative suitable source.

LOADSHAPE

Lighting BUS

Ext Lighting BUS

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

$$\Delta kWh = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * WHF_e$$

Where:

[245] Refer to the referenced code documents for specifics on calculating lighting power density using either the whole building method (IECC) or the Space by Space method (ASHRAE 90.1).

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

WSF_{base} = Baseline lighting watts per square foot or linear foot as determined by building or space type. IECC example whole building analysis values are presented in the Reference Tables below.[247]

WSF_{effic} = The actual installed lighting watts per square foot or linear foot.

SF = Provided by customer based on square footage of the building area applicable to the lighting design for new building.

Hours = Annual site-specific hours of operation of the lighting equipment collected from the customer or selected from the Reference Table in Section 2.8 if unavailable.

WHF_e = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 2.8 for each building type. If building is not cooled, the value is 1.0.

<u>Heating Penalty</u>

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{248} = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent 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:

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

= 0.0001899635 for indoor lighting

= 0.0000056160 for exterior lighting

= 0.0001379439 for 24/7 lighting

Other factors as defined above

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each building type.

[247] See IECC 2009, 2012 and 2015 - Reference Code documentation for additional information.

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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 [249]	IECC 2009 Lighting Power Density (w/ft^2)	IECC 2012 Lighting Power Density (w/ft^2)	IECC 2015 Lighting Power Density (w/ft^2)
Automotive Facility	0.9	0.9	0.80
Convention Center	1.2	1.2	1.01
Court House	1.2	1.2	1.01
Dining: Bar Lounge/Leisure	1.3	1.3	1.01
Dining: Cafeteria/Fast Food	1.4	1.4	0.9
Dining: Family	1.6	1.6	0.95
Dormitory	1.0	1.0	0.57
Exercise Center	1.0	1.0	0.84
Fire station	1.0	0.8	0.67
Gymnasium	1.1	1.1	0.94
Healthcare – clinic	1.0	1.0	0.90
Hospital	1.2	1.2	1.05
Hotel	1.0	1.0	0.87
Library	1.3	1.3	1.19
Manufacturing Facility	1.3	1.3	1.17
Motel	1.0	1.0	0.87
Motion Picture Theater	1.2	1.2	0.76
Multifamily	0.7	0.7	0.51
Museum	1.1	1.1	1.02
Office	1.0	0.9	0.82
Parking Garage	0.3	0.3	0.21
Penitentiary	1.0	1.0	0.81
Performing Arts Theater	1.6	1.6	1.39
Police Station	1.0	1.0	0.87
Post Office	1.1	1.1	0.87
Religious Building	1.3	1.3	1.0
Retail[250]	1.5	1.4	1.26
School/University	1.2	1.2	0.87
Sports Arena	1.1	1.1	0.91
Town Hall	1.1	1.1	0.89
Transportation	1.0	1.0	0.70
Warehouse	0.8	0.6	0.66
Workshop	1.4	1.4	1.19

[249] In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.

[250] Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the small of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.

Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

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

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

(continued)

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

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

(continued)

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

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

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

Allowable Design Levels from IECC 2015:

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

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

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

MEASURE CODE:

2.6.9 Metal Halide Fixtures and Lamps

DESCRIPTION

This measure involves the installation of high efficiency pulse start metal halide fixtures and lamps in place of a standard metal halide. Pulse start metal halide luminaires produce more lumens per watt and have an improved lumen maintenance compared to standard probe start technology. Similarly, the high efficiency pulse start metal halide ballast lasts longer than a standard system due to their cooler operating temperatures.[251]

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an EISA-compliant pulse start metal halide lamp and ballasts for luminaires. Under 2009 federal rulings metal halide ballasts in low-watt options (150W-500W fixtures) must be pulse start and have a minimum ballast efficiency of 88%.[252] Amendments made in 2014 require more stringent energy conservations standards with compliance required by February 10, 2017.[253]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing bulb and fixture. If unknown assume, High Intensity Discharge (HID) Metal Halide lighting with probe start fixture and a standard ≤ 400 Watt lamp.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[254]

DEEMED MEASURE COST

As a retrofit measure, actual costs should be used. If unknown, cost is assumed to be $267.[255]

LOADSHAPE

Lighting BUS

Ext Lighting BUS

---

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

[252] Under EISA rulings, metal halide ballasts in low-watt options must be pulse start and have a minimum ballast efficiency of 88%. This ruling virtually eliminates the manufacture of probe start (ceramic) fixtures but some exemptions exist including significantly the 150w wet location fixtures (as rated per NEC 2002, section 410.4 (A)). These will be replaced by 150W. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9

[253] The revised 2014 efficiency standards for metal halides require that luminaires produced on or after February 10, 2017, must **not** contain a probe-start metal halide ballast. Exceptions to this ruling include, metal halide luminaires with a regulated-lag ballast that utilize an electronic ballasts which operates at 480V and those which utilize a high-frequency (≥1000Hz) electronic ballast. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9

[254] GDS Associates, *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*, June 2007, http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

[255] Assuming cost of lamp and fixture combined per Itron, Inc. *2010-2012 WO017 Ex Ante Measure Cost Study – Final Report (Deemed Measures)*, May 27, 2014.

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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 2.8. If hours or building type are unknown, use the C&I Average value.

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 2.8 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate is assumed to be 100%

Heating Penalty:

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{256} = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (-IFkWh)$$

Where:

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

SUMMER COINCIDENT DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

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

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

= 0.0001379439 for 24/7 lighting

NATURAL GAS SAVINGS

$$\Delta Therms^{257} = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (-IFTherms)$$

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

No O&M adjustments apply to this measure.[258]

REFERENCE TABLES[259]

Lamp $Watt_{EE}$	Efficient Fixture Ballast	Efficient System Lumen	System $Watt_{EE}$	Lamp $Watt_{Base}$	Baselines Ballast[260]	System $Watts_{Base}$	Baseline System Lumen
Pulse Start MH 150W	Pulse Start-CWA Ballast	10500	185	Probe Start MH 175W	standard C&C	210	9100
Pulse Start MH 175W	Pulse Start-CWA Ballast	11200	208	Probe Start MH 175W	standard C&C	210	9100
Pulse Start MH 200W	Pulse Start-CWA Ballast	16800	232	Probe Start MH250W	standard C&C	295	13500
Pulse Start MH 250W	Pulse Start-CWA Ballast	16625	290	Probe Start MH250W	standard C&C	295	13500
Pulse Start MH 320W	Pulse Start-CWA Ballast	21000	368	Probe Start MH400W	standard C&C	458	24000
Pulse Start MH350W	Pulse Start-CWA Ballast	25200	400	Probe Start MH400W	standard C&C	458	24000
Pulse Start MH 400W	Pulse Start-CWA Ballast	29820	452	Probe Start MH400W	standard C&C	458	24000

MEASURE CODE:

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

258 Given that probe start MH technology is becoming a technology of the past, it is assumed that upon failure they would have been replaced with pulse start technology.

259 Per lamp/ballast.

260 Standard Magnetic Core and Coil ballast systems are common for Metal Halide lamp wattages 175-400. See Panasonic "Metal Halide: Probe Start vs. Pulse Start."

2.6.10 Occupancy Lighting Sensor Controls

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels by turning lights on or off in response to the presence (or absence) of people in a defined area. Associated energy savings depends on the building type, location area covered, type of lighting and activity, and occupancy pattern.[261]

This measure relates to the installation of interior occupancy sensors on an existing lighting system. Lighting control types covered by this measure include switch-mounted, remote-mounted, and fixture-mounted. It does not cover automatic photo sensors, time clocks, and energy management systems. All sensors must be hard wired and control interior lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

It is assumed that this measure characterization applies to only those automatic controlled lighting occupancy sensors that control a minimum average wattage greater than 45W per control.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with no occupancy controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years.[262]

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

Lighting control type	Cost[263]
Full cost of switch (wall) mounted occupancy sensor (interior)	$54
Full cost of fixture (bi-level) mounted occupancy sensor	$67
Full cost of remote (ceiling) mounted occupancy sensor	$105

LOADSHAPE

Lighting BUS

Miscellaneous BUS

[261] United States Department of the Interior. Greening the Department of Interior. http://www.doi.gov/archive/greening/energy/occupy.html
[262] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[263] Based on averaging typical prices quoted by online vendors. See reference table "Occupancy Sensor Reference Costs 2015.xls" for more information.

Ext Lighting BUS **Algorithm**

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{Controlled} * Hours * ESF * WHFe$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer, or use the default values presented below used;

Lighting Control Type Interior	Default kW controlled[264]
Switch (wall) mounted occupancy sensor	0.304 (per control)
Fixture-mounted occupancy sensor	0.180 (per fixture)
Remote (ceiling) mounted occupancy sensor	0.517 (per control)

Hours = The total annual operating hours of lighting for each type of building before occupancy sensors. This number should be collected from the customer. If no data is available, the deemed average number of operating hours by building type should be used as provided by Lighting Reference Table in Section 2.8. If buidling type is unknown, use the C&I Average value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis or using the default values below:

Lighting Control Type	Energy Savings Factor[265]
Switch (wall) mounted occupancy sensor	24%
Fixture-mounted sensor	24%
Remote (ceiling) mounted occupancy sensor	24%

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 2.8.

Heating Penalty:

If electrically heated building:[266]

[264] Based on review of custom Efficiency Vermont program data of installed occupancy sensors from 2009-2014. See reference table "Updated-Occupancy-Sensor-ReferenceCosts-7-30-15.xls."
[265] Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Page & Associates Inc. 2011.
http://eetd.lbl.gov/publications/meta-analysis-energy-savings-lighting-controls-commercial-buildings.
LBNL's meta study of energy savings from lighting controls in commercial buildings bases its savings analysis on over 240 actual field installations. The report found that savings are over-represented and do not filter for external factors such as building orientation, location, use, weather, blinds, commissioning, changes in behavior after controls are set, etc. As such, their value of 24% represented the best conservative estimate of occupancy controls energy savings achievable in the field today.
[266] Negative value because this is an increase in heating consumption due to the efficient lighting.

$$\Delta kWhheatpenalty = kW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Lighting Reference Table 2.8.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = As calculated above

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

= 0.0001899635 for indoor lighting

= 0.0000056160 for exterior lighting

Natural Gas Energy Savings

If gas heated building (or unknown):

$$\Delta Therms = kW_{Controlled} * Hours * ESF * -IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the Lighting Reference Table in Section 2.8 by building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.6.11 Street Lighting

DESCRIPTION

This measure characterizes the savings associated with LED street lighting conversions where a LED fixture replaces a high-intensity discharge (HID) outdoor lighting system, including metal halide, high pressure sodium, and mercury vapor. LED street lights provide considerable benefits compared to HID lights, including:

- Improved nighttime visibility and safety through better color rendering, more uniform light distribution and elimination of dark areas between poles.
- Reduced direct and reflected uplight which are the primary causes of urban sky glow.
- 40-80% energy savings (dependent on incumbent lighting source).
- 50-75% street lighting maintenance savings.[267]

This measure includes LED fixture housings including cobrahead and post-top and is applicable only where utility tariffs support LED street lighting conversions.

This measure was developed to be applicable for a one-to-one RF opportunity only.[268]

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment must be an LED fixture that meets the United Illuminating Rate Schedule, alongside all other luminary performance requirements, based on site characteristics[269] and all local, state and federal codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the existing lighting system – a metal halide, high pressure sodium, or mercury vapor outdoor lamp, ballast, and fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12.5 years.[270]

---

[267] See NEEP "LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic," January 2015, and the Municipal Solid State Street Lighting Consortium for more information http://www1.eere.energy.gov/buildings/ssl/consortium.html

[268] Many light fixtures were placed in service 20-50 years ago and may no longer service their intended purpose. It is important to conduct a comprehensive assessment of lighting needs with a lighting professional when considering a LED street lighting project. LED street lighting can result in removal of lighting altogether as LED lights provide better CRI and lighting levels than existing HID lighting types. While this measure only characterizes a one-to-one replacement value, it is recommended that this measure be updated following a Missouri assessment to see where LED street lighting has resulted in the removal of street lighting to ensure additional savings calculations are captured. Recommend using Street and Parking Facility Lighting Retrofit Financial Analysis Tool developed by DOE Municipal Solid-State Street Lighting Consortium and the Federal Energy Management Program.

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

[270] The measure lifetime is calculated using 4,000 annual hours of use from Ameren Missouri "Light Emitting Diode (LED) Street and Area Lighting Report," July 2013 and a typical LED streetlight lifetime of 50,000 hours from Massachusetts Department of Energy Resources "LED Streetlights: What is Your Plan? (webinar)," September 11, 2013.

DEEMED MEASURE COST

Actual measure installation cost should be used, including material and labor.[271] If the actual cost of the LED unit is unknown, use the default values for typical LED streetlight retrofits provided below.[272]

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS [273]

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

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following nominal wattage based on technology[274]

Metal Halide = 554W

High Pressure Sodium = 157W

Mercury Vapor = 228W

$Watts_{EE}$ = Actual wattage[275]

Hours = Annual operating hours

= 4,000 hours[276]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer peak savings should be claimed for street lighting, as street lights are not expected to be operational during system peak loads.

NATURAL GAS ENERGY SAVINGS

N/A

[271] Labor should include the removal of the old fixture and installation of the new fixture. Assume the typical prevailing wage as per the Annual Wage Order No. 23 published by the Missouri Department of Labor.
[272] LED unit costs from New York State Energy Research and Development Authority "Street Lighting in New York State: Opportunities and Challenges," Revised January 2015.
[273] There is no ISR input. Savings are per unit.
[274] Baseline wattages are a weighted average of products evaluated in Ameren Missouri "Light Emitting Diode (LED) Street and Area Lighting Report," July 2013. See "Street Lighting_Baseline Wattages.xlsx."
[275] It is important to ensure that retrofit opportunities base efficient wattage on a lumen per watt equivalence.
[276] Ameren Missouri "Light Emitting Diode (LED) Street and Area Lighting Report," July 2013.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Annual O&M savings are estimated at $50/LED streetlight.[277]

MEASURE CODE:

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

2.7 Miscellaneous

2.7.1 Laptop Computer

DESCRIPTION

This measure estimates savings for a laptop (or notebook) computer with that has been certified by ENERGY STAR® (ES) Version 6.0.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is laptop meeting the requirements set forth by ENERGY STAR® Version 6.0.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR® qualified laptop.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.[278]

DEEMED MEASURE COST[279]

The incremental cost is $5.

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[280]

$$\Delta kWh = Hours_{idle} * (P_{idle\_base} - P_{idle\_eff}) + Hours_{sleep} * (P_{sleep\_base} - P_{sleep\_eff}) + Hours_{off} * (P_{off\_base} - P_{off\_eff})$$

Where:

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

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).

[278] Based on Energy Star® Office Equipment Calculator. See "Office Equipment Calculator.xlsx."
[279] Computer CASE Report, CA IOUs. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Standards_Proposal_Computers_UPDATED_2013-08-06_TN-71813. The small incremental cost is in alignment with Energy Star® reporting, which lists an incremental cost of $0.
[280] Based on the algorithms used by the Energy Star® Office Equipment Calculator. See "Office Equipment Calculator.xlsx."

$Hours_{sleep}$ = Annual hours the computer is in sleep mode. Custom input or based on usage pattern (see table below).

P_{sleep_base} = Power draw (kW) of baseline unit while in sleep mode. Based on computer performance level (see table below).

P_{sleep_eff} = Power draw (kW) of efficient unit while in sleep mode. Based on computer performance level (see table below).

$Hours_{off}$ = Annual hours the computer is off. Custom input or based on usage pattern (see table below).

P_{off_base} = Power draw (kW) of baseline unit while off. Based on computer performance level (see table below).

P_{off_eff} = Power draw (kW) of efficient unit while off. Based on computer performance level (see table below).

Table: Default Hours of Use[281]

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[282]

Performance Level[283]	Baseline			Efficient		
	P_{idle_base}	P_{sleep_base}	P_{off_base}	P_{idle_eff}	P_{sleep_eff}	P_{off_eff}
Low	0.01104	0.00104	0.000563	0.0064	0.000787	0.000382
Medium	0.01482	0.00121	0.000606	0.00861	0.000889	0.000457
High	0.01724	0.00134	0.000619	0.01024	0.00122	0.000522

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Energy Savings as calculated above

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

= 0.0001379439

[281] Based on Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.” “Unknown” based on data suggesting 36% of computers are shut off at night and 8% have sleep mode enabled.

[282] Based on Energy Star® Office Equipment Calculator. See “Office Equipment Calculator.xlsx.”

[283] “Low” refers to budget or low-end models, “Medium” refers to mid-grade models and “High” refers to high-end models. For more specific performance definitions, refer to Energy Star® 6.0 Requirements.

Natural Gas Savings

N/A

Water and Other Non-Energy Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.7.2 Computer Power Management Software

DESCRIPTION

Computer power management software is installed on a network of computers. This is software which monitors and records computer and monitor usage, as well as allows centralized control of computer power management settings.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined by the requirements listed below:

- Allow centralized control and override of computer power management settings of workstations which include both a computer monitor and CPU (i.e. a desktop or laptop computer on a distributed network).
- Be able to control on/off/sleep states on both the CPU and monitor according to the network administrator-defined schedules and apply power management policies to network groups.
- Have capability to allow networked workstations to be remotely wakened from power-saving mode (e.g. for system maintenance or power/setting adjustments).
- Have capability to detect and monitor power management performance and generate energy savings reports.
- Have capability to produce system reports to confirm the inventory and performance of equipment on which the software is installed.

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

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

DEFINITION OF BASELINE EQUIPMENT

Baseline is defined as a computer network without software enforcing the power management capabilities in existing computers and monitors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 4 years.[284]

DEEMED MEASURE COST

The deemed measure cost is $29 per networked computer, including labor.[285]

LOADSHAPE

Miscellaneous BUS

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$kWh_{savings}$ = Annual energy savings per workstation

= 200 kWh[286] for desktops, 50 kWh for laptops[287]

= If unknown, assume 161 kWh (based on 74% desktop and 26% laptop)[288]

N = Number of desktop or laptop workstations controlled by the power management software

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

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

= 0.0001379439

NATURAL GAS SAVING

NA

DEEMED O&M COST ADJUSTMENT CALCULATION

Assumed to be $2/unit annually.[289]

MEASURE CODE:

[286] Based on average energy savings/computer from the following sources:
South California Edison, Work Paper WPSCNROE0003 (200k Wh)
Surveyor Network Energy Manager Evaluation Report, NEEA (68, 100, and 128kWh)
Regional Technical Forum http://rtf.nwcouncil.org/measures/measure.asp?id=95 (200 kWh)
EnergySTAR® Computer Power Management Savings Calculator (~190 kWh for a mix of laptop/desktop and assuming 30% are already turned off at night)
http://www.energystar.gov/ia/products/power_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).

[287] Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry.

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

[289] Based on Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec LLC and review of CLEARResult document providing Qualifying Software Providers for ComEd program and their licensing fees; "Qualifying Vendor Software Comparison.pdf."

2.7.3 Heat Pump Pool Heater

DESCRIPTION

This measure applies to the installation of a heat pump pool heater in place of a standard electric pool heater on an outdoor pool at a commercial location.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new, standard efficiency electric resistance pool heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[290]

DEEMED MEASURE COST

The incremental equipment cost difference between an electric resistance pool heater and a heat pump pool heater is $1,000 per unit.[291]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Q_{PoolHeating}$ = Required annual heat transfer to pool water (kWh), calculated as follows:[292]

= For an uncovered pool: [53.075 * (SQFT)] + 1631.1

= For a pool that is regularly covered when not in use: [8.079 * (SQFT)] + 1295.4

Where SQFT is the total surface area of the pool.

---

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

[291] Measure cost based on "The Definitive Guide to Heating Your Swimming Pool," AquaCal, July 2013. Electric resistance pool heaters can be purchased for less than $2,000, and heat pump pool heaters cost between $2,000 and $4,000.

[292] Based on the results of a swimming pool energy calculation tool found at http://noanderson.com/services/swimming-pool-energy-temperature-calculator/. Results use St. Louis weather-related assumptions and assume a pool season of May through October (per Energy Star® guidelines), with a water temperature of 80 degrees Fahrenheit.

Where:

Eff_{Base} = Efficiency of electric resistance pool heater

= 100%

Eff_{EE} = Efficiency (COP) of heat pump pool heater

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Calculated value above.

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

= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.7.4 Computer Server

DESCRIPTION

This measure estimates savings for a computer server with that has been certified by ENERGY STAR® (ES) Version 2.0.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is computer server meeting the requirements set forth by ENERGY STAR® Version 2.0.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR® qualified computer server.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.[293]

DEEMED MEASURE COST[294]

The incremental cost is $9.80.

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[295]

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

Power Supply Rated Output (W)	Baseline Annual Energy Consumption (kWh)	Efficient Annual Energy Consumption (kWh)	Annual Energy Savings (kWh)
Up to 500	1,221	742	479
501-1000	3,024	1,837	1,187
1001-1500	5,883	3,575	2,308
1501-2000	9,152	5,561	3,591

[293] Consistent with Energy Star® computing equipment. It is important to note that lifetime doesn't necessarily reflect the expected functional lifetime of mechanical components, but rather the lifetime of operating system technology, which is generally assumed to become obsolete after a period of four years.

[294] Computer CASE Report, CA IOUs. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Standards_Proposal_Computers_UPDATED_2013-08-06_TN-71813. The small incremental cost is in alignment with Energy Star® reporting, which lists an incremental cost of $0 for all office equipment.

[295] Based on current Energy Star® qualified product performance and assumptions drawn from the Energy Savings From Energy Star®- Qualified Servers report and Energy Star® Computer Specifications version 4.0. See "Computer Server Savings.xlsx" for additional details and methodology.

Power Supply Rated Output (W)	Baseline Annual Energy Consumption (kWh)	Efficient Annual Energy Consumption (kWh)	Annual Energy Savings (kWh)
2001-2500	8,667	5,266	3,401
2501-3000	19,633	11,929	7,704

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

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

= 0.0001379439

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8 Motors

2.8.1 Motors

DESCRIPTION

This measure applies to the one-for-one replacement of an old, working or failed/near failure 1-350 horsepower, constant speed, uniformly loaded HVAC fan or pumping motor with a new motor of the same rated horsepower that meets or exceeds National Electrical Manufacturers Association (NEMA) Premium efficiency levels.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new motor that meets or exceeds NEMA Premium efficiency levels.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment efficiency is the efficiency of the existing motor, or if unknown, the federal minimum required efficiency is assumed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[296]

DEEMED MEASURE COST

Actual incremental costs should be used if available. If actual costs are unknown, use default installed cost from table below.[297]

Motor Size (HP)	Installed Cost
1	$730
1.5	$725
2	$800
3	$840
5	$860
7.5	$1,165
10	$1,298
15	$2,242
20	$2,522
25	$2,873
30	$3,095
40	$3,716
50	$4,073
60	$5,128
75	$5,888
100	$7,392

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

Motor Size (HP)	Installed Cost
125	$9,076
150	$9,401
200	$11,250
250	$13,958
300	$17,744
350	$25,653

LOADSHAPE

Motors BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * LF * 0.746 * (1/\eta_{Bmotor} - 1/\eta_{EEmotor}) * \ Hours$$

Where:

HP = Nominal horsepower (HP) of new motor

= Actual

LF = Load Factor; Motor Load at Fan/Pump Design CFM

= 75%[298]

0.746 = Conversion factor from HP to kWh

η_{Bmotor} = Actual efficiency of existing motor, or if unknown, use federal baseline nominal/nameplate motor efficiency as shown in table below for Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC)[299]

Motor Size (HP)	Open Drip Proof (ODP) # 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%

298 Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. *Determining Electric Motor Load and Efficiency*, US DOE Motor Challenge, a program of the US Department of Energy, https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf.

299 For 1-200 HP motors, baseline efficiency is from NEMA MG 1 Table 12-12. For motors over 200 hp, baseline efficiency is from NEMA MG 1 Table 12-11.

Motor Size (HP)	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
25	93.00%	93.60%	91.70%	93.00%	93.60%	91.70%
30	93.60%	94.10%	91.70%	93.00%	93.60%	91.70%
40	94.10%	94.10%	92.40%	94.10%	94.10%	92.40%
50	94.10%	94.50%	93.00%	94.10%	94.50%	93.00%
60	94.50%	95.00%	93.60%	94.50%	95.00%	93.60%
75	94.50%	95.00%	93.60%	94.50%	95.40%	93.60%
100	95.00%	95.40%	93.60%	95.00%	95.40%	94.10%
125	95.00%	95.40%	94.10%	95.00%	95.40%	95.00%
150	95.40%	95.80%	94.10%	95.80%	95.80%	95.00%
200	95.40%	95.80%	95.00%	95.80%	96.20%	95.40%
250	95.40%	95.80%	95.00%	95.80%	96.20%	95.80%
300	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%
350	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%

$\eta_{EEmotor}$ =Efficient motor nominal/nameplate motor efficiency

= Actual

Hours = Annual hours of operation for motor; see table below for HVAC motors[300]

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours	Fan Motor Run Hours
Large Office	5,233	6,385	6,753
Medium Office	3,437	5,921	6,968
Small Office	3,715	3,774	6,626
Warehouse	4,587	1,292	6,263
Stand-alone Retail	4,040	2,713	6,679
Strip Mall	3,908	2,548	6,687
Primary School	4,754	5,160	5,906
Secondary School	5,594	5,279	6,702
Supermarket	4,868	4,255	6,900
Quick Service Restaurant	4,231	3,378	7,679
Full Service Restaurant	4,595	4,897	7,664
Hospital	8,760	8,717	8,760
Outpatient Health Care	8,760	8,689	8,760
Small Hotel - Building	3,533	7,976	8,760
Large Hotel - Building	5,538	8,308	8,760

[300] Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each building type. “Heating and Cooling Run Hours” are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each building type. This may over claim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours	Fan Motor Run Hours
Midrise Apartment - Building	5,197	4,347	8,728
Nonresidential Average	4,411	3,539	6,773

SUMMER COINCIDENT PEAK DEMAND SAVINGS[301]

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

Where:

ΔkWh = Energy Savings as calculated above

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

= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[301] Since savings will be constant and without fluctuation over the period of operation, demand savings are simply the energy savings divided by the hours of operation. Demand savings are expected to coincide with peak demand period definitions, consistent with assumptions in VFD measures on HVAC pumps and fans.

2.8.2 Pool Pump

DESCRIPTION

This measure applies to the installation of a variable frequency drive (VFD) on an existing single-speed pool pump at a commercial location. VFDs save energy by reducing the speed of the pool pump motor to match the pool's required flow rate. Additionally, VFD's soft-starting extends motor life by reducing wear.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new VFD meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing, single-speed pool pump without a VFD or other motor control device.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[302]

DEEMED MEASURE COST

Actual costs (equipment and labor) should be used if available. If actual costs are unknown, assume equipment costs of $200/motor horsepower and labor cost of $46.[303]

LOADSHAPE

Motors BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

1,747 = Average annual energy savings per pool pump motor horsepower (kWh/HP)[304]

HP = Pool pump motor horsepower

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

[302] Measure life from 2017 Michigan Energy Measures Database.
[303] Costs from 2017 Michigan Energy Measures Database.
[304] Energy savings based on monitoring performed at commercial pool facilities, from "Commercial Variable Speed Pool Pump Market Characterization and Metering Study," Southern California Edison, February 2015.

Where:

kWh = Electric energy savings, as calculated above.

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

= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8.3 Pool Pump Timer

DESCRIPTION

This measure applies to the installation of a pump timer on an existing single-speed pool pump at a commercial location. Many times, it is not necessary to run a pool's circulation pump 24 hours a day.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new pump timer meeting program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing, single-speed pool pump without a VFD or other motor control device.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.

DEEMED MEASURE COST

Actual costs (equipment and labor) should be used if available. If actual costs are unknown, assume equipment costs of $100.[305]

LOADSHAPE

Motors BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HRS * HP * .746$$

Where:

HRS = Hours Timer will shut off pump annually

= Actual.

HP = Pool pump motor horsepower

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

kWh = Electric energy savings, as calculated above.

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

= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8.4 Pump Optimization

DESCRIPTION

Pump improvements can be done to optimize the design and control of centrifugal water pumping systems, including water solutions with freeze protection up to 15% concentration by volume. Other fluid and gas pumps cannot use this measure calculation. The measurement of energy and demand savings for commercial and industrial applications will vary with the type of pumping technology, operating hours, efficiency, and existing and proposed controls. Depending on the specific application slowing the pump, trimming or replacing the impeller may be suitable options for improving pumping efficiency. Pumps up to 40 HP are allowed to use this energy savings calculation. Larger motors should use a custom calculation (which may result in larger savings than this measure would claim).

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is proven to be an optimized centrifugal pumping system meeting the applicable program efficiency requirements:

- Pump balancing valves no more than 15% throttled; and
- Balancing valves on at least one load 100% open.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[306]

DEEMED MEASURE COST

The incremental capital cost for this measure can vary considerably depending upon the strategy employed to achieve the required efficiency levels and should be determined on a site-specific basis.

LOADSHAPE

Process BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

HP_{motor} = Installed nameplate motor horsepower

= Actual

---

[306] Martin, N. et al., Emerging Energy-Efficient Industrial Technologies: New York State Edition, American Council for an Energy Efficient Economy (ACEEE), March 2001 (as stated in the OH State TRM, page 269).

0.746 = Conversion factor from horse-power to kW (kW/hp)

LF / η_{motor} = Combined as a single factor since efficiency is a function of load

= 0.65[307]

Where:

LF = Load Factor; Ratio of the peak running load to the nameplate rating of the motor

η_{motor} = Motor efficiency at pump operating conditions

HOURS = Annual operating hours of the pump

= Actual

ESF = Energy Savings Factor; assume a value of 15%.[308]

Summer Coincident Peak Demand Savings

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

Where:

CF = Summer Coincident Peak Factor for measure

= 0.0001379439[309]

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

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

[308] Published estimates of typical pumping efficiency improvements range from 5 to 40%. For analysis purposes, assume 15%. United States Industrial Electric Motor Systems Market Opportunities Assessment December 2002, Table E-7, Page 18, https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf.

[309] Based on Ameren Missouri 2016 Process Loadshape.

2.8.5 Variable Frequency Drives for Chilled Water and Hot Water Distribution Pumps

DESCRIPTION

This measure applies to VFDs installed on HVAC chilled water and hot water distribution pumps. There is a separate measure for HVAC supply and return fans. The VFD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a pump motor 1-75 HP that does not have a VFD. The hydronic system that the VFD is applied to must have a variable or reduced load. Installation is to include the necessary control points and parameters (example: differential pressure, differential temperature, return water temperature) as determined by a qualified engineer.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.[310]

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default measure costs are listed below for 1 to 75 HP motors.[311] The average of the values below is $179/HP.

HP	Cost
1-9 HP	$1,874
10-19 HP	$2,967
20-29 HP	$4,060
30-39 HP	$5,154
40-49 HP	$6,247
50-59 HP	$7,340
60-69 HP	$8,433
70-75 HP	$9,526

LOADSHAPE

Cooling BUS
Heating BUS
HVAC BUS

[310] Consistent with Ameren Missouri program assumptions.
[311] Average costs observed by other Midwestern states energy efficiency programs – specific data reflects results from Iowa program costs.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

BHP = System Brake Horsepower

(Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.[312] Custom load factor may be applied if known.

EFFi = Motor efficiency, installed. Actual motor efficiency shall be used to calculate kW. If not known, a default value of 93% is an appropriate assumption.

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type.[313] When available, actual hours should be used.

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours
Large Office	5233	6385
Medium Office	3437	5921
Small Office	3715	3774
Warehouse	4587	1292
Stand-alone Retail	4040	2713
Strip Mall	3908	2548
Primary School	4754	5160
Secondary School	5594	5279
Supermarket	4868	4255
Quick Service Restaurant	4231	3378
Full Service Restaurant	4595	4897
Hospital	8760	8717
Outpatient Health Care	8760	8689
Small Hotel - Building	3533	7976
Large Hotel - Building	5538	8308
Midrise Apartment - Building	5197	4347

[312] Del Balso, Ryan J. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications," University of Colorado, Department of Civil, Environmental and Architectural Engineering, 2013.

[313] Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each building type. "Heating and Cooling Run Hours" are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each building type. This may over claim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours
Nonresidential Average	4411	3539

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

Application	ESF[314]
Hot Water Pump	0.3577
Chilled Water Pump	0.3389

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

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

= 0.0001379439 Chilled Water Pumps

= 0.000443983 Hot Water Pumps

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[314] Developed from datasets produced from the Northeast Energy Efficiency Partnerships Variable Speed Drive Loadshape Project. See supporting workbook "VSD HVAC Pump Savings.xlsx" for derivation.

2.8.6 Variable Frequency Drives for HVAC Supply and Return Fans

DESCRIPTION

This measure applies to VFDs installed on HVAC supply fans and return fans. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is applicable to the following program types: TOS and RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to an HVAC fan motor that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (example: differential pressure, temperature, or volume). Savings are based on the application of VFDs to a range of baseline system conditions, including no control, inlet guide vanes, outlet guide vanes, relief dampers, and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The TOS baseline is a new motor installed without a VFD or other methods of control. The RF baseline is an existing motor operating as is. RF baselines may or may not include guide vanes, throttling valves, or other methods of control.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.[315]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.[316] The average of the values below is $168/HP.

HP	Cost
1-9 HP	$1,874
10-19 HP	$2,967
20-29 HP	$4,060
30-39 HP	$5,154
40-49 HP	$6,247
50-59 HP	$7,340
60-69 HP	$8,433
70-79 HP	$9,526
80-89 HP	$10,620
90-100 HP	$11,713

LOADSHAPE

HVAC BUS

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[317]

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

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

ΔkWh_{fan} = $kWh_{Base} - kWh_{Retrofit}$

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

Where:

kWh_{Base} = Baseline annual energy consumption (kWh/yr)

$kWh_{Retrofit}$ = Retrofit annual energy consumption (kWh/yr)

ΔkWh_{fan} = Fan-only annual energy savings

ΔkWh_{total} = Total project annual energy savings

0.746 = Conversion factor for HP to kWh

HP = Nominal horsepower of controlled motor

LF = Load Factor; Motor Load at Fan Design CFM (Default = 65%)[318]

η_{motor} = Installed nominal/nameplate motor efficiency

= Actual. If unknown, default can be assumed as a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor, with efficiency indicated in the following table:

[317] Methodology developed and tested in Del Balso, Ryan Joseph. “Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications.” A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

[318] Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry,” U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory.

NEMA Premium Efficiency Motors Default Efficiencies[319]

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800 Default	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.954	0.958	0.950	0.958	0.962	0.958
300	0.954	0.958	0.954	0.958	0.962	0.958
350	0.954	0.958	0.954	0.958	0.962	0.958
400	0.958	0.958	0.958	0.958	0.962	0.958
450	0.962	0.962	0.958	0.958	0.962	0.958
500	0.962	0.962	0.958	0.958	0.962	0.958

$RHRS_{Base}$ = Annual operating hours for fan motor based on building type.

Default hours are provided for HVAC applications which vary by building type.[320] When available, actual hours should be used.

Building Type	Total Fan Run Hours
Large Office	6753
Medium Office	6968
Small Office	6626

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

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

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

%FF = Percentage of run-time spent within a given flow fraction range[321]

Flow Fraction (% of design cfm)	Percent of Time at Flow Fraction
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 40%	15.5%
40% to 50%	22.0%
50% to 60%	25.0%
60% to 70%	19.0%
70% to 80%	8.5%
80% to 90%	3.0%
90% to 100%	0.5%

PLR_{Base} = Part load ratio for a given flow fraction range based on the baseline flow control type (see table below)

$PLR_{Retrofit}$ = Part load ratio for a given flow fraction range based on the retrofit flow control type (see table below)

Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07

[321] Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

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

Provided below are the resultant values based upon the defaults provided above:

Control Type	$\sum_{0\%}^{100\%}(\%FF \times PLR_{Base})$
No Control or Bypass Damper	1.00
Discharge Dampers	0.80
Outlet Damper, BI & Airfoil Fans	0.78
Inlet Damper Box	0.69
Inlet Guide Vane, BI & Airfoil Fans	0.63
Inlet Vane Dampers	0.53
Outlet Damper, FC Fans	0.53
Eddy Current Drives	0.49
Inlet Guide Vane, FC Fans	0.39
VFD with duct static pressure controls	0.30
VFD with low/no duct static pressure	0.27

IE_{energy} = HVAC interactive effects factor for energy (default = 15.7%)[322]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh_{total} = As calculated above.

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

= 0.000443983

NATURAL GAS ENERGY SAVINGS

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

[322] Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications." A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.9 Refrigeration

2.9.1 Commercial Solid and Glass Door Refrigerators & Freezers

DESCRIPTION

This measure applies to ENERGY STAR® vertical closed and horizontal closed refrigerators or freezers installed in a commercial kitchen. ENERGY STAR® commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new ENERGY STAR® certified vertical closed or horizontal closed, solid or glass door refrigerator or freezer meeting energy 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 (ft^3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.02V + 1.60	≤ 0.25V + 1.55
15 ≤ V < 30	≤ 0.09V + 0.55	≤ 0.20V + 2.30
30 ≤ V < 50	≤ 0.01V + 2.95	≤ 0.25V + 0.80
V ≥ 50	≤ 0.06V + 0.45	≤ 0.14V + 6.30
Glass Door		
0 < V < 15	≤ 0.10V + 1.07	≤ 0.56V + 1.61
15 ≤ V < 30	≤ 0.15V + 0.32	≤ 0.30V + 5.50
30 ≤ V < 50	≤ 0.06V + 3.02	≤ 0.55V – 2.00
V ≥ 50	≤ 0.08V + 2.02	≤ 0.32V + 9.49
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.06V + 0.60	≤ 0.10V + 0.20

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new vertical closed or horizontal closed, solid or glass door refrigerator or freezer that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[323]

[323] 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.

DEEMED MEASURE COST

The incremental capital cost for this measure varies by size as shown in the table below:

Measure	Incremental Cost
Commercial Glass Door Freezers less than 15 ft^3	$220
Commercial Glass Door Freezers 15 to 30 ft^3	$950
Commercial Glass Door Freezers 30 to 50 ft^3	$1,307
Commercial Glass Door Freezers more than 50 ft^3	$2,300
Commercial Glass Door Refrigerators less than 15 ft^3	$250
Commercial Glass Door Refrigerators 15 to 30 ft^3	$500
Commercial Glass Door Refrigerators 30 to 50 ft^3	$1,307
Commercial Glass Door Refrigerators more than 50 ft^3	$2,300
Commercial Solid Door Freezers/Refrigerators less than 15 ft^3	$150
Commercial Solid Door Freezers/Refrigerators 15 to 30 ft^3	$400
Commercial Solid Door Freezers/Refrigerators 30 to 50 ft^3	$550
Commercial Solid Door Freezers/Refrigerators more than 50 ft^3	$700
Horizontal Closed - Solid or Glass Door Refrigerator (all volumes)	$525
Horizontal Closed - Solid or Glass Door Freezer (all volumes	$595

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.[324]

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

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline refrigerator or freezer

= Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{Base}[325]
Solid Door Refrigerator	0.10V + 2.04
Glass Door Refrigerator	0.12V + 3.34
Solid Door Freezer	0.40V + 1.38
Glass Door Freezer	0.75V + 4.10

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR® refrigerator or freezer

[324] Algorithms and assumptions from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
[325] 10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers.

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

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.02V + 1.60	≤ 0.25V + 1.55
15 ≤ V < 30	≤ 0.09V + 0.55	≤ 0.20V + 2.30
30 ≤ V < 50	≤ 0.01V + 2.95	≤ 0.25V + 0.80
V ≥ 50	≤ 0.06V + 0.45	≤ 0.14V + 6.30
Glass Door		
0 < V < 15	≤ 0.10V + 1.07	≤ 0.56V + 1.61
15 ≤ V < 30	≤ 0.15V + 0.32	≤ 0.30V + 5.50
30 ≤ V < 50	≤ 0.06V + 3.02	≤ 0.55V – 2.00
V ≥ 50	≤ 0.08V + 2.02	≤ 0.32V + 9.49
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.06V + 0.60	≤ 0.10V + 0.20

V = Refrigerated volume (ft^3) calculated in accordance with the Department of Energy test procedure in 10 CFR §431.64

= Actual installed

Days = Days of refrigerator or freezer operation per year

= Custom, or if unknown assume 365.25 days per year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001357383[326]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[326] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.9.2 Refrigerated Beverage Vending Machine

DESCRIPTION

This measure applies to new ENERGY STAR®, Class A or Class B refrigerated vending machines. ENERGY STAR® vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR®, Class A or Class B[327] 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	≤ 0.0523V + 2.432
Class B	≤ 0.0657V + 2.844

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new or rebuilt, Class A or Class B refrigerated vending machine that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[328]

DEEMED MEASURE COST

The incremental cost of this measure is $140.[329]

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.

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

[327] Class A means a refrigerated bottled or canned beverage vending machine that is fully cooled, and is not a combination vending machine. Class B means any refrigerated bottled or canned beverage vending machine not considered to be Class A, and is not a combination vending machine. See 10 CFR §431.292 "Definitions concerning refrigerated bottled or canned beverage vending machines."

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

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

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline vending machine

= Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{Base} [330]
Class A	0.055V + 2.56
Class B	0.073V + 3.16

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR® vending machine

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

Equipment Type	kWh_{EE} [331]
Class A	≤ 0.0523V + 2.432
Class B	≤ 0.0657V + 2.844

V = Refrigerated volume[332] (ft^3)

= Actual installed

Days = Days of vending machine operation per year

= 365.25 days per year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001357383[333]

MEASURE CODE:

[330] 10 CFR §431.296 - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

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

[332] *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.

[333] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

2.9.3 Door Heater Controls for Cooler or Freezer

DESCRIPTION

This measure applies to door heater controls installed on commercial coolers or freezers. There are two main categories of commercially available control strategies that achieve "on-off" control of door heaters based on either (1) the relative humidity of the air in the store or (2) the "conductivity" of the door (which drops when condensation appears). In the first strategy, the system activates door heaters when the relative humidity in a store rises above a specific set point and turns them off when the relative humidity falls below that set point. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain set point and turns them off when the conductivity rises above that set point. Savings result from a reduction in electric energy use due to heaters not running continuously and from reduced cooling loads when heaters are off. The assumptions included within this measure assume that door heater controls which are properly designed and commissioned will achieve approximately equivalent savings, regardless of control strategy.

This measure applies to the following program type: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a door heater control installed on a commercial glass door cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a door heater without controls, installed on a commercial glass door cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[334]

DEEMED MEASURE COST

Actual incremental costs should be used if available. The incremental capital cost $151 per door.[335]

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

kW_{Base} = Per door electric energy consumption of door heater without controls

[334] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.
[335] Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

= Assume 0.130 kW per door[336]

DOORS = Number of doors controlled with door heater controls

= Actual or if unknown, use 1 (a per door savings)

$\%ON_{Base}$ = Effective run time of uncontrolled door heater

= Actual or if unknown, use 90.7%[337]

$\%ON_{Control}$ = Effective run time with anti-sweat door heater controls

= Actual or if unknown, use 45.6%[338]

Hours = Annual hours of cooler or freezer operation

= Assume 8,766 hours per year

BF = Cooling Bonus factor for reduction in waste heat inside of the refrigerated space.

= 1.3 for a refrigerator (medium/high temp), 1.5 for freezers (low temp)[339]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001357383[340]

Other variables as defined above.

Savings calculated with default values as defined above.

Door Heater Control Application	ΔkWh/door	ΔkW/door
Refrigerator	668.1	0.0907
Freezer	770.9	0.1046

NATURAL GAS ENERGY SAVINGS

N/A

MEASURE CODE:

[336] The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 75, Table 42.

[337] The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 37.

[338] The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 37.

[339] The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

[340] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

2.9.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers/Freezers

DESCRIPTION

This measure consists of replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins.

This measure achieves savings by installing a more efficient motor, thereby moving the same amount of air with less energy requirements. Additionally, less waste heat is produced, resulting in a decreased refrigeration load.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure applies to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an electronically commutated motor (ECM). Savings assume that efficient motors operate continuously.

DEFINITION OF BASELINE EQUIPMENT

The baseline is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[341]

DEEMED MEASURE COST

The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer, including the cost of the motor plus installation.[342]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association and supported by PGE workpaper PGE3PREF126. Note that climate differences across all California climate zones resulted in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Missouri. Savings found in the aforementioned source are presented in combination with savings from controllers, however for the purposes of this measure only those associated with the ECM upgrade are considered.

---

[341] DEER database.

[342] Difference in the fully installed cost ($468) for ECM motor and controller, listed in Work Paper PGE3PREF126, "ECM for Walk-In Evaporator with Fan Controller," June 20, 2012, and the measure cost specified in the DEER database for controller ($291).

ELECTRIC ENERGY SAVINGS

ΔkWh = Savings per motor * motors

Where:

Savings per motor[343] = based on the motor rating of the ECM motor:

Evaporator Fan Motor Rating (of ECM)	Annual kWh Savings/motor
16W	408
1/15 - 1/20HP	1,064
1/5HP	1,409
1/3HP	1,994
1/2HP	2,558
3/4HP	2,782

motors = number of fan motors replaced

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above.

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

= 0.0001379439

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

343 See reference workbook "ECM Savings.xlsx" for derivation.

2.9.5 Strip Curtain for Walk-in Coolers and Freezers

Description

This commercial measure pertains to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the cooling load. As a result, compressor run time and energy consumption are reduced. The engineering assumption is that the walk-in door is open for varying durations per day based on facility type, and the strip curtain covers the entire door frame. All assumptions are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission.[344]

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

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

Definition of Efficient Equipment

The efficient equipment is a strip curtain added to a walk-in cooler or freezer. The new strip curtain must cover the entire area of the doorway when the door is opened.

Definition of Baseline Equipment

The baseline assumption is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 4 years.[345]

Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening.[346]

Loadshape

Refrigeration BUS

Algorithm

Calculation of Savings

Electric Energy Savings[347]

$$\Delta kWh = \Delta kWh/sq\ ft * A$$

344 The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short term monitoring of over 100 walk-in units. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.

345 DEER 2014 Effective Useful Life.

346 The reference for incremental cost is $10.22 per square foot of door opening (includes material and labor). 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation," California Public Utilities Commission, December 16, 2008.

347 The source algorithm from which the savings per square foot values are determined is based on Tamm's equation (an application of Bernoulli's equation) [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].

Where:

ΔkWh/sq ft = Average annual kWh savings per square foot of infiltration barrier. Based on application type, as indicated by the following table:[348]

Type	Pre-Existing Curtains	Energy Savings 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

A = Doorway area. Use actual measurements, if unknown assume the following:

Facility Type	Doorway Area (sq ft)
Supermarket - Cooler	35
Supermarket - Freezer	35
Convenience Store - Cooler	21
Convenience Store - Freezer	21
Restaurant - Cooler	21
Restaurant - Freezer	21
Refrigerated Warehouse	80

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

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

= 0.0001357383[349]

NATURAL GAS ENERGY SAVINGS

N/A

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

[349] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Refrigeration. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.10 Shell

2.10.1 Windows

DESCRIPTION

Energy and demand saving are realized through the installation of windows that offer performance improvements over baseline windows. Savings may be realized from reducing air infiltration, improved insulating properties, and changes to solar heat gain through the glazed surfaces of the building.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of the IECC. For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing window assemblies.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012. An efficient window would have specifications not exceeding these values.

	Climate Zones 4 & 5
U-Factor	
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.[350]

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used, including both material and labor costs to install the windows.

In all other scenarios, the incremental cost for this measure is assumed to be $1.50 per square foot of window area.[351]

LOADSHAPE

Cooling BUS

Algorithm

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

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

Heating and cooling savings are composed of three components: infiltration, conduction and solar gains. In instances where infiltration savings do not apply or are not eligible, it may be disregarded.

If central cooling, the electric energy saved in annual cooling due to the added insulation is:

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

$$Infiltration_{cooling} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

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:

Weather Basis (City based upon)	$OA_{AVG,cooling}$ [°F][352]	$\Delta T_{AVG,cooling}$ [°F]
St Louis, MO	80.8	5.8

0.018 = Specific Heat Capacity of Air (Btu/ft^3 °F)

LM = Latent Multiplier to account for latent cooling demand: [353]

[352] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

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

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

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual

$$Conduction_{\text{cooling}} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

U_{base} = U-factor value of baseline window assembly (Btu/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.

$$Solar_{\text{cooling}} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

$SHGC_{base}$ = Solar Heat Gain Coefficient of the baseline window assembly (fractional)

$SHGC_{eff}$ = Solar Heat Gain Coefficient of the efficient window assembly (fractional)

$\Psi_{cooling}$ = Incident solar radiation during the cooling season (Btu/ft^2):[354]

Weather Basis (City based upon)	$\Psi_{cooling}$
St Louis, MO	40996

Other variables as defined above.

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the window upgrade is:

$$\Delta \text{kWh}_{\text{heating}} = Infltration_{heating} + Conduction_{heating} - Solar_{heating}$$

[354] See “Windows SHG.xlsx” for derivation.

$$Infiltration_{\text{heating}} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(3{,}412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.7, HVAC end use

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

Weather Basis (City based upon)	$OA_{AVG,heating}$ [°F][355]	$\Delta T_{AVG,heating}$ [°F]
St Louis, MO	43.2	11.8

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system

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

Other variables as defined above.

$$Conduction_{\text{heating}} = \frac{\left(U_{base} - U_{eff}\right) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Variables as defined above.

$$Solar_{\text{heating}} = \frac{\left(SHGC_{base} - SHGC_{eff}\right) * A_{window} * \psi_{heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$\Psi_{heating}$ = Incident solar radiation during the heading season (Btu/ft^2):

Weather Basis (City based upon)	$\Psi_{cooling}$
St Louis, MO	66592

Other variables as defined above.

Summer Coincident Peak Demand Savings

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

Where:

[355] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above

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

= 0.000910684

NATURAL GAS SAVINGS

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

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

$$Infiltration_{\text{gasheating}} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(100{,}000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other variables as defined above.

$$Conduction_{\text{gasheating}} = \frac{\left(U_{base} - U_{eff}\right) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

$$Solar_{\text{gasheating}} = \frac{\left(SHGC_{base} - SHGC_{eff}\right) * A_{window} * \psi_{heating}}{(100{,}000 * \eta_{heat})}$$

Variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.10.2 Ceiling and Wall Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of IECC. For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012:

	ASHRAE/IECC Climate Zone 5 (A, B, C) Nonresidential	
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-11.4 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.064	R-13 + R-3.8 ci or R-20

	ASHRAE/IECC Climate Zone 6 (A, B, C) Nonresidential	
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-13.1 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.051	R-13 + R-7.5 ci or R-20 + R-3.8 ci

Note: ci = continuous insulation

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

HVAC BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

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

Where:

$R_{existing}$ = Assembly heat loss coefficient with existing insulation [(hr-^{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[356]

$EFLH_{cooling}$ = 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

Weather Basis (City based upon)	$OA_{AVG,cooling}$ [°F][357]	$\Delta T_{AVG,cooling}$ [°F]
St Louis, MO	80.8	5.8

356 Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, "Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls."

357 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.7, HVAC end use

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

Weather Basis (City based upon)	$OA_{AVG,heating}$ [°F][358]	$\Delta T_{AVG,heating}$ [°F]
St Louis, MO	43.2	11.8

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system

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

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[359]

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above

358 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

359 F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star® version 3 criteria for 2% F_e. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

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

= 0.0004439830

NATURAL GAS SAVINGS

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

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

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 temperature difference [^{0}F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

Measure Code: