Volume 2: Commercial and Industrial Measures

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

Revision	Date	Description
1.0	05/30/2018	Initial version filed for Commission approval.
1.1	06/19/2020	Updated version to include new measures and updates to existing measures
2.0	10/15/2020	Updated version to include updates to existing measures.
3.0	9/15/2021	Update "Deemed Tables" with PY2020 Evaluation results plus updates to existing measures (lighting, chiller, pool pump). Added EUL lookup table for lighting measures from PY19.
4.0	9/26/2022	Updated "Deemed Tables" with PY2021 Evaluation results and added two new measures: 2.2.2 Compressed Air Leak Repair (shifting Compressed Air Nozzle and VSD Air Compressor to 2.2.3 and 2.2.4, respectively) and 2.5.10 Chiller Tune-Up.
5.0	10/05/2023	Updated baselines to 2015 IECC (effective 1/1/2024) for 2.5.5, 2.5.6, and 2.5.8. Updated baseline table to include only 2015 IECC for 2.5.7 PTAC/PTHP. Added "exterior" to 24/7 lighting coincidence factor because 24/7 interior lighting (e.g., exit signs) are included in the indoor lighting coincidence factor. Retired measures 2.6.4 and 2.6.7 in response to the EISA backstop provision becoming effective 8/1/2023. Expanded measure 2.2.4 VSD Air Compressor description to include units up to 200-hp.
6.0	12/01/2024	Added Efficient Pumps, Efficient Cooling Towers, Dedicated Outdoor Systems. Removed several measures currently not active in the programs. Reviewed and updated all measures including source documentation.

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 in the following table, as required by the program. The current Version 8.0, is effective as of February 2018. Or a top load commercial grade clothes washer exceeding the California Modernized Appliance Efficiency Database (CA MAEDBS) minimum qualifications.

Efficiency Level		Top loading	Front Loading
Efficient	ENERGY STAR® Or CA MAEDBS	≥1.49 MEF, ≤7.92 IWF	≥2.2 MEF, ≤4.0 IWF

Definition of Baseline Equipment

The baseline condition is a commercial-grade clothes washer meeting the minimum federal energy efficiency baseline as of January 2018.[1]

Efficiency Level		Top loading	Front Loading
Baseline	Federal Standard	1.35 MEF, 8.8 IWF	2.00 MEF, 4.1 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 Integrated Water Factor (IWF) 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 all wash cycles, 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]

Deemed Measure Cost

[1] DOE, Commercial Clothes Washer efficiency, https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431#431.97
[2] ENERGY STAR® | Clothes Washers | https://www.energystar.gov/products/clothes_washers/key_product_criteria
[3] DOE, Multifamily EUL 11.3 and Laundromat 7.1, applied 11 years to align with other TRMs, Page 76, "Energy Conservation Standards for Commercial Clothes Washers" , https://www.energy.gov/eere/buildings/articles/issuance-2014-12-05-energy-conservation-standards-commercial-clothes

The incremental cost is assumed to be $200.[4]

Loadshape

Loadshape – Miscellaneous BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

Capacity = Clothes washer capacity (cubic feet)
= Actual - If capacity is unknown, assume 3.8 cubic feet [5]

MEF_{base} = Modified Energy Factor of baseline unit
= Actual for early replacement, else federal standard in following table.

MEF_{eff} = Modified Energy Factor of efficient unit, must exceed minimum values in following table.

Standard	Top Load	Front Load
Baseline- Federal standard	1.35 MEF[6]	2.00 MEF[7]
Efficient - ENERGY STAR®	N/A	2.39 MEF[8]
Efficient - CA MAEDBS	1.50 MEF[9]	

Ncycles = Number of wash cycles per year

[4] ENERGY STAR® | https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/energy-star-appliance-calculator.xlsx ("Clothes Washer Calcs" tab Cell E11).
[5] ENERGY STAR® | Average volume of certified models | https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results.
[6] Footnote 1
[7] IBID
[8] CA MAEDBS & ENERGY STAR, Weighted MEF average, Aggregated in local file "2024 ENERGY STAR® , CA MAEDBS Clothes Washer.xlsx"
[9] CA MAEDBS, MEF average of 110 top load units, "Commercial Top Load Clothes Washers", (August 2024), Aggregated in local file "2024 ENERGY STAR® , CA MAEDBS Clothes Washer.xlsx"

	= 2190[10]
%CW	= Percentage of total energy consumption for clothes washer operation (different for baseline and efficient unit – see table below)
%DHW	= Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)
%Dryer	= Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)
$\%Electric_{DHW}$	= Percentage of DHW savings assumed to be electric
$\%Electric_{Dryer}$	= Percentage of dryer savings assumed to be electric

Efficiency Level	Percentage of Total Energy Consumption [11]		
	%CW	%DHW	%Dryer
Federal Standard	6.5%	25.9%	67.6%
ENERGY STAR®	3.5%	14.1%	82.4%

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

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

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.[12]

Efficiency Level	ΔkWh			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®	679	92	735	149

[10] Based on DOE Technical Support Document, 2009; Chapter 8 "*Life-Cycle Cost and Payback Period Analysis*", p 8-15.
[11] 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.
[12] 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.

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[13]

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

	ΔkW			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®	0.0937	0.0127	0.1014	0.0205

NATURAL GAS SAVINGS

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

Where:

$\%Gas_{DHW}$ = Percentage of DHW savings assumed to be natural gas
R_eff = Recovery efficiency factor
= 1.26[14]
$\%Gas_{Dryer}$ = Percentage of dryer savings assumed to be natural gas
Therm_convert = Conversion factor from kWh to therm
= 0.03412

Other factors as defined above.

[13] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"
[14] 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 Therefore a factor of 0.98/0.78 (1.26) is applied.

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

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

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = Capacity \text{ x } (IWFbase - IWFeff) \text{ x } Ncycles$$

Where:

WFbase = Water Factor of baseline clothes washer

WFeff = Water Factor of efficient clothes washer

= Actual - If unknown assume average values provided below

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

Efficiency Level	WF			ΔWater (gallons per year)
	Top Loaders	Front Loaders	Weighted Average	Weighted Average
Federal Standard [15]	8.5	5.5	7.4	n/a
ENERGY STAR®	4.5			19,874

[15] 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%

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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.[16] 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® version 1.1 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. As the DOE Federal Efficiency Standard performs testing with the D1 method in their appendix and the ENERGY STAR® certifies with the D2 test, the federal standard CEF value is adjusted.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 14 years.[17]

Deemed Measure Cost

Dryer Size	Incremental Cost [18]
Standard	$75
Compact	$105

Loadshape

Loadshape - Miscellaneous BUS

Algorithm

Calculation of Savings

[16] 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

[17] 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

[18] Cost based on ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances. https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/energy-star-appliance-calculator.xlsx ("Clothes Dryer Calcs" tab Cell E8)

Electric Energy Savings

$$\Delta kWh = (Load/CEF_{base} - Load/CEF_{eff}) \text{ x } Ncycles \text{ x } \%Electric$$

Where:

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

Dryer Size	Load (lbs.)[19]
Standard	8.45
Compact	3

CEF_{base} = 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.[20] If product class unknown, assume electric, standard.

Product Class	CEFbase (lbs./kWh)
Vented/Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented/Ventless Electric, Compact (120V) (< 4.4 ft^3)	3.80
Vented Electric, Compact (240V) (<4.4 ft^3)	3.45
Ventless Electric, Compact (240V) (<4.4 ft^3)	2.68
Vented Gas	3.48[21]

CEF_{eff} = CEF (lbs./kWh) of the ENERGY STAR® unit based on ENERGY STAR® requirements. [22] If product class unknown, assume electric, standard.

Product Class	CEFeff (lbs./kWh)
Vented or Ventless Electric, Standard (≥ 4.4 ft3)	3.93
Vented or Ventless Electric, Compact (120V) (<4.4 ft3)	3.80
Vented Electric, Compact (240V) (< 4.4 ft3)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft3)	2.68
Vented Gas	3.48[23]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, refer to the table below.[24]

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[19] ENERGY STAR® |Certification criteria |https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[20] ENERGY STAR® 1.1 Clothes Dryers Data and Analysis
[21] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[22] ENERGY STAR® Clothes Dryers Key Product Criteria, https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[23] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[24] 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. Metering data in local file: "VEIC GTI Analysis.xlsx"

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

%Electric = 100% for electric dryers, 5% for gas dryers[25]

Using defaults provided above, with the average CEF efficiency of ENERGY STAR certified dryers:

Product Class	ΔkWh		
	Multifamily	Laundromat	On-Premise Laundromat
Vented/Ventless Electric, Standard (≥ 4.4 ft^3)	96	132	322
Vented/Ventless Electric, Compact (120V) (< 4.4 ft^3)	342	472	1,149
Vented Electric, Compact (240V) (<4.4 ft^3)	0	0	0
Ventless Electric, Compact (240V) (<4.4 ft^3)	310	428	1,040
Vented Gas	0	0	0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = h * CF$$

Where:

ΔkWh = Energy savings as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[26]

Using defaults provided above:

[25] %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® Version 1.1 Clothes Dryers Data and Analysis. Value reported in 2015 EPA EnergySTAR® appliance calculator.

[26] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

Product Class	ΔkW		
	Multifamily	Laundromat	On-Premise Laundromat
Vented Electric, Standard (≥ 4.4 ft^3)	0.0132	0.0182	0.0443
Vented Electric, Compact (120V) (<4.4 ft^3)	0.0472	0.0651	0.1584
Vented Electric, Compact (240V) (<4.4 ft^3)	0	0	0
Ventless Electric, Compact (240V) (<4.4 ft^3)	0.0428	0.0589	0.1435
Vented Gas	0	0	0

NATURAL GAS ENERGY SAVINGS

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

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

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[27]

Using defaults provided above:

$\Delta Therms$ = (8.45/2.84 – 8.45/3.48) x Ncycles x 0.03413 x 0.84

Product Class	ΔTherms		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Gas	0	0	0

All certified models (2024) have efficiency values equal to the standard, resulting in zero savings.

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

[27] % 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® Version 1.0 Clothes Dryers Data and Analysis.

365.25 = Days per year

Using defaults provided above:

Product Class	ΔPeakTherms		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Gas	0	0	0

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.[28]

Deemed Measure Cost

The measure cost is $778 per drain.[29]

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[30]

[28] Energy & Resource Solutions (prepared for the Massachusetts Joint Utilities), "Measure Life Study", Table 1-1, 2005, https://www.ers-inc.com/wp-content/uploads/2018/04/Measure-Life-Study_MA-Joint-Utilities_ERS.pdf.

[29] Ameren MO DSM program participants 2020 to 2024, equipment and labor cost, 7 projects.

[30] Reduced CFM consumption is based on a 90 CFM timer drain opening for 10 seconds every 300 seconds as the baseline. Local file: "Install NoLoss CondDrainValves worksheet, cell G44,"Industrial System Standard Deemed Saving Analysis.xls."

kW_{CFM} = System power demand reduction per reduced air consumption (kw/CFM), depending on the type of compressor control, see table below[31]

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, less holidays & scheduled down time
2-shift (16/5)	3952 hours: 7AM – 11 PM, weekdays, less holidays & scheduled down time
3-shift (24/5)	5928 hours: 24 hours per day, weekdays, less holidays & scheduled down time
4-shift (24/7)	8320 hours: 24 hours per day, 7 days, less holidays & scheduled down time

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[32]

MEASURE CODE:

[31] Calculated based on load curves from Compressed Air Challenge. Aggregated data assumed the compressor will be between 40% and 100% capacity. Worksheet “Install High Efficiency Nozzles”, Range N18:AG38, . Local file: “Industrial System Standard Deemed Saving Analysis.xls.”

[32] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.2.2 Compressed Air Leak Repair

Description

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The effective useful life is 2 years. [33]

Deemed Measure Cost

Measure cost should include the inspection and repair cost.

Loadshape

Air Comp BUS

Algorithm

Calculation of Savings

Electric Energy Savings

When a CFM-bin approach model built with trended data is not available, the simplified approach listed below may be used.

$$\Delta kWh = CFM\text{leak} \text{ x } k\text{W/CFM x CCAF x } Hours$$

Where:

CFM_{leak} = CFM leaks repaired

[33] 2022 WI TRM, PA Consulting Group. “Focus on Energy, Business Programs: Measure Life Study Final Report”. (August 25, 2009). https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf (See table1-2 on page 1-4)

= Sum of CFM using dB from ultrasonic measurement and psig reading in the table below[34]

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

kW/CFM = System power generation efficiency, obtained from model plate or CAGI sheets, full load power/full flow. Adjust for output pressure if different than specification sheets.
=If unknown, assume 0.19 kW/CFM.

CCAF =Trim compressor control type adjustment factor[35]
=Values applicable to trim air compressor, in following table.

Control Method	CCAF
Reciprocating – On/Off control	1.00
Reciprocating – Load/Unload	0.74
Screw-Load/Unload oil free	0.73
Screw – Load/Unload 1 gal CFM	0.43
Screw – Load/Unload 3 gal CFM	0.53
Screw – Load/Unload 5 gal CFM	0.63
Screw – Load/Unload 10 gal CFM	0.73
Screw-inlet modulation w/o blowdown	0.29
Screw-inlet modulation, blowdown	0.74
Screw-variable displacement	0.60
Screw-variable speed drive	0.97
Centrifugal IBV blowdown	0.20
Centrifugal IGV blowdown	0.26
Start/Stop	1.00

Hours = Compressed air system pressurized hours

[34] Values extrapolated from "Compressed Air Ultrasonic Leak Detection Guide" from UE Systems. Readings compensated for atmospheric pressure and taken at 40 kHz. (See page 6) Local file: "UE Systems compressed air ultrasonic leak detection.jpg"

[35] NREL, Factors based on power vs capacity curves from table 5 on page 16 for reciprocating, rotary screw compressors and table 2 on page 9 for centrifugal compressors, , "Chapter 22: Compressed Air Evaluation Protocol", https://www.nrel.gov/docs/fy17osti/68577.pdf

= Actual hours, or if unknown, assume values in table below, based on compressor operating schedule

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \text{ x } CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor = 0.0001379439[36]

MEASURE CODE:

[36]Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.2.3 Compressed Air Nozzle

DESCRIPTION

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

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 high efficiency compressed air nozzle meeting program requirements.

The air flow, CFM, is from the manufacturer model specification sheet, for the applicable working pressure.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard air nozzle that is OSHA approved for hand tools, or a standard blow off nozzle for continuous processing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 15 years.[37]

DEEMED MEASURE COST

Incremental measure costs are presented in the following table.[38]

Nozzle Diameter	Measure Cost
1/8”	$42
1/4"	$59
3/8”	$236
1/2"	$335

LOADSHAPE

Air Comp BUS

[37] “Focus on Energy Evaluation - Business Programs: Measure Life Study,” prepared for State of Wisconsin Public Service Commission by PA Consulting Group, August 25, 2009 (See page 89 or search "compressed air nozzle").
[38] 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. Data in local file: “2024 Air nozzle incremental cost.xlsx”

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = (CFM_{base} - CFM_{eff}) * kW/CFM * CCAF * Hours \text{ x \% Use}$$

Where:

CFM_{base} = Air flow through standard open nozzle.
= Actual rated flow at 80 psi, if known. If unknown, use CFM by orifice diameter for rounded edge, from table below.[39]

Orifice Diameter	SCFM
1/16"	5
1/8"	21
1/4"	85
3/8"	193
1/2"	343

CFM_{eff} =Engineered nozzle rate flow at 80 psi.

kW/100CFM = System power generation efficiency, obtained from model plate or CAGI sheets, full load power/full flow. Adjust for output pressure if different than specification sheets.
=If unknown, assume 0.19 kW/100 CFM, typical air compressor

CCAF =Trim compressor control type adjustment factor[40]
=Values applicable to trim air compressor, in following table.

Control Method	CCAF
Reciprocating – On/Off control	1.00
Reciprocating – Load/Unload	0.74
Screw-Load/Unload oil free	0.73
Screw – Load/Unload 1 gal CFM	0.43
Screw – Load/Unload 3 gal CFM	0.53
Screw – Load/Unload 5 gal CFM	0.63
Screw – Load/Unload 10 gal CFM	0.73
Screw-inlet modulation w/o blowdown	0.29
Screw-inlet modulation, blowdown	0.74
Screw-variable displacement	0.60
Screw-variable speed drive	0.97
Centrifugal IBV blowdown	0.20
Centrifugal IGV blowdown	0.26

[39] Moss, Sanford, "Flow of gases", https://www.engineersedge.com/fluid_flow/images/oriifce-pressure-drop.gif

[40] NREL, Factors based on power vs capacity curves from table 5 on page 16 for reciprocating, rotary screw compressors and table 2 on page 9 for centrifugal compressors, , "Chapter 22: Compressed Air Evaluation Protocol", https://www.nrel.gov/docs/fy17osti/68577.pdf

Start/Stop	1.00

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

%Use = Percent of the compressor total operating hours that the nozzle is in use
= Custom, or if unknown, assume 5%[41]

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh \text{ x } CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[42]

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

[41] 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.

[42] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.2.4 VSD Air Compressor

DESCRIPTION

This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls, or variable displacement control. A baseline modulating compressor regulates output by choking off the inlet air, which is not efficient. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per US Department of Energy (DOE) data for a variable speed compressor versus a modulating compressor. This measure applies only to an individual compressor ≤ 200 hp. Only one compressor per compressed air distribution system is eligible.

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a compressor 5-200 hp with variable speed control.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a modulating compressor with blow down 5-200 hp

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

10 years.[43]

DEEMED MEASURE COST[44]

Incremental Cost (\$) = ((127 x $hp_{compressor}$) + 1446) x 1.43[45]

Where:

$hp_{compressor}$ = compressor motor nominal horsepower

127 and 1,446 = compressor motor nominal hp to incremental cost conversion factor and offset

LOADSHAPE

Air Comp BUS

Algorithm

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

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

[45] Adjustment for inflation since incremental cost study is in 2008. The U.S. Bureau of Labor Statistic CPI Inflation Calculator was used to adjust 2008 (July) to 2024 (July). The resulting factor was 1.43. This adjustment was evaluated against current pricing of compressors (2024) and found to be a reasonable and appropriate.

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

0.9 = compressor motor nominal horsepower to full load kW conversion factor[46]

HOURS = compressor total annual hours of operation. Custom input, if unknown use the defaults based on shift structure 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
Unknown / Weighted average[47]	5702 hours: Weighting of 16% single shift, 23% two shift, 25% three shift and 36% continual

Co_{bb} = baseline compressor factor, refer to table below

[46]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 "VSD Air Compressor – Supporting Information_with40to50hpbucket.xlsx" for more information.

[47] Weighting based on DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules. (see Table 2-5 on page 2-3 https:/www.compressedairchallenge.org/data/sites/1/media/library/evaluation/Evaluation.pdf.

Baseline Compressor	Compressor Factor (≤ 40 hp)[48]	Compressor Factor (> 40 – 49 hp)[49]	Compressor Factor (50 – 200 hp) [50]
Modulating w/ Blowdown	0.890	0.886	0.863
Load/No-Load w/ 1 Gallon/CFM	0.909	0.905	0.887
Load/No-Load w/ 3 Gallon/CFM	0.831	0.827	0.811
Load/No-Load w/ 5 Gallon/CFM	0.806	0.802	0.786

CF_e = efficient compressor factor[51]
=0.705 for units ≤ 40 hp
=0.701 for units > 40 hp and < 50 hp
=0.658 for units 50 – 200 hp

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta k = \Delta kWh \times CF$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[52]

MEASURE CODE:

[48] 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 "VSD Air Compressor – Supporting Information_with40to50hpbucket.xlsx" for more information.
[49] Compressor factors for the size range between 40 and 50 hp were interpolated from data used to derive the compressor factors for the other size ranges. See "VSD Air Compressor – Supporting Information_with40to50hpbucket.xlsx" for more information.
[50] Compressor factors for this size range were developed using DOE part-load data for different compressor control types as well as load profiles from 45 compressors and 20 facilities. This data comes from ComEd Custom and Industrial Systems programs. The compressors were filtered to reflect only rotary screw compressors, between 50 and 200 hp, and operating a minimum of 4 hours per day, Additionally, compressors with clear and consistent baseload profiles were excluded from this analysis. See "VSD Air Compressor – Supporting Information_with40to50hpbucket.xlsx" for more information.
[51] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. 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.See "VSD Air Compressor – Supporting Information_with40to50hpbucket.xlsx" for more information.
[52] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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 ≥ 3 and ≤ 40 and to full or half-sized natural gas fired ENERGY STAR® combination ovens with a pan capacity ≥ 5 and ≤ 40 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 3.0, Effective October 12, 2023) [53]

Fuel Type	Operation	Idle Rate (Btu/hr for Gas, kW for Electric)	Cooking-Energy Efficiency (%)
Natural Gas (5-40 pan)	Steam Mode Convection Mode	≤ 200P+6,511 ≤ 140P+3,800	≥ 41 ≥ 57
Electric (5-40 pan)	Steam Mode Convection Mode	≤ 0.133P+0.64 ≤ 0.083P+0.35	≥ 55 ≥ 78
Electric (3-4 pan)	Steam Mode Convection Mode	≤ 0.60P ≤ 0.05P+0.55	≥ 51 ≥ 70

Note: P = Pan capacity as defined in Section 1.T of the Commercial Ovens Program Requirements Version 3.0.[54]

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

[53] ENERGY STAR® | Commercial Food Service Equipment | Commercial Ovens | ENERGY STAR® version 3.0 | https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria

[54] Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F1495-20 standard specification, required for ENERGY STAR® product certification. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf

The expected measure life is assumed to be 12 years. [55]

Deemed Measure Cost

The incremental capital cost for each type of combination oven is listed in the following table.

Equipment	Size	Incremental Cost[56]
Electric combination oven	All sizes	$1,850
Electric combination oven	All sizes	$1,701

Loadshape

Cooking BUS

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation for an electric combination oven below, default values are provided for each input and in the following tables, sourced from the "*Commercial Kitchen Equipment Savings Calculator*", published by ENERGY STAR® on March 2024. [57]

$$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec} + \Delta \text{PreHeat}Energy_{Elec}) \text{ x } Days/1{,}000$$

Where:

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

= $FoodCookedElec \text{ x } (EFOODConvElec / ElecEFFConvBase - EFOODConvElec / ElecEFFConvEE) \text{ x } \%Conv$

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

= $FoodCookedElec \text{ x } (EFOODSteamElec / ElecEFFSteamBase - EFOODSteamElec / ElecEFFSteamEE) \text{ x } \%Steam$

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

[55] ENERGY STAR®, "Results Detail" worksheet (Equipment Life field), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[56] ENERGY STAR®, "Oven Calcs" hidden worksheet (Incremental Cost field), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[57] ENERGY STAR®, Algorithms and assumptions derived from *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

	= $((ElecIDLE_{ConvBase}$ x $((Hours – FoodCooked_{Elec}$ $/ElecPC_{ConvBase})$ x $\%_{Conv}))$ - $(ElecIDLE_{ConvEE}$ x ((Hours - $FoodCooked_{Elec}$ /ElecPCConvEE) x %Conv)))
$\Delta IdleEnergy_{SteamElec}$	= Difference in idle energy between baseline and efficient combination oven in steam mode = $[(ElecIDLE_{SteamBase}$ x ((Hours – $FoodCooked_{Elec}$ / ElecPCSteamBase) x %Steam)) - (ElecIDLESteamEE x ((Hours - FoodCookedElec / ElecPCSteamEE) x %Steam))]
$\Delta PreHeatEnergy_{Elec}$	=Difference in preheat energy between baseline and efficient $=PreHeat_{Conv} - PreHeat_{EE}$
Days	= Annual days of operation = Actual, if unknown, use 365.25 days per year
1,000	= Watt-hour to kilowatt-hour conversion factor
$FoodCooked_{Elec}$	= Food cooked per day for electric combination oven = Actual, if unknown, use 200 lbs if P >4 or 125 lbs if P ≥ 15
$EFOOD_{ConvElec}$	= ASTM energy to food for electric combination oven in convection mode =73.2 Watt-hour/lb
ElecEff	=Energy efficiency of electric combination oven = Actual, if unknown use, use values from table below

Equipment	Base	Efficient
$ElecEFF_{Conv}$ (5-40 Pan)	72%	78%
$ElecEFF_{Conv}$ (>5 Pan)	65%	70%
$ElecEFF_{Steam}$ (5-40 Pan)	52%	55%
$ElecEFF_{Steam}$ (>5 Pan)	47%	51%

$\%_{Conv}$	= Percentage of time in convection mode = Actual, or if unknown, use 50%
$EFOOD_{SteamElec}$	= ASTM energy to food for electric combination oven in steam mode = 30.8 Watt-hour/lb
$\%_{steam}$	= Percentage of time in steam mode = 1 - $\%_{conv}$
$ElecIDLE_{Base}$	= Idle energy rate (W) of baseline electric combination oven = Actual, or if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecIDLE_{ConvBase}$)	Steam Mode ($ElecIDLE_{SteamBase}$)
> 5	680	2,090
≥ 5 to 40	1,320	5,260

Hours	= Average daily hours of operation = Actual, or if unknown, use 12 hours per day
$ElecPC_{Base}$	= Production capacity (lbs/hr) of baseline electric oven

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

Pan Capacity	Convection Mode ($ElecPC_{ConvBase}$)	Steam Mode ($ElecPC_{SteamBase}$)
> 5	29	45
5 to 40	107	151

$ElecIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR® electric combination oven in convection mode
= (0.083xP + 0.35)x1,000 for 5-40 pan capacity
= (0.05xP + 055)x1,000 for 3-4 pan capacity

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

Pan Capacity	Convection Mode ($ElecPC_{ConvEE}$)	Steam Mode ($ElecPC_{SteamEE}$)
> 5	37	59
5 to 40	174	247

$ElecIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR® electric combination oven in steam mode
= (0.133xP + 0.64)x1,000 for 5-40 pan capacity
= (0.60xP)x1,000 for 3-4 pan capacity

Summer Coincident Peak Demand Savings

$$\Delta k = \Delta kWh \text{ x } CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[58]

Natural Gas Energy Savings

Custom calculation for a gas combination oven below:[59]

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58 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

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

Where:

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

= FoodCookedGas x (EFOODConvGas / GasEFFConvBase EFOODConvGas/ GasEFFConvEE) x %Conv

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

= *FoodCookedGas x (EFOODSteamGas / GasEFFSteamBase – EFOODSteamGas / GasEFFSteamEE) x %Steam*

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

$= ((GasIDLEConvBase\ x\ ((Hours - FoodCookedGas / GasPCConvBase)\ x\ \%Conv)) - (GasIDLEConvEE\ x\ ((Hours - FoodCookedGas / GasPCConvEE)\ x\ \%Conv)))$

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

$= [(GasIDLESteamBase\ x\ ((Hours - FoodCookedGas / GasPCSteamBase)\ x\ \%Steam)) - (GasIDLESteamEE\ x\ ((Hours - FoodCookedGas / GasPCSteamEE)\ x\ \%Steam))]$

$\Delta PreHeatEnergy_{SteamGas}$ =Difference in daily preheat energy from baseline to efficient

100,000 = Btu to therms conversion factor

$FoodCooked_{Gas}$ = 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

= Actual, 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

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

Pan Capacity	Convection Mode ($GasIDLE_{ConvBase}$)	Steam Mode ($GasIDLE_{SteamBase}$)
< 15	9,840	24,003

15 ≤ P 30	11,734	27,795
≥30	15,376	27,957

$GasPC_{Base}$ = Production capacity (lbs/hr) of baseline gas combination oven
= Actual, 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
= 140xP + 3,800

$GasPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR® gas combination oven
= Actual, 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
= 200xP +6,511

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		≤ 10,417 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.[60]

Deemed Measure Cost

Actual incremental cost for this measure should be used. If actuals are unavailable use $2,000 for all electric cooker pan sizes and $1,000 for gas cooker.[61]

Loadshape

Cooking BUS

[60] ENERGY STAR®, "Results Detail" worksheet (Equipment Life field), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[61] Cost from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "EPA research using AutoQuotes, October 2020." https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx (See "Steam Cookers Calcs" tab rows 10 &51)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below with inputs for the existing cooker and efficient cooker; otherwise use deemed values from the variable default value and the table that follows, sourced from the *EnergyStar Commercial Equipment Savings Calculator,*.[62]

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

Where:

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

$= [(1 - SteamMode)\ x (IdleRate_{base} + SteamMode\ x\ Production_{base}\ x\ Pans\ xEFOOD/Eff_{base}) x\ (Hours - FoodCooked/(ProductionBase\ x\ Pans))] - [(1 - SteamMode)\ x (IdleRate_{ESTAR} + SteamMode\ x\ Production_{ESTAR}\ x\ Pans\ x\ EFOOD/Eff_{ESTAR}) x\ (Hours - FoodCooked/(Production_{ESTAR}\ x\ Pans))]$

ΔPreHeatEnergy =Difference in preheat energy between baseline and efficient cooker

=104.3Watt-hour

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

$= (FoodCooked\ x\ EFOOD/Eff_{base}) - (FoodCooked\ x\ EFOOD/Eff_{ESTAR})$

Days = Annual days of operation

= Actual, if unknown, use 365.25 days per year

1,000 = Watt to kWh conversion factor

SteamMode = Time (%) in constant steam mode

= Actual, if unknown, use 40%

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

= 1,200 W for steam generator, or 1,000 W for all others[63]

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

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

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

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

= Actual, if unknown, use 23.3 lb/hr

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

= Actual, if unknown, use 16.7 lb/hr

Pans = Pan capacity of steam cooker

= Actual, if unknown, use 6 pans

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

EFOOD	= ASTM energy to food testing standard = 30.8 Watt-hour/lb
Eff_{Base}	= Cooking efficiency (%) of baseline electric steam cooker[64]= Actual, if unknown, use 30%
Eff_{ESTAR}	= Cooking efficiency (%) of ENERGY STAR® electric steam cooker = Actual, if unknown, use 50%
Hours	= Average daily hours of operation = Acutal, if unknown, use 12 hours per day
FoodCooked	= Food cooked per day (lbs) = Actual, 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	37,857	17,642	7,383
4	45,004	21,543	8,569
5	52,047	25,509	9,693
6	59,040	29,410	10,822
10	86,803	41,452	16,564
Average	56,150	27,111	10,606

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh \ x \ CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[65]

Other variables as defined above.

Natural Gas Energy Savings

Custom calculation for a natural gas steam cooker below; otherwise use deemed value from the table that follows.[66]

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[64] ENERGY STAR®, “Steam Cooker Calcs” hidden worksheet: Cells C21, *Commercial Kitchen Equipment Savings Calculator*, (March 2024), Source of algorithms and assumptions for savings, https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[65] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[66] ENERGY STAR®, Algorithms and assumptions derived from *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

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

Where:

ΔIdleEnergy = $[(1 - SteamMode)\ x (IdleRateBase + SteamMode\ x\ ProductionBase\ x\ Pans\ x EFOOD/ EffBase) x\ (Hours - FoodCooked/ (ProductionBase\ x\ Pans))] - [(1 - SteamMode)\ x (IdleRateESTAR\ SteamMode\ x\ ProductionESTAR\ x\ Pans\ x\ EFOOD/ EffESTAR) x\ (Hours - FoodCooked/ProductionESTAR\ x\ Pans)]$

ΔCookingEnergy = $(FoodCooked\ x\ EFOOD/ EffBase) - (FoodCooked\ x\ EFOOD\ /\ EffESTAR)$

ΔPreHeatEnergy =Difference in daily preheat energy from baseline to efficient

100,000 = Btu to therms conversion factor

$IdleRate_{Base}$ = Idle energy rate (Btu/hr) of baseline gas steam cooker
= 16,500 Btu/hr[67]

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

Pan Capacity	$IdleRate_{ESTAR}$
3	6,250
4	8,333
5	10,417
6 to 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
= Actual, or if unknown, use 20 lb/hr

EFOOD = ASTM energy to food
= 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker[68]
= 16.5%

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

Other variables as defined above.

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

[67] Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR® for steam generator and boiler-based cookers (See formula in "Steam Cooker Calcs" tab cell "F26").

[68] Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR® for steam generator and boiler-based cookers (See formula in "Steam Cooker Calcs" tab cell "F21").

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.[69] Savings are the same for electric and gas steam cookers.

$$\Delta Water = (WaterUseBase - WaterUseESTAR)\ x\ Hours\ x\ Days$$

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[70]
= Actual, or if unknown, use 9.3 gal/hr

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

[70] 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 (See formula in "Steam Cooker Calcs" tab cell "G19" average of 15,10 &3).

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 3.0, Effective October 1, 2016)

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

The incremental capital cost for this measure is $1,500 for standard electric, $500 for large vat electric, $1,000 for standard gas, and $2,000 for large vat gas fryers.[72]

LOADSHAPE

Cooking BUS

[71] ENERGY STAR®, "Results Detail" worksheet (Equipment Life), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[72] ENERGY STAR®, "Fryer Calcs" hidden worksheet (Incremental Cost), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation for an electric fryer below; otherwise use deemed value of 3,311 kWh for standard fryers and 2,720 kWh for large vat fryers.[73]

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

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient fryer

$= (ElecIdle_{base} x\ (Hours - FoodCooked/ElecPC_{base})) - ElecIdle_{ESTAR}\ x\ (Hours - FoodCooked/ElecPC_{ESTAR}))$

ΔPreHeatEnergy =Difference in daily preheat energy between baseline and efficient

ΔCookingEnergy = Difference in cooking energy between baseline and efficient fryer

$= (FoodCooked\ x\ EFOODElec/ElecEff_{base}) - (FoodCooked\ x\ EFOOD_{Elec}/ElecEff_{ESTAR})$

ΔPreHeatEnergy =Difference in daily preheat energy from baseline to efficient

=Actual, or if unknown, 500 watts for standard and large vat

Days = Annual days of operation

= Actual, 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

= 1,200 W for standard fryers and 1,350 W for large vat fryers

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

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

Hours = Average daily hours of operation

= Actual, 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

= Actual, 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

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

$EFOOD_{Elec}$ = ASTM energy to food

= 167 Wh/lb

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73 ENERGY STAR®, "Results Detail" worksheet: Cells F25:F28, *Commercial Kitchen Equipment Savings Calculator*, (March 2024), Source of algorithms and assumptions for savings, https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

$ElecEff_{Base}$	= 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 = Actual, or if unknown, use 83% for standard and 80% for large vat fryers

Other variables as defined above

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta k = \Delta kWh \ x \ CF$$

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 fryer below; otherwise use deemed value of 512 therms/yr for standard fryers and 420 therms/yr for large vat fryers.[75]

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

Where:

ΔIdleEnergy	$= (GasIdleBase \ x \ (Hours - FoodCooked/GasPCBase)) - (GasIdleESTAR \ x \ (Hours - FoodCooked/GasPCESTAR))$
ΔCookingEnergy	$= (FoodCooked \ x \ EFOODGas/GasEffBase) - (FoodCooked \ x \ EFOOD_{Gas}/GasEff_{ESTAR})$
ΔPreHeatEnergy	=Difference in daily preheat energy between baseline and efficient
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 = Actual, 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

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[74] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[75] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx (See "Fryer Calcs" tab).

$GasPc_{ESTAR}$	= Production capacity of ENERGY STAR® gas fryer = Actual, or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers
$EFOOD_{Gas}$	= ASTM energy to food = 570 Btu/lb
$GasEff_{Base}$	= Cooking efficiency of baseline gas fryer = 35% for both standard and large vat fryers
$GasEff_{ESTAR}$	= Cooking efficiency of ENERGY STAR® gas fryer = Actual, 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 full 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 3.0, Effective January 12, 2023) [76]

Oven Capacity	Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency
Electric, Full Size, ≥ 5 pans	≤ 1.40 kW	≥ 76%
Electric, Full Size, < 5 pans	≤ 1.00 kW	≥ 76%
Half Size	≤ 1.00 kW	≥ 71%
Gas, full size	≤ 9,500 Btu/hr	≥ 49%

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.[77]

Deemed Measure Cost

[76] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria

[77] ENERGY STAR®, "Results Detail" worksheet (Equipment Life), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

The incremental capital cost for this measure is \$828 for half-size oven and \$1,191 for full size ovens.[78]

LOADSHAPE

Cooking BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric convection oven below; otherwise use 1,090 W for ≥5 pan full-size ovens, 4,576 W for <5 pan and 2,491 W for half-size ovens.[79]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta \text{PreHeat}Energy) \text{ x } Days/1{,}000$$

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient oven

$= (ElecIdleBasex\ (Hours - FoodCooked/ElecPCBase)) - (ElecIdleESTAR\ x\ (Hours - FoodCooked/ElecPCESTAR))$

ΔCookingEnergy = Difference in cooking energy between baseline and efficient oven

$= (FoodCooked\ x\ EFOODElec/\ ElecEffBase) - (FoodCooked\ x\ EFOODElec/\ ElecEffESTAR)$

ΔPreHeatEnergy =Difference in daily preheat energy from baseline and efficient oven

Days = Annual days of operation

= Actual, 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

= 1,630 W for ≥5 pan full-size ovens, 2,000 W for <5 pan and 1,510W for half-size ovens

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

= Actual, or if unknown, use values in efficient equipment table

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[78] Measure cost from ENERGY STAR® https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx (See "Oven Calcs" tab rows 11 and 149) which cites reference as https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf.

[79] ENERGY STAR®, "Results Detail" worksheet: Cells F26:F43, *Commercial Kitchen Equipment Savings Calculator*, (March 2024), Source of algorithms and assumptions for savings, https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

Hours	= Average daily hours of operation = Actual, or if unknown, use 12 hours per day
FoodCooked	= Food cooked per day = Actual, or if unknown, use 100 pounds
$ElecPC_{Base}$	= Production capacity of baseline electric convection oven, lb/hr = 102 for ≥5 pan full-size ovens, 68 for <5 pan and 45 for half-size ovens
$ElecPC_{ESTAR}$	= Production capacity of ENERGY STAR® electric convection oven = Actual, or if unknown, use 98 for ≥5 pan full-size ovens, 60 for <5 pan and 42 for half-size ovens
$EFOOD_{Elec}$	= ASTM energy to food for electric convection oven = 73.2 Wh/lb
$ElecEff_{Base}$	= Cooking efficiency of baseline electric convection oven = 74% for ≥5 pan full-size ovens, 65% for <5 pan and 64% for half-size ovens
$ElecEff_{ESTAR}$	= Cooking efficiency of ENERGY STAR® electric convection oven = Actual, or if unknown, use values in efficient equipment table

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[80]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 111 therms/yr.[81]

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

Where:

$$\Delta \text{IdleEnergy} = (GasIdleBasex \; (Hours - FoodCooked/GasPCBase)) - (GasIdleESTAR \; x \; (Hours - FoodCooked/GasPCESTAR))$$

$$\Delta \text{CookingEnergy} = (FoodCooked \; x \; EFOODGas/ \; GasEffBase) - (FoodCooked \; x \; EFOODGas/ \; GasEffESTAR)$$

ΔPreHeatEnergy =Difference in daily preheat energy from baseline and efficient oven, if unknown, assume 1,190 BTU/hr

100,000 = Btu to therms conversion factor

$GasIdle_{Base}$ = Idle energy rate of baseline gas convection oven
= 12,245 Btu/hr

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas convection oven
= Actual, or if unknown, use 9,500 Btu/hr

$GasPC_{Base}$ = Production capacity of baseline gas convection oven
= 95 lb/hr

$GasPC_{ESTAR}$ = Production capacity of ENERGY STAR® gas convection oven
= Actual, or if unknown, use 91 lb/hr

$EFOOD_{Gas}$ = ASTM energy to food for gas convection oven
= 250 Btu/lb

$GasEff_{Base}$ = Cooking efficiency of baseline gas convection oven
= 48%

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas convection oven
= Actual, or if unknown, use 49%.

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[80] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[81] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator. https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

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) [82]

Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
Idle Energy Rate	Cooking Efficiency Consumption	Idle Energy Rate	Cooking Efficiency Consumption
≤ 320 W/ft²	Reported	≤ 2,650 Btu/hr/ft²	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.[83]

Deemed Measure Cost

The incremental capital cost for this measure is:

Electric: $850 for a single sided and $0 for double sided

Gas: $1,250 for a single sided and $0 for double sided.[84]

Loadshape

Cooking BUS

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[82] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

[83] ENERGY STAR®, "Results Detail" worksheet (Equipment Life), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[84] Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "EPA research on available models using AutoQuotes, July 2016." https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx (See "Griddle Calcs" tab rows 23 & 51).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric griddle below; otherwise use deemed value of 2,641kWh.[85]

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

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient griddle

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

ΔCookingEnergy = Difference in cooking energy between baseline and efficient griddle

= $(FoodCooked\ x\ EFOOD_{Elec} / ElecEff_{Base}) - (FoodCooked\ x\ EFOOD_{Elec} / ElecEff_{ESTAR})$

ΔPreHeatEnergy =Difference in daily preheat energy baseline and efficient griddle

=Actual, if unknown, assume 2,000 W, 1 per day

Days = Annual days of operation

= Actual, 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

= Actual, or if unknown, use 320 W/ft^2

Width = Griddle width

= Actual, or if unknown, use 3 feet

Depth = Griddle depth

= Actual, or if unknown, use 2 feet

Hours = Average daily hours of operation

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

FoodCooked = Food cooked per day

= Actual, 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

= Actual, or if unknown, use 40 lb/hr

$EFOOD_{Elec}$ = ASTM energy to food

= 139 Wh/lb

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

[85] ENERGY STAR®, "Results Detail" worksheet, *Commercial Kitchen Equipment Savings Calculator*, (March 2024), Source of algorithms and assumptions for savings, https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

	= 65%
$ElecEff_{ESTAR}$	= Cooking efficiency of ENERGY STAR® electric griddle
	= Actual, or if unknown, use 70%

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \times CF$$

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.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas griddle below; otherwise use deemed value of 131.4 therms.[87]

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

Where:

ΔIdleEnergy	= $[GasIdle_{Base} \times (Width \times Depth) \times (Hours – FoodCooked/GasPC_{Base})] – [GasIdle_{ESTAR} \times (Width \times Depth) \times (Hours – FoodCooked/GasPC_{ESTAR}))$
ΔCookingEnergy	= $(FoodCooked \times EFOOD_{Gas}/ GasEff_{Base}) – (FoodCooked \times EFOOD_{Gas}/ GasEff_{ESTAR})$
ΔPreHeatEnergy	=Difference in daily preheat energy baseline and efficient griddle
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
	= Actual, 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
	= Actual, 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%

[86] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas griddle
= Actual, or if unknown, use 38%

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.3.6 Kitchen Demand Ventilation Controls

DESCRIPTION

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT[88]

The expected measure life is assumed to be 15 years.

MEASURE COST[88]

The incremental capital cost for this measure is:

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

LOADSHAPE

Cooking BUS

Algorithm

Calculation of Savings

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

Electric Energy Savings[89]

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

[89] https://www.nvenergy.com/publish/content/dam/nvenergy/brochures_arch/about-nvenergy/rates-regulatory/recent-regulatory-filings/nve/irp/NVE-18-06003-IRP-VOL9.pdf (NVE-18-06003-IRP-VOL9.pdf See page 147,182,340 first paragraph).

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

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[90]

Natural Gas Savings

$$\Delta Therms = CFM \; x \; HPx \; Annual \; Heating \; Load \; /(Eff(heat) \; x \; 100{,}000)$$

Where:

CFM = the average airflow reduction with ventilation controls per hood
= 430 cfm/HP

HP = actual if known, otherwise assume 7.75 HP[91]

Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air dependent on location. Actual, else value in table below.

Zone	Annual Heating Load (BTU/cfm)
Missouri Average[92]	137,000

Eff(heat) = Heating Efficiency
= actual if known, otherwise assume 80%[93]

100,000 = conversion from Btu to Therm

[90] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[91] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0, Volume 2: Commercial and Industrial Measures," Section 4.2.16, Kitchen Demand Ventilation Controls; IL Statewide TRM IL Statewide TRM Version 6.0 - Illinois Energy Efficiency Stakeholder Advisory GroupIllinois Energy Efficiency Stakeholder Advisory Group (ilsag.info)

[92] Opinion Dynamics Used IL-TRM_Version_8.0_dated_October-17-2019_Final_Volumes_1-4_Compiled "AMO_TRM Updates_Heating Load Estimate for Kitchen DCV_2020-06-12.xlsx" to compare savings values by weather zone from the IL TRM to zone-specific HDD values, and determined a linear relationship between Heating Load and HDD, then applied that linear relationship to HDD values (using base 60) for MO weather stations to estimate Heating Load values for zones in Ameren Missouri territory

[93] "Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0, Volume 2: Commercial and Industrial Measures", Section 4.2.16, Kitchen Demand Ventilation Controls; IL Statewide TRM IL Statewide TRM Version 6.0 - Illinois Energy Efficiency Stakeholder Advisory GroupIllinois Energy Efficiency Stakeholder Advisory Group (ilsag.info)

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

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) [94]

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[95]

Deemed Measure Cost

Actual incremental costs should be used if available. If actual costs are unknown, assume $1,000.[96]

Loadshape

Cooking BUS

Algorithm

[94] ENERGY STAR®, ,https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria

[95] ENERGY STAR®, "Results Detail" worksheet (Equipment Life), *Commercial Kitchen Equipment Savings Calculator*, (March 2024), https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

[96] ENERGY STAR® https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[97]

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

Where:

$IdleRate_{Base}$ = Idle energy rate (W) of baseline HFHC
= 30 x V

V = Interior volume (ft^3) of new HFHC
= Custom

$IdleRate_{ESTAR}$ = Idle energy rate (W) of ENERGY STAR® HFHC
= See table below for idle energy rates based on interior volume

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

Hours = Average daily hours of operation
= Actual, or if unknown, use 15 hours per day

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

1,000 = Wh to kWh conversion factor

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta k = \Delta kWh \ x \ CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001998949[98]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

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97 ENERGY STAR®, "Results Detail" worksheet, Commercial Kitchen Equipment Savings Calculator, (March 2024), Source of algorithms and assumptions for savings, https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

98 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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 the maximum flow for the product class, as listed by the DOE Energy Efficiency Standards, effective January 2019.

Product Class (spray force, ozf)	Maximum Flow Rate
Class 1, ≤ 5.0 ozf	<1.00 gpm
Class 2, >5.0 ozf to ≤8.0 ozf	<1.20 gpm
Class 3, >8.0 ozf	<1.28 gpm

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment will vary based on the delivery method with the maximum flow rate from the DOE Energy Conservation Standards[99] . The current standard, effective January 2019 is the baseline for TOS, the previous standard, effective January 2006, the baseline for retrofits and direct install.

Product Class (spray force, ozf)	Time of Sale Flow Rate	Retrofit, Direct Install, Flow Rate
Class 1, ≤ 5.0 ozf	1.00 gpm	1.6 gpm
Class 2, >5.0 ozf to ≤8.0 ozf	1.20 gpm	1.6 gpm
Class 3, >8.0 ozf	1.28 gpm	1.6 gpm

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

[99] US Energy Policy and Conservation Act, "Commercial Prerinse spray Valves, (January 2019), https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-O#431.266

The expected measure life is assumed to be 5 years.[100]

DEEMED MEASURE COST

When available, the actual cost of the measure should be used. If unknown, a default value of $92.90[101] may be assumed.

LOADSHAPE

Cooking BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

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

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

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
T_{out} = Water Heater Outlet Water Temperature
= Custom, otherwise assume Tin + 70°F temperature rise from Tin[102]
T_{in} = Inlet Water Temperature
= Custom, otherwise assume 59.3F[103]
EFF_{Elec} = Efficiency of electric water heater supplying hot water to pre-rinse spray valve
=Actual, otherwise assume 97%[104]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh\ x\ CF$$

Where:

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

[100] Consistent with Ameren Missouri MEEIA 2016-18 and KCPL TRM assumptions. Also consistent with DOE Final Determination Technical Support Document: Commercial Pre-Rinse Spray Valves, https://www.regulations.gov/document/EERE-2019-BT-STD-0034-0020.
[101] Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100).
[102] 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.
[103] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps.
[104] 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.

= 0.0001998949[105]

Natural Gas Energy Savings

ΔTherms = ΔGallons x 8.33 x 1 x (T_{out} - T_{in}) x (1/EFF_{Gas}) / 100,000

Where:

EFF_{Gas} = Efficiency of gas water heater supplying hot water to pre-rinse spray valve
= Actual, otherwise assume 80%[106]

Other variables as described above.

Water Impact Calculation

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

Where:

FLO_{base} = Base case flow in gallons per minute (gal/min). Use actual when appropriate if available, otherwise use values in table below.[107]

Product Class (spray force, ozf)	Time of Sale Flow (gpm)	Retrofit, Direct Install, Flow Rate
Class 1, ≤ 5.0 ozf	1.00 gpm	1.6 gpm
Class 2, >5.0 ozf to ≤8.0 ozf	1.20 gpm	1.6 gpm
Class 3, >8.0 ozf	1.28 gpm	1.6 gpm

FLO_{eff} = Efficient case flow in gallons per minute (gal/min). Use actual flow rate if known, otherwise use values in table below.

Product Class (spray force, ozf)	Maximum Flow Rate
Class 1, ≤ 5.0 ozf	1.00 gpm
Class 2, >5.0 ozf to ≤8.0 ozf	1.20 gpm
Class 3, >8.0 ozf	1.28 gpm

[105] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"
[106] IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment.
[107] EPA, https://www.epa.gov/watersense/pre-rinse-spray-valves

60 = Minutes per hour

$HOURS_{day}$ = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise use values in the table below.[108]

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

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

MEASURE CODE:

[108] 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 or low flow faucet 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, RF,TOS

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

Definition of Efficient Equipment

Low flow faucets or aerators for bathrooms meeting the EPA WaterSense flow rate of ≤1.5 gpm.[109]
Faucets or aerators for kitchen sinks exceeding the values in the Code of Federal Regulations listed for maximum allowable water flow at ≤2.2 gpm.[110]
Faucets or aerators for public lavatories exceeding the IPC Plumbing Code of ≤0.5 gpm.[111]

Fixture	Maximum Flow Rate gpm
Bathroom faucet, private	≤1.5
Kitchen faucet	<2.2
Lavatory faucet, public	<0.5

Definition of Baseline Equipment

The baseline condition flow rate faucet or aerator is the maximum flow requirement by the DOE Federal Regulations[112]

Fixture	Flow Rate gpm
Lavatory faucet or aerator	2.2
Kitchen faucet or aerator	2.2
Lavatory faucet, public	0.5

[109] US EPA, "High Efficiency Lavatory Faucet Specification", (October 2007),| https://www.epa.gov/watersense/bathroom-faucets
[110] CFR:: 10 Part 430, Kitchen faucet maximum flow rate, "Energy Conservation Program For Consumer Products", https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430
[111] ICC Plumbing Code, Maximum flow rate table, "Chapter 6 – Water Supply and Distribution", https://codes.iccsafe.org/content/IPC2021P3/chapter-6-water-supply-and-distribution
[112] IBID 110

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[113]

Deemed Measure Cost

The incremental cost for this measure is $9.40[114] for faucet low flow aerator and $44.40[115] for kitchen swivel low flow or program actual cost.

Loadshape

Water Heating BUS

Algorithm

Calculation of Savings

Electric Energy Savings

Savings are *per* faucet retrofitted.[116]

$$\Delta kWh = \%ElectricDHW \ x \ ((GPM_{base} - GPM_{low}) \ / \ GPM_{base}) \ x \ Usage \ x \ EPG_{electric} \ x \ ISR$$

Where:

%ElectricDHW = Actual

=If unknown, reference the water heat proportion by fuel type in the table below[117]

DHW fuel	%Electric_DHW
Electric	37.5%
Fossil Fuel	62.0%
Other	0.5%

GPM_{base} = Flow rate in gallons per minute, actual, or sourced from baseline equipment table.

GPM_{low} = Flow rate in gallons per minute, actual or certified equipment rate.

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113 Navigant Consulting, "ComEd Effective Useful Life Research Report", page 20 (May 14, 2018), https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf

114 Ameren MFLI direct install costs, Program years 2022 to 2023. Local file: "2.4.1 Low flow faucet aerator costs MFLI 2022 to 2023.xlsx"

115 IBID

116 This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

117 TRC program tracking data, Ameren MO C&I program participants (2014 to 2024), self-reported water heating fuel source, Local file: "2.4.1. C&I water heat source 2014 to 2024"

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 defaults in the table below (or substitute custom information into the calculation):

Building Type	Gallons HW per unit per day[118] (A)	Unit	Estimated % HW from Faucets[119] (B)	Multiplier[120] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (AxBxCxD)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Restaurant	0.7	meal/day	50%	75	meals per faucet	365	9,581
Sit-Down Restaurant	2.4	meal/day	50%	36	meals per faucet	365	15,768
Retail	2	employee	100%	5	employees per faucet	365	3,650
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
JrHigh 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 x 1.0 x (WaterTemp - SupplyTemp)) / ($RE_{electric}$ x 3412)
= (8.33 x 1.0 x (90 – 57.9)) / (0.98 x 3412) = 0.0800 kWh/gal

[118] ASHRAE, "Chapter 51: Service Water Heating", Table 6: Hot Water Demands and Use for Various Types of Buildings, *2023 ASHRAE HVAC Applications Handbook* (2023).

[119] Pacific Institute, estimated based on data provided in, "Appendix E: Details of Commercial Water Use and Potential Savings, by Sector," (2003), https://pacinst.org/wp-content/uploads/2013/02/appendix_e3.pdf

[120] 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 Waste Not, Want Not: The Potential for Urban Water Conservation in California - Pacific Institute (pacinst.org)) – 250/7 = 36. Fast food assumption estimated.

8.33	= Specific weight of water (lbs/gallon)
1.0	= Heat Capacity of water (btu/lb-F)
WaterTemp	= Assumed temperature of mixed water = 91 F [121]
SupplyTemp	= Assumed temperature of water entering building = 59.3 F [122]
$RE_{electric}$	= Recovery efficiency of electric water heater = 98% [123]
3412	= Converts Btu to kWh (Btu/kWh)
ISR	= In service rate of faucet aerators = Assumed to be 1.0

Summer Coincident Peak Demand Savings

$\Delta kW = \Delta kWh \times CF$

Where:

ΔkWh = calculated value above on a per faucet basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001811545 [124]

Fossil Fuel Impact Descriptions and Calculation

$\Delta Therms = \%FossilDHW \times ((GPM_{base} - GPM_{low}) / GPM_{base}) \times Usage \times EPG_{gas} \times ISR$

Where:

%FossilDHW	= proportion of water heating supplied by fossil fuel heating (see table below)
EPG_gas	= Energy per gallon of mixed water used by faucet (gas water heater) = (8.33 x 1.0 x (WaterTemp - SupplyTemp)) / (RE_gas x 100,000) = 0.00772 Therm/gal
RE_gas	= Recovery efficiency of gas water heater = 67% [115]
100,000	= Converts Btus to Therms (Btu/Therm)

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[121] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7x93)+(0.3x86)=0.91, https://www.efis.psc.mo.gov/Document/Display/34102.

[122] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps

[123] Electric water heater have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory https://beta.ahridirectory.org/search/24

[124] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

Other variables as defined above.

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	57%[125]

WATER IMPACT DESCRIPTIONS AND CALCULATION

$\Delta gallons = ((GPM_{base} - GPM_{low}) / GPM_{base}) \times Usage \times ISR$

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[125] Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region (see 'HC8.9 Water Heating in Midwest Region.xls'). If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used. [115] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

2.4.2 Circulator Pump

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The effective useful life is 15 years.[126]

Deemed Measure Cost

The assumed measure cost is $1,200 per pump.[127]

Loadshape

Miscellaneous BUS

Algorithm

Calculation of Energy Savings

Savings shown are per pump.

Electric Energy Savings

[126] 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 (see page 11).

127 Gas Technology Institute. (2014). 1003: Demand-based domestic hot water recirculation public project report. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014. (https://www.ilsag.info/wp-content/uploads/SAG_files/Portfolio_Planning_Process/Small_Group_Follow-up_Calls/Grundfos/1003_Demand_CDHW_Public_Project_Report_REVISED_FINAL_08-06-2014.pdf)

Deemed at 651 kWh per pump.[128]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \ x \ CF$$

Where:

ΔkWh = calculated value above on a per faucet basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor =0.0001379439[129]

NATURAL GAS SAVINGS

ΔTherms = 55.9 x number of dwelling units[130]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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[128] Gas Technology Institute. (2014). 1003: Demand-based domestic hot water recirculation public project report. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014. Average of 725 kWh and 578 kWh reported savings per pump, page 9. Value is pump only savings and not water heater savings. (https://www.ilsag.info/wp-content/uploads/SAG_files/Portfolio_Planning_Process/Small_Group_Follow-up_Calls/Grundfos/1003_Demand_CDHW_Public_Project_Report_REVISED_FINAL_08-06-2014.pdf)

[129] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[130] IBID 128, Average therms saved per dwelling unit for water heating.

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 storage 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, 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.[131] Residential storage water heaters greater than 55 gallons may not be eligible as the baseline is near that of a heat pump water heater.

Equipment	Size	Draw	Efficiency, UEF
Residential storage, ≤75 kBTUh	≤55 gal	Very small	.8808 - (0.0008 x V_{rated})
Residential storage, ≤75 kBTUh	≤55 gal	Low	.9254 - (0.0003 x V_{rated})
Residential storage, ≤75 kBTUh	≤55 gal	Medium	.9307 - (0.0002 x V_{rated})
Residential storage, ≤75 kBTUh	≤55 gal	High	.9349 - (0.0001 x V_{rated})
Residential storage, ≤75 kBTUh	>55 gal and ≤120 gal	Very small	1.9236 - (0.0011 x V_{rated})
Residential storage, ≤75 kBTUh	>55 gal and ≤120 gal	Low	2.0440 - (0.0011 x V_{rated})
Residential storage, ≤75 kBTUh	>55 gal and ≤120 gal	Medium	2.1171 - (0.0011 x V_{rated})
Residential storage, ≤75 kBTUh	>55 gal and ≤120 gal	High	2.2418 - (0.0001x V_{rated})
Commercial storage, all	All	Medium	0.98

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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131 CFR:: 10 Part 430, Electric storage water heater efficiency, "Energy Conservation Program For Consumer Products", https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C#p-430.32(d)(1) for residential water heaters and CFR:: 10 Part 430, Electric storage water heater efficiency, "Energy Conservation Program For Industrial Products", for commercial water heaters.

The expected measure life is assumed to be 15 years.[132]

Deemed Measure Cost

Actual costs should be used where available. Incremental capital costs are presented in the table below for heat pump water heaters from 40 gallons to 80 gallons of storage volume.[133]

Type	Rated Volume (gal)	Incremental Cost
Heat Pump	40 to 50	$1,154
Heat Pump	55 to 65	$1,269
Heat Pump	66 to 80	$1,646

For larger HPWHs, incremental capital costs are presented below based on heating capacity.[134]

Heating Capacity (MBtu/hr)	Incremental Cost
10-50	$4,000
>50-100	$7,000
>100-300	$10,000
>300-500	$14,000
>500	$18,000

Loadshape

Water Heating BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

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

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

Where:

[132]DOE, Table I.2, lifetime of storage water heaters, "Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters", https://www.federalregister.gov/documents/2024/05/06/2024-09209/energy-conservation-program-energy-conservation-standards-for-consumer-water-heaters

[133] Big box retail online pricing (August 2024), Comparison of electric resistance to heat pump water heater for three manufacturer's with the same model series, Local file: "2.4.3 Electric water heater retail cost August 2024 data.xlsx"

134 MEMD, Commercial heat pump water heater incremental costs, "Commercial" worksheet, Cell range Q332:Q336, *2024 MEMD Master Database*, https://www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database

kWh_cool	= Cooling savings from conversion of heat in building to water heat[135]
kWh_heat	= Heating cost from conversion of heat in building to water heat (dependent on heating fuel)
UEF_{BASE}	= Efficiency of baseline water heater according to federal standards, expressed as Uniform Energy Factor (EF)
	= See table below
UEF_{EE}	= UEF of heat pump water heater
	= Actual
HWU_{GAL}	= Estimated annual hot water consumption (gallons)
	= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided below to develop an estimate.
γWater	= Specific weight of water
	= 8.33 pounds per gallon
T_{OUT}	= Tank temperature
	= Actual, if unknown assume 125 °F [136]
T_{IN}	= Incoming water temperature from well or municipal system
	= 59.3 °F [137]
1.0	= Heat capacity of water (1 Btu/lbx°F)
3,412	= Conversion factor from Btu to kWh
LF	= Location Factor
	= 1.0 for HPWH installation in a conditioned space
	= 0.5 for HPWH installation in an unknown location[138]
	= 0.0 for installation in an unconditioned space
53%	= Portion of reduced waste heat that results in cooling savings[139]
43%	= Portion of reduced waste heat that results in increased heating load[140]
LM	= Latent multiplier to account for latent cooling demand[141]
	= 3.0 for St. Louis, MO
COP_{COOL}	= COP of central air conditioner
	= Actual

[135] 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.
[136] 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.
[137] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps
[138] Professional judgment.
[139] 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.
[140] 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.
[141] 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.

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

%Cool = Percentage of buildings with central cooling
= 100% for cooling in the home and 0% for no cooling in the home

%ElectricHeat = Percentage of buildings with electric heat
= 100% for electric heating fuel and 0% for gas heating fuel

Equipment Type	Size Category	Federal Standard Minimum Efficiency
HPWH ≤12 kW	≤55 gallon	EF: 0.96 – (0.0003 x rated volume in gallons)
HPWH >12 kW	>120 gallon	Et: 98%[142]

Method 1 to estimate HWU_{GAL} – Consumption per water heater capacity

$$HWU = Consumption/cap \ x \ Capacity$$

Where:

Consumption/cap = Estimate of consumption per gallon of tank capacity, dependent on Building Type (see table below)[143]

Capacity = Capacity of hot water heater in gallons
= Actual

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

Method 2 to estimate HWUGAL – Consumption by facility size[144]

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

143 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.

144 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting," Lawrence Berkeley National Library, December 1995 (See Table 2, page 6).

Building Type	Gallons HW 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 Restaurant	0.7	meal/day	784.6	365	200,465
Sit-Down Restaurant	2.4	meal/day	340	365	297,840
Retail	2	employee	1	365	730
Grocery	2	employee	1.1	365	803
Warehouse	2	employee	0.5	250	250
Elementary School	0.6	person	9.5	200	1,140
Jr High/High School	1.8	person	9.5	200	3,420
Health	90	patient	3.8	365	124,830
Motel	20	room	5	365	36,500
Hotel	14	room	2.2	365	11,242
Other	1	employee	0.7	250	175

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \ x \ CF$$

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001811545[145]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

145 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.4.4 Low Flow Showerheads

Description

This measure relates to the direct installation of a low flow showerhead in a commercial building or common areas in other building types. Expected applications include small business, office, restaurant, or motel. For living units, the residential low flow showerhead should be used.

This measure was developed to be applicable to the following program type: DI, RF,TOS

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

Definition of Efficient Equipment

Low flow showerheads meeting the EPA WaterSense flow rate of ≤2.0 gpm.[146]

Fixture	Maximum Flow Rate, gpm
Showerhead	≤2.0

Definition of Baseline Equipment

The baseline condition flow rate showerhead is 2.5 gpm.

Fixture	Flow Rate, gpm
Showerhead	2.5

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years. [147]

Deemed Measure Cost

The incremental cost for this measure is $12.00 or program actual.[148]

Loadshape

Water Heating BUS, or Water Heating RES if installed in the common area of multi-family housing.

Algorithm

[146] DOE, Showerhead regulations, https://www.epa.gov/watersense/showerheads#:~:text=Did%20you%20know%20that%20standard,no%20more%20than%202.0%20gpm.

[147] GDS Associates, Page C-14, Table C-6, "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", (June 2007) .Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family.

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

Calculation of Savings

Electric Energy Savings

Note these savings are *per* showerhead retrofitted.

$$\Delta kWh = \%ElectricDHW \times (GPM_{base} \times L_{base} - GPM_{low} \times L_{low}) \times NSPD \times 365.25 \times EPG_{electric} \times ISR$$

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating (see values in table below)

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	43%[149]

GPM_{base} = Flow rate in gallons per minute, actual, or 2.67 gpm if unknown.

L_{base} =Shower length in minutes with baseline showerhead
=8.20 minutes

GPM_{low} = Flow rate in gallons per minute, actual or certified equipment rate.

L_{low} =Shower length in minutes with low flow showerhead
=8.20 minutes

NSPD =Estimated showers per day per showerhead
=Actual. If unknown, apply 1.0 conservative assumption.

$EPG_{electric}$ =Energy per gallon of hot water supplied by electric

=(8.33 x1.0 x(ShowerTemp-SupplyTemp)/($RE_{electric}$x3412)

=0.125 kWh/gallon

8.33 =Specific weight of water (lbs/gallon)

1.0 =Heat capacity of water (BTU/lb-°F)

ShowerTemp =Assumed mixed water temperature

=105.0 F[150]

SupplyTemp =Assumed water temperature entering water heater

=59.3 F[151]

$EPG_{electric}$ = Energy per gallon of mixed water used by faucet (electric water heater)

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[149] 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.

[150] Ameren Missouri Efficient Kits Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 32.

[151] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps

= *(8.33 x 1.0 x (WaterTemp - SupplyTemp)) / (RE$_{electric}$ x 3412)*
= (8.33 x 1.0 x (90 – 57.9)) / (0.98 x 3412) = 0.0800 kWh/gal

RE$_{electric}$ = Recovery efficiency of electric water heater
= 98% [152]

3412 = Converts Btu to kWh (Btu/kWh)

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh \ x \ CF$

Where:

ΔkWh = calculated value above on a per showerhead basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001811545[153], installed in the common area of multi-family housing.
= 0.0000887318[154] if installed in the living area of multi-family housing.

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Therms = \%FossilDHW \ x \ (GPM_{base} \ x \ L_{base} - GPM_{low} x \ L_{low}) \ x \ NSPD x \ 365.25 x \ EPG_{gas} \ x \ ISR$$

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating (see table below)

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	57%

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

RE_gas = Recovery efficiency of gas water heater
= 67%

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

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

153 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

154 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

WATER IMPACT DESCRIPTIONS AND CALCULATION

$\Delta gallons = x\ (GPM_{base} x\ L_{base} - GPM_{low} x L_{low})\ x\ NSPD x\ 365.25 x ISR$

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

Table 1 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 Metro		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[155]	1067	1018	1196	937	1217	865	1118	1085	910	996	1060	1053	1164	986

[155] 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 learning 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,[156] 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 9 years[157] based upon a residential EUL analysis.

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 $264. [158]

Loadshape

Cooling BUS
Heating BUS

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[156] The square footage of the small office prototype building modeled in is 7,500 sf.
157 CADMUS, "EUL analysis of residential smart communicating thermostat – Vendor A and B", Memorandum for Southern California Edison, (February 2019), for the California eTRM, Residential Smart Thermostat Measure, https://www.caetrm.com/measure/SWHC039/08/.

[158] Ameren Missouri DSM Business Program participants, 1/2019 through 7/2024, includes equipmentLocal file: "2.5.1 Measure Cost.xlsx"

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \Delta\Delta kWh_{cooling} + \Delta\Delta kWh_{heating}$$

$$\Delta kWhcooling_{cooling} = EFLH_{COOL} \; x \; kBtuh_{COOL} \; x \; (1/SEER2) \; x \; ESF_{COOL}$$

$$\Delta kWh_{heating} = EFLH_{HEAT} \; x \; kBTUh_{HEAT} \; x \; (1/HSPF2) \; x \; ESF_{HEAT}$$

Where:

SEER2 = Seasonal Energy Efficiency Ratio for cooling
= Actual; or if unknown, assume 13.4 SEER2.

HSPF2 =Heating Seasonal Performance Factor
= Actual; or if unknown, assume 8.2 HSPF2.

$EFLH_{COOL}$ = Effective Full Load Cooling Hours
= Actual; or if unknown, refer to *Table 1* by building type.

$EFLH_{HEAT}$ = Effective Full Load H Hours
= Actual; or if unknown, refer to *Table 1* by building type.

$kBTUh_{COOL}$ = Cooling system capacity; 1,000 Btu/h
= Actual

$kBTUh_{HEAT}$ =Heating system capacity: 1,000 Btuh/h
=Actual

ESF_{COOL} = Cooling energy savings factor
= Assume 0.139[159]

ESF_{HEAT} =Heating energy savings factor
=Assume 0.125[160]

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh_{cool} \; x \; CF$$

Where:

ΔkWh = Cooling electric energy savings, as calculated above

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[159] Cadmus (Aarish, C., M. Perussi, A. Rietz, and D. Korn). *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program,* page 41. Prepared for Northern Indiana Public Service Company and Vectren Corporation. (January 2015) http://www.cadmusgroup.com/wp-content/uploads/2015/06/Cadmus_Vectren_Nest_Report_Jan2015.pdf?submissionGuid=7cbc76e9-41bf-459a-94f5-2b13f74c4e52%20%20.

[160] IBID

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840[161]

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms_{heating} = EFLH_{HEAT} \times kBTUh_{GAS} \times (1/AFUE) \times ESF_{HEAT}$$

Where:

$EFLH_{HEAT}$ = Effective Full Load Heating Hours
= Actual; or if unknown, refer to *Table 1* by building type

$kBTUh_{Gas}$ = Heating system capacity: 1,000 Btuh/h
=Actual

AFUE = Annual Fuel Utilization Efficiency
=Actual, or if unknown, assume 0.80.

ESF_{HEAT} =Heating energy savings factor
=Assume 0.125[162]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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[161] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[162] Cadmus (Aarish, C., M. Perussi, A. Rietz, and D. Korn). Evaluation of the 2013–2014 Programmable and Smart Thermostat Program, page 41. Prepared for Northern Indiana Public Service Company and Vectren Corporation. (January 2015) http://www.cadmusgroup.com/wp-content/uploads/2015/06/Cadmus_Vectren_Nest_Report_Jan2015.pdf?submissionGuid=7cbc76e9-41bf-459a-94f5-2b13f74c4e52%20%20.

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,[163] 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[164] based upon equipment life only.[165]

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 $160.[166]

Loadshape

Cooling BUS

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

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

[165] 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.

[166] Based upon Nicor, https://www.ilsag.info/wp-content/uploads/Nicor-Gas-2022-2025-EE-Plan_filed-March-2021.pdf (see measure# 239 pg 141, $84 measure cost + $56 labor + $28 material). If Missouri average costs are available, they should be used.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = SQft \ x \ SavingsFactor \ x \ PF \ / \ EER_{EXIST}$$

Where:

Sqft = Square footage of building controlled by thermostat

SavingsFactor = 0.578 kWh/sf-yr[167]

PF = Persistence Factor to account for thermostat being placed on hold, reset or bypassed.
= Actual if provided in program evaluation, else assume 50%[168]

EER_{EXIST} = Efficiency rating of existing cooling equipment EER (btu hr/W)

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kW \ x \ CF$$

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840[169]

Natural Gas Energy Savings

$$\Delta Therms = SQft \ x \ SavingsFactor \ x \ PF \ / \ (100 \ x \ AFUE_{EXIST})$$

Where:

SQft = Square footage of building controlled by thermostat

Savings Factor = 9.940 kBtu/sf-yr[170]

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

$AFUE_{EXIST}$ = Efficiency rating of existing heating equipment (AFUE), in decimal form.

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[167] 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).

[168] 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" https://www.nrel.gov/docs/fy13osti/56637.pdf, 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)." https://eta.lbl.gov/publications/usability-residential-thermostats

[169] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

[170] 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:

2.5.3 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 & 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 a terminal reheat system, a custom savings calculation should be used to determine the heating savings; cooling savings are still applicable to the measure.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability, and is not required by the local building code. The current code minimum for outdoor air (OA) is 5 CFM per occupant (ASHRAE 62.1-2022) for office buildings, which is the value assumed in this measure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years.[171]

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

[171] Based on CO_2 sensor estimated life, determined through conversations with contractors to have a minimum lifetime of 10 years. It is recommended that they are part of a normal preventive maintenance program, as calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they can fall out of tolerance over time.

Calculation of Energy Savings

Electric Energy Savings

For facilities heated by natural gas, cooling savings are:

$$\Delta kWh = SQFT_{cond} \,/\, 1000 \; x \; SF_{cooling}$$

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

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

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

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

Where:

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

Savings factors are based on Building Type and weather zone – see tables below.[172]

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 Metro, 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

[172] 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 Metro, MO	Kansas City, MO	Average/ Unknown (Knob Noster, MO)
Office - Low-rise	171	191	145	151	156	176	159
Office - Mid-rise	114	128	97	100	104	117	106
Office - High-rise	154	172	130	135	140	158	143
Religious Building	1,118	1,248	945	983	1,018	1,149	1,036
Restaurant	799	892	675	702	727	821	740
Retail - Department Store	277	310	234	244	252	285	257
Retail - Strip Mall	184	205	155	161	167	189	170
Convenience Store	134	150	114	118	122	138	125
Elementary School	475	531	402	418	433	488	440
High School	465	519	393	409	423	478	431
College/University	923	1,031	780	812	840	949	856
Healthcare Clinic	331	370	280	291	301	340	307
Lodging	157	175	132	138	143	161	145
Manufacturing	122	136	103	107	111	125	113
Special Assembly Auditorium	1,335	1,490	1,128	1,173	1,215	1,371	1,236

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWhcooling \ x \ CF$$

Where:

$\Delta\ kWh_{cooling}$ = Electric energy savings, as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840[173]

NATURAL GAS SAVINGS

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

Where:

$SF_{Heat\ Gas}$ Savings factor for facilities heated by natural gas – see table below

Building Type	$SF_{Heat\ Gas}$ (Therm/1000 sq ft)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis Metro, 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:

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173 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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.[174]

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:[175]

Supply Fan 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

LOADSHAPE

[174] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for electronic building controls.
[175] Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656. U.S. Department of Energy, (July 2013).

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

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

Where:

P_{sf} = Nominal horsepower of supply fan motor

SF = Fan energy savings factor (kWh/hour/horsepower)
= 0.558[176]

$Hours_{fan}$ = Annual operating hours for fan motor based on Building Type. Default hours are provided for HVAC applications by Building Type.[177] When available, actual hours should be used, especially in instances where RTU operation is seasonal.

176 US Department of Energy, "Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656.", page 86, (July 2013). https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf?__hstc=249664665.3c4d37ff926a6dcbd64478550ad8ba16.1723665944789.1723665944789.1723665944789.1&__hssc=249664665.1.1723665944789&__hsfp=2087961721. Savings factors were consistent across the capacity range. See "RTU Control Savings.xlsx" for additional details.

177 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	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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \, x \, CF$$

Where:

ΔkWh = As calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004439830[178]

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:

[178] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.5.5 Electric Chiller

Description

This measure involves the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life or the installation of a new system in an existing building (i.e., time of sale). Only single-chiller applications should be assessed with this methodology. For multiple chiller projects, a custom analysis should be used to establish savings.

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to meet the 2015 IECC energy efficiency requirements. Chillers are rated for both the full load efficiency and the integrated part load efficiency. Chiller efficiency can be sourced by either Path A when the system is designed for full load efficiency, or Path B when designed for part load efficiency.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 23 years.[179]

Deemed Measure Cost

The incremental capital cost for this measure is based on the IPLV efficiency improvement over a code based minimum efficient chiller. The cost is per 0.01 IPLV improvement over code, per ton. A 150 ton screw chiller with an IPLV of 0.374, has an incremental cost of $27,834, when the minimum code based efficiency is 0.44.

Equipment	Incremental Cost[180] $/0.01 IPLV above code/ton	Base IPLV
Water cooled screw chiller	$28	2015 IECC or better
Water cooled centrifugal chiller	$35	2015 IECC or better

Loadshape

Cooling BUS

[179] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for centrifugal chillers (page 38.3).

[180] Incremental cost aggregated from Southern California Edison data in the California eTRM,"Water Cooled Chiller" measure incremental cost data (November 2020), https://www.caetrm.com/measure/SWHC005/03/. Aggregated data in file "SWHC005_Water-Cooled_Chiller_Cost_Data_2020Q3_aggregated by 0.01 IPLV per ton.xlsx"

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For a chiller operating primarily at full load, (Path A compliance).

$$\Delta kWh = TONS\ x\ (IPLV_{BASE} - IPLV_{EE})\ x\ EFLH$$

For a chiller operating primarily at part load, (Path B compliance).

$$\Delta kWh = TONS\ x\ (FL_{BASE} - FL_{EE})\ x\ EFLH$$

Where:

TONS = Chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)
= Actual installed

$IPLV_{BASE}$ =Efficiency of baseline equipment expressed as Integrated Part Load Value (kW/ton). Chiller units are dependent on chiller type. See 'Chiller Units, Conversion Values' and 'Baseline Efficiency Values by Chiller Type' and Capacity in the Reference Tables section.
=Code based minimum part load efficiency for same type, capacity installed

FL_{BASE} = Efficiency of baseline equipment expressed as Full Load (kW/ton).

=Code based minimum part load efficiency for same type, capacity installed

$IPLV_{EE}$ = Efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)
= Actual installed

FL_{EE} = Efficiency of high efficiency equipment expressed as Full Load (kW/ton)
=Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in Table 1.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWH\ x\ CF$$

Where:

ΔkWh = Annual electricity savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009106840[181]

[181] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Reference Tables

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

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

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

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

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

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

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

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

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

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

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

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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[e]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≥ 0.680 FL	≥ 0.718 FL	≥ 0.660 FL	≥ 0.680 FL	
			≥ 0.580 IPLV	≥ 0.540 IPLV	≥ 0.540 IPLV	≥ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.
c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.
d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

MEASURE CODE:

2.5.6 Heat Pump Systems

Description

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

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

Definition of Efficient Equipment

For this characterization to apply, the efficient equipment is assumed to be a high-efficiency air-cooled, water source, ground water source, or ground source heat pump system that exceeds the heating and cooling efficiency listed in Federal Energy Efficiency Standards.

Federal Energy Efficiency Standards (effective January 2023)[182]

Heat Rejection	Capacity kBTUh	Type	Supplemental Heat Source	
			ER heat or No heat	All other heat
Air Source	< 65	Packaged 1 or 3 phase	13.4 SEER2 6.7 HSPF2	13.4 SEER2 6.7 HSPF2
	<65	Split 1 or 3 phase	14.3 SEER2 7.5 HSPF2	14.3 SEER2 7.5 HSPF2
	≥65 and <135	Packaged	14.1 IEER 3.4 COP	13.9 IEER 3.4 COP
	≥135 and <240	Packaged	13.5 IEER 3.3 COP	13.3 IEER 3.3 COP
	≥240 and <760	Packaged	12.5 IEER 3.2 COP	12.3 IEER 3.2 COP
Water Source	<17	Packaged	12.2 EER 4.3 COP	
	≥17 and <65	Packaged	13.0 EER 4.3 COP	
	≥65 and <135	Packaged	13.0 EER 4.3 COP	

For VRF heat pumps, vertical heat pumps, and other heat pumps, refer to the tables within the Federal Energy Efficiency Standards.

Definition of Baseline Equipment

Time of Sale, New Construction: 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 Federal Energy Efficiency Standards.

[182] DOE|Title10,Part 431|https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431

Retrofit, Early Replacement: For this characterization to apply, the existing equipment is working with a remaining useful life. After, remaining useful life period, the baseline is the Time of Sale baseline meeting the Federal Energy Efficiency Standards.

For unit with a capacity less than 65 kBTUh, the baseline efficiency may be converted to the newer ratings expressed by SEER2 and HSPF2.

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent. Equipment capacities less than 65 kBtu/hr may be rated with the SEER2 efficiency (single phase, residential units), while larger units rated with EER or IEER.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[183]

Deemed Measure Cost

For analysis purposes, the incremental capital cost for this measure is assumed as $104 per ton per SEER or IEER unit increase over the base case efficiency for air-cooled units.[184] The incremental cost for all other equipment types should be determined on a site-specific basis.

For a 120,000 BTUh, 16.1 IEER air cooled heat pump without auxiliary heat, the incremental cost is:

10 tons x (16.1 IEER – 14.1 IEER) x $104 = $2,080

Loadshape

Cooling BUS
Heating BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

$$\Delta kWh = Annual\ kWh\ Savings_{cool} + Annual\ kWh\ Savings_{heat}$$

$$Annual\ kWh\ Savings_{cool} = kBtu/hr_{cool}\ x\ [(1/SEER2_{base}) - (1/SEER2_{EE})]\ x\ EFLH_{cool}$$

$$Annual\ kWh\ Savings_{heat} =$$

[183] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for commercial air to air heat pumps (pg 651 or 38.3).

[184] AESC Inc, ASK Energy Inc, SDGE, "Industry Standard Practice Study of Commercial Unitary Air Conditioning and Heat Pumps Systems", page 36 (September 2021) https://www.caetrm.com/media/reference-documents/Unitary_HVAC_ISP_Report_Final.pdf

$$kBtu/hr_{heat} x\ [(1/HSPF2_{base}) - (1/HSPF2_{EE})]\ x\ EFLH_{heat}$$

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

$$\Delta kWh\ =\ Annual\ kWh\ Savings_{cool}\ +\ Annual\ kWh\ Savings_{heat}$$

$$Annual\ kWh\ Savings\ _{cool} =$$

$$kBtu/hr_{cool}\ x\ [(1/IEER_{base}) - (1/IEER_{EE})]\ x\ EFLH_{cool}$$

$$Annual\ kWh\ Savings_{heat}\ =$$

$$kBtu/hr_{heat}\ x\ [\frac{1}{(COP_{base} x\ 3.412)} - \frac{1}{(COP_{EE}\ x\ 3.412)}]\ x\ EFLH_{heat}$$

Where:

$kBtu/hr_{cool}$	= Capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr). = Actual installed
$SEER_{base}$	= Seasonal Energy Efficiency Ratio of the baseline equipment = SEER based on current DOE energy efficiency standards for TOS,NC =SEER based on existing efficiency for Retrofit = For units with cooling capacity <65kbtu/hr and efficient unit is measured in terms of SEER2, convert $SEER_{base}$ to $SEER2_{base}$.[185]
$SEER_{ee}$	= Seasonal Energy Efficiency Ratio of the energy efficient equipment. = Actual installed
$EFLH_{cool}$	= Equivalent Full Load Hours for cooling are provided in Table 1 Effective Full Load Heating and Cooling Hours, by Building Type
$HSPF_{base}$	= Heating Seasonal Performance Factor of the baseline equipment = HSPF from tables below, based on the applicable IECC. For units with cooling capacity <65kbtu/hr and efficient unit is measured in terms of HSPF2, convert $HSPF_{base}$ to $HSPF2_{base}$.[186]
$HSPF_{ee}$	= Heating Seasonal Performance Factor of the energy efficient equipment. = Actual installed. If rating is COP, HSPF = COP x 3.413
$EFLH_{heat}$	= Heating mode equivalent full load hours are provided in Table 1 Effective Full Load Heating and Cooling Hours, by Building Type

[185] SEER to SEER2 conversion factor: SEER2 = SEER x 96%. Conversion factor for SEER to SEER2 is used when converting an existing system that is rated in SEER to SEER2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in the same metrics (e.g., both SEER or SEER2) before applying formulas.

[186] HSPF to HSPF2 conversion factor: HSPF2 = HSPF x 87%. Conversion factor for HSPF to HSPF2 is used when converting an existing system that is rated in HSPF to HSPF2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in the same metrics (e.g., both HSPF or HSPF2) before applying formulas.

$IEER_{base}$ = Integrated Energy Efficiency Ratio of the baseline equipment

= IEER from tables below, based on the applicable IECC.

$IEER_{ee}$ = Integrated Energy Efficiency Ratio of the energy efficient equipment.

= Actual installed

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

= Actual installed

3.412 = Btu per Wh.

COP_{base} = Coefficient of performance of the baseline equipment

= COP from tables below, based on the applicable IECC. If rating is HSPF, COP = HSPF / 3.412. If rating is HSPF2, COP2 = HSPF x 87% / 3.412

COPee = Coefficient of performance of the energy efficient equipment.

= Actual installed

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[187]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[187] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

Description

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

This measure characterizes:

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

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed the Federal Energy Efficiency Standards.[188] The non-standard size equipment type applies to installations with wall openings less than 16” high or less than 42” wide, and only for retrofit applications.

Equipment Type	Capacity	Minimum Efficiency (Cap= Btuh)
PTAC Standard Size	<7 kBtuh	11.9 EER
PTAC Standard Size	7kBtuh≥Cap≤15 kBtuh	14.0-(0.3 x Cap) EER
PTAC Standard Size	>15 kBtuh	9.5 EER
PTAC Non-Standard Size	<7 kBtuh	9.4 EER
PTAC Non-Standard Size	7kBtuh≥Cap≤15 kBtuh	10.9-(0.213xCap) EER
PTAC Non-Standard Size	>15 kBtuh	7.7 EER
PTHP Standard Size	<7 kBtuh	11.9 EER 3.3 COP
PTHP Standard Size	7kBtuh≥Cap≤15 kBtuh	14.0-(0.3 x Cap) EER 3.7-(0.052 x Cap) COP
PTHP Standard Size	>15 kBtuh	9.5 EER 2.7 COP

[188] DOE, Commercial Air Conditioners and Heat Pumps|https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431#431.97

PTHP Non-Standard Size	<7 kBtuh	9.3 EER 2.7 COP
PTHP Non-Standard Size	7kBtuh≥Cap≤15 kBtuh	10.8-(0.213 x Cap) EER 2.9-(0.026 x Cap) COP
PTHP Non-Standard Size	>15 kBtuh	7.6 EER 2.5 COP

DEFINITION OF BASELINE EQUIPMENT

TOS: the baseline conditions is the efficiency that meets the Federal Energy Efficiency Standards by size and type.

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. When the existing model data is not available, the baseline efficiency is the federal standard in effect when installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[189]

Remaining life of existing equipment is assumed to be 5 years.[190]

DEEMED MEASURE COST

TOS: The incremental capital cost for this equipment is estimated to be $84/ton.[191]

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.[192]

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton.[193] This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Cooling BUS

Algorithm

[189] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for commercial through-the-wall air conditioners.
[190] Standard assumption of one third of effective useful life.
[191] DEER 2008. This assumes that baseline shifts between IECC versions carries the same incremental costs. Values should be verified during evaluation
[192] Based on DCEO – IL PHA Efficient Living Program data.
[193] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

ENERGY SAVINGS

TOS:

$PTAC\ \Delta kWh$[194] $= \Delta kWh_{cool}$

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

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

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

EREP:

ΔkWh for remaining life of existing unit (1^{st} 5years)

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

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

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

ΔkWh for remaining measure life (next 10 years)

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

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

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

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 Table 1HVAC End Use

$EFLH_{heat}$ = Equivalent Full Load Hours for heating are provided in Table 1 HVAC End Use

EER_{exist} = Energy Efficiency Ratio of the existing equipment,actual.
= If unknown, determine by federal efficiency standard in effect when manufactured. The baseline efficiency for a standard size, 1 ton unit is listed in the following table.

Manufactured Date	1/1/2017 - Current	1/8/2012-12/31/2016	Prior to 1/8/2012
PTAC	10.4 EER	10.2 EER	8.1 EER
PTHP	10.4 EER	10.4 EER	8.1 EER

EER_{base} = Energy Efficiency Ratio of the baseline equipment.

[194] 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.

= Equal to Federal Energy Efficiency Standard.

EER_{ee} = 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:[195] EER = (-0.02 x SEER^2) + (1.12 x SEER)

= Actual installed

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

= Actual installed

3.412 = Btu per Wh.

COP_{exist} = Coefficient of performance of the existing equipment, actual.

= If unknown, determine by federal efficiency standard in effect when manufactured. The baseline efficiency for a standard size, 1 ton unit is listed in the following table.

Manufactured Date	1/1/2017 - Current	1/8/2012- 12/31/2016	Prior to 1/8/2012
PTAC	1.0 COP	1.0 COP	1.0 COP
PTHP	3.1 COP	3.1 COP	2.6 COP

COP_{base} = Coefficient of performance of the baseline equipment; equal to Federal Energy Efficiency Standard.

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

= Actual installed

SUMMER COINCIDENT PEAK DEMAND SAVINGS

TOS:

$$\Delta kW = \Delta kWH_{cool} \; x \; CF$$

EREP:

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

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

ΔkW for remaining measure life (next 10 years)

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

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

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[195] 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.

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.5.8 Single-Package and Split System Unitary Air Conditioner

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively cooled air conditioner that exceeds Federal Energy Efficiency Standards.

Federal Energy Efficiency Standards (effective January 2023)[196]

Heat Rejection	Capacity, kBTUh	Type	Electric resistance or No heat	All other heat
Air Source	< 65	Packaged,Split	13.4 SEER2	
	≥65 and <135	Packaged	14.8 IEER	14.6 IEER
	≥135 and <240	Packaged	14.2 IEER	14.0 IEER
	≥240 and <760	Packaged	13.2 IEER	13.0 IEER
Water Source	< 65	Packaged,Split	12.1 EER	
	≥65 and <135	Packaged	12.1 EER	11.9 EER
	≥135 and <240	Packaged	12.5 EER	12.3 EER
	≥240 and <760	Packaged	12.4 EER	12.2 EER

DEFINITION OF BASELINE EQUIPMENT

TOS, New Construction: 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 Federal Energy Efficiency Standards.

Retrofit, Early Replacement: For this characterization to apply, the existing equipment is working with a remaining useful life. The efficiency is the actual if known, else the standard efficiency

[196] DOE|Title10,Part 431|https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431

when manufactured. After, remaining useful life period, the baseline is the Time of Sale baseline meeting the Federal Energy Efficiency Standards.

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.[197]

Deemed Measure Cost

For analysis purposes, the incremental capital cost for this measure is assumed to be $104 per ton per SEER or IEER unit increase over the base case efficiency for air-cooled units.[198]

The incremental cost for all other equipment types should be determined on a site-specific basis.

For a 144,000 BTUh, 16.2 IEER air source packaged air conditoner without heat, the incremental cost is:

12 tons x (16.2 IEER – 14.2 IEER) x $104 = $2,496

Loadshape

Cooling BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

$$\Delta kWH = kBtu/hr \times (1/SEER2_{base} - 1/SEER2_{ee}) \times EFLH$$

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

$$\Delta kWH = kBtu/hr \times (1/IEER_{base} - 1/IEER_{ee}) \times EFLH$$

Where:

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

$SEER2_{base}$ = Seasonal Energy Efficiency Ratio of the baseline equipment
= SEER values from tables below, based on the applicable IECC.

[197] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for commercial roof top air conditioners, single zone or multi zone.

[198] AESC Inc, ASK Energy Inc, SDGE, "Industry Standard Practice Study of Commercial Unitary Air Conditioning and Heat Pumps Systems", page 36 (September 2021) https://www.caetrm.com/media/reference-documents/Unitary_HVAC_ISP_Report_Final.pdf

= For units with cooling capacity <65kbtu/hr and efficient unit is measured in terms of SEER2, convert $SEER_{base}$ to $SEER2_{base}$.[199].

$SEER2_{ee}$ = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed)

$IEER_{base}$ = Integrated Energy Efficiency Ratio of the baseline equipment

= IEER values from tables below, based on the applicable IECC.

$IEER_{ee}$ = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed.)

EFLH = Equivalent Full Load Hours for cooling are provided in Table 1 HVAC End Use

[199] SEER to SEER2 conversion factor: SEER2 = SEER x 96%. Conversion factor for SEER to SEER2 is used when converting an existing system that is rated in SEER to SEER2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in the same metrics (e.g., both SEER or SEER2) before applying formulas.

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

$$\Delta kW = \Delta kWH \ x \ CF$$

Where:

ΔkWH = Annual electricity savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling
= 0.0009106840[200]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

[200] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

N/A

MEASURE CODE:

2.5.9 High Volume Low Speed Fans

Description

The measure applies to 16-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non HVLS fans that have reached the end of useful life.

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be classified as HVLS and have a VFD.[201]

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years. [202]

Deemed Measure Cost

The incremental capital cost for the fans are as follows:

Fan Diameter Size (feet)	Incremental Cost[203]
16	$4,072
18	$4,110
20	$4150
22	$4180
24	$4225

Loadshape

HVAC BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

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

[202] Michigan Energy Measures DatabaseMichigan Energy Measures Database | 2024 MEMD Master Database | High Volume Low Speed Fans | https://www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database (See "Commercial" tab rows 426:431)

[203] Michigan Energy Measures Database | 2024 MEMD Master Database | High Volume Low Speed Fans | https://www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database (See "Commercial" tab rows 426:431)

Fan Diameter Size (feet)	Energy Savings (kWh)[204]
16	3,218
18	4,938
20	6,577
22	8,543
24	10,018

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh \times CF$$

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.000443983[205]

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

[204] Michigan Energy Measures Database | 2024 MEMD Master Database | High Volume Low Speed Fans | https://www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database (See "Commercial" tab cells M861:M865)

[205] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.5.10 Chiller Tune Up

Description

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

Definition of Efficient Equipment

The efficient condition is an existing chiller post tune-up.

Definition of Baseline Equipment

The baseline condition is an existing chiller prior to receiving the tune-up.

Deemed Lifetime of Efficient Equipment

The expected lifetime of the measure is 5 years.

Deemed Measure Cost

The incremental cost for this measure varies. Use actual cost.

Deemed O&M Cost Adjustments

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

Baseline Efficiency Values by Chiller Type and Capacity

Refer to 2012 IECC Minimum Efficiency Requirements in Reference Tables section of this measure.

Loadshape

Cooling BUS

Algorithm

Calculation of Savings

Electric Energy Savings[206]

$$\Delta kWh = TONS * IPLV_{Base} \, x \, EFLH \, x \, ESF$$

Where:

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

$IPLV_{BASE}$ = Efficiency of baseline equipment expressed as Integrated Part Load Value (kW/ton). Chiller units are dependent on chiller type. See 'Chiller Units, Conversion Values' and 'Baseline Efficiency Values by Chiller Type' and Capacity in the Reference Tables section within this measure section.

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

[206] New York TRM, Savings factor 5%, page 838 "Tune Up Chiller System". https://dps.ny.gov/system/files/documents/2023/12/nys-trm-v11_filing.pdf

ESF = Energy savings factor (= 0.05)

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

$$\Delta kWh = TONS * IPLV_{BASE} * EFLH * ESF = 350 * .540 * 1386 * 0.05 = 13{,}098 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor =0.0009106840[207]

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

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

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES

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

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

[207] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

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

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity[208]

[208] 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.

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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010 FULL LOAD	BEFORE 1/1/2010 IPLV	AS OF 1/1/2010[b] PATH A FULL LOAD	AS OF 1/1/2010[b] PATH A IPLV	AS OF 1/1/2010[b] PATH B FULL LOAD	AS OF 1/1/2010[b] PATH B IPLV	TEST PROCEDURE[c]
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA	NA	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.

2018 IECC Baseline Efficiency Values by Chiller Type and Capacity

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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[e]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[c]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water cooled, electrically operated positive displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≥ 0.680 FL	≥ 0.718 FL	≥ 0.660 FL	≥ 0.680 FL	
			≥ 0.580 IPLV	≥ 0.540 IPLV	≥ 0.540 IPLV	≥ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water cooled, electrically operated centrifugal	< 150 Tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air cooled, absorption, single effect	All capacities	COP	≥ 0.600 FL	NA[c]	≥ 0.600 FL	NA[c]	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥ 0.700 FL	NA[c]	≥ 0.700 FL	NA[c]	
Absorption, double effect, indirect fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP	≥ 1.000 FL	NA[c]	≥ 1.000 FL	NA[c]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.
c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.
d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

MEASURE CODE:

2.5.11 Efficient Cooling Towers

DESCRIPTION

This measure characterizes the replacement of cooling towers used for heat rejection with an efficient cooling tower. The measure is applicable to open circuit, closed circuit cooling towers and fluid coolers.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a replacement cooling tower exceeding the 2021 IECC efficiency for heat rejection equipment, listed in the following table.

Cooling Tower Type	Rating Condition	Minimum Efficiency
Propeller, or axial fan open circuit	95°F entering water 85°F leaving water 85°F entering WB	.>40.2 gpm/hp
Centrifugal fan open circuit	95°F entering water 85°F leaving water 85°F entering WB	.>20.0 gpm/hp
Propeller, or axial fan closed circuit	102°F entering water 90°F leaving water 75°F entering WB	.>16.1 gpm/hp
Centrifugal fan closed circuit	102°F entering water 90°F leaving water 75°F entering WB	.>7.0 gpm/hp
Propeller, or axial fan dry cooler (fluid cooler)	115°F entering water 105°F leaving water 95°F entering WB	.>4.5 gpm/hp

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a cooling tower meeting the 2021 IECC efficiency for heat rejection equipment.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected lifetime of the measure is 20 years[209]

DEEMED MEASURE CO

[209] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for galvanized metal cooling towers.

The incremental cost for this measure varies. Use actual cost.

DEEMED O&M COST ADJUSTMENTS

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

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[210]

$$\Delta kWh = Tons\ x\ 3\ x\ \left(\frac{1}{(GPM/HP)_{base}} - \frac{1}{(GPM/HP)_{eff}}\right) x\ 0.7457 x\ EFLH$$

Where:

TONS	= Chiller tons required on design day for HVAC space cooling
	= Average chillers tons required for process heat rejection
3	= Assumed condenser water gpm/ton, use actual if known
GPM/HP_{base}	= 2021 IECC heat rejection efficiency
GPM/HP_{eff}	= Installed cooling tower heat rejection efficiency, use weighted values for multiple cooling towers
0.7457	=kW/hp; convert horsepower to kilowatt
EFLH	= Equivalent full load hours (= dependent on location and building type, see table 2.5 in Appendix H)

For example, energy savings for a three chiller plant, 200 Tons, with two required on design day for a medium office building in St Louis, when efficient axial fan open circuit cooling towers (80 gpm/hp) replace the existing towers is calculated as:

$$\Delta kWh = (200x2)Tons\ x\ 3\ x\ \left(\frac{1}{40.2} - \frac{1}{80}\right) x\ 0.7457\ x1386\ hours$$

$\Delta kWh = 15{,}348\ kWh$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW\ =\ \Delta kWh\ x\ CF$$

Where:

ΔkWh = Electric energy savings, as calculated above

[210] Standard condenser water flow sizing of 3 gpm/ton with flow efficiency of two pumps

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor =0.0009106840[211]

For example, demand reduction for the above cooling tower replacement with 15,348 kWh of energy savings is calculated as:

$$\Delta kW = 15{,}348\ kWh \times 0.0009106840 = 13.98\ kW$$

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Reference Tables

[211] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.5.12 Dedicated Outdoor Systems (DOAS)

Description

This measure promotes the installation of high-efficiency dedicated outdoor systems (DOAS) utilizing direct expansion (DX) cooling (DOAS) to precondition the outside air brought into a building for ventilation.

This measure was developed to be applicable to the following program types: TOS, EREP, 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 be a high-efficiency dedicated outdoor air system that exceeds Federal Energy Efficiency Standards. The efficiency ratings are assumed to be based on the AHRI920-2020 testing method for ISMRE2 and ISCOP2.

ISMRE2 is the integrated seasonal moisture removal efficiency, pounds of moisture per kilowatt-hour. ISCOP2 is the integrated seasonal coefficient of performance for heating efficiency. The measure is applicable to DOAS equipment with and without ventilation recovery systems (VERS) with a capacity less than 324 lb of moisture/hour.

Federal Energy Efficiency Standards (effective May 2024) for direct expansion dedicated outdoor air systems.[212]

Category	Ventilation Recovery System	Efficiency
Air Conditioning	No	3.8 ISMRE2
Air Conditioning	VERS	5.0 ISMRE2
Air source heat pump	No	3.8 ISMRE2 2.05 ISCOP2
Air source heat pump	VERS	5.0 ISMRE2 3.2 ISCOP2
Water cooled	No	4.7 ISMRE2
Water cooled	VERS	5.1 ISMRE2
Water source heat pump	No	3.8 ISMRE2 2.13 ISCOP2
Water source heat pump	VERS	4.6 ISMRE2 4.04 ISCOP2

Definition of Baseline Equipment

The baseline equipment for all program types is assumed to be a standard-efficiency DOAS, without a ventilation.

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

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[212] DOE CFR::429,431, Effective May 2024, https://www.federalregister.gov/documents/2022/11/01/2022-23185/energy-conservation-program-energy-conservation-standards-for-direct-expansion-dedicated-outdoor-air

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years[213]

DEEMED MEASURE COST

For analysis purposes, the incremental equipment cost[214] for this measure is assumed to $2.00 per CFM for DOAS without VERS, and $4.6 per CFM for DOAS with VERS.

LOADSHAPE

Cooling BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{dehumidification,cooling} + \Delta kWh_{heating}$$

For dehumidification energy savings or dehumidification with cooling:

$$\Delta kWh = MRC \; x \; (1/ISMRE2_{base} - 1/ISMRE2_{EE}) \; x \; EFLH_{DOAS}$$

For units with heat pump heating:

$$\Delta kWh = KBTU/hr \; x \; (1/(ISCOP_{base} \; x \; 3.412) - 1/(ISCOP2_{EE} \; x \; 3.412) \; x \; EFLH_{DOAS}$$

Where:

MRC = Moisture removal capacity, lb/hour
=AHRI rating or manufacturer specification if installed system

$ISMRE2_{base}$ = Integrated seasonal moisture removal efficiency of the baseline equipment
=Federal code compliant system of same category, capacity without VERS

$ISMRE2_{EE}$ = Integrated seasonal moisture removal efficiency of the efficient equipment
=Actual

$EFLH_{DOAS}$ = Effective full load hours for dehumidification or dehumidify with cooling
= Actual, or from table below by city, and operating schedule

kBTU/hr =Heat pump heating capacity at 47F
=Actual installed

$ISCOP2_{base}$ = Integrated seasonal coefficient of performance of the baseline equipment

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[213] REDCAR Analytics, Page 32 DOAS lifetime,“Economic Analysis of Heat Recovery Equipment in Commercial Dedicated Outside Air Systems” (2019),https://betterbricks.com/uploads/resources/NEEA-DOAS-Analysis-Report_Red-Car_Final.pdf

[214] REDCAR Analytics, Page 19 cost per CFM for mid tier and high tier DOAS compared to low tier,“Economic Analysis of Heat Recovery Equipment in Commercial Dedicated Outside Air Systems” (2019),https://betterbricks.com/uploads/resources/NEEA-DOAS-Analysis-Report_Red-Car_Final.pdf

	=Federal code compliant system of same category, capacity without VERS
$ISCOP2_{ee}$	= integrated seasonal coefficient of performance of the efficient equipment
	=Actual
3.412	=Convert COP to BTU/watt
$EFLH_{DOAS}$	= Effective full load hours at 32F or cold climate heat pump at 17F
	= Actual, or from table below by city and operating schedule

Area	Building or Schedule	EFLH Dehumidify	EFLH Latent,Sensible Cooling	EFLH Heat pump 17F rated	EFLH Heat Pump 47F rated
St Louis	24/7	1,213	1,611	1,976	1,544
St Louis	Food service	1,026	1,423	1,585	1,260
St Louis	Big Box	668	1,035	957	785
St Louis	School/Office	512	787	764	633
Kirksville	24/7	1,051	1,270	2,059	1,406
Kirksville	Food service	912	1,132	1,656	1,129
Kirksville	Big Box	660	871	977	671
Kirksville	School/Office	526	679	769	520
Jefferson City	24/7	1,035	1,410	2,026	1,512
Jefferson City	Food service	881	1,255	1,611	1,203
Jefferson City	Big Box	572	926	948	713
Jefferson City	School/Office	441	694	754	562
Liberty,KC	24/7	1,035	1,410	1,912	1,427
Liberty,KC	Food service	881	1,255	1,521	1,136
Liberty,KC	Big Box	572	926	894	673
Liberty,KC	School/Office	441	694	711	531
Cape Girardeau	24/7	1,515	1,803	1,918	1,593
Cape Girardeau	Food service	1,279	1,567	1,543	1,287
Cape Girardeau	Big Box	837	1,117	922	781
Cape Girardeau	School/Office	632	839	735	628

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings from dehumidification or dehumidify with cooling

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor =0.0009106840[215]

[215] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.6 Lighting

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

Building Type - Space Type	Fixture Annual Operating Hours[216] (Annual Hours)	WasteHeat Cooling Energy Factor[217] (WHFe)	WasteHeat Electric Resistance Heating[218] (IFkWh)	WasteHeat Heat Pump Heating (IFkWh)	WasteHeat Gas Heating[219] (IFTherms)
Automotive Services	3,010	1.04	0.26	0.11	0.011
Education - Primary School	2772	1.08	0.28	0.12	0.012
Education - Secondary School	2772	1.14	0.30	0.13	0.013
Entertainment/Recreation	3858	1.07	0.26	0.11	0.011
Office - Large	3220	1.06	0.32	0.14	0.014
Office - Medium	3220	1.14	0.19	0.08	0.008
Office - Small	3220	1.11	0.21	0.09	0.009
Government - offices	3788	1.14	0.19	0.08	0.008
Grocery/Convenience Store	5646	1.07	0.26	0.11	0.011
Hotel/Motel – Guest rooms	2390	1.21	0.22	0.09	0.009
Hotel/Motel – Common area	6138	1.24	0.01	0.00	0.000
Hospital/Senior Living - Corridors	8608	1.11	0.34	0.15	0.015
Hospital/Senior Living – Guest rooms	995	1.11	0.34	0.15	0.015
Hospital/Outpatient – Treatment areas	3189	1.21	0.28	0.12	0.012
Industrial/Manufacturing	3831	1.04	0.26	0.22	0.011
Indoor Horticulture	4818	Custom	Custom	Custom	Custom

[216] TRC; applicant self reported lighting hours by measure, participants from 2014 through June 2024, Local file: "2024 C&I Lighting Hours Review.xlsx"
[217] The Waste Heat Factor for Energy is developed using computer models for the various Building Types. Similar building types aggregated. Indoor agriculture waste heat effects to be determined by building modeling by application.
[218] Electric heat penalty assumptions are based on converting the IFTherm multiplier value into kWh and then applying relative heating system efficiencies. The gas efficiency was assumed to be 80% AFUE, electric resistance is assumed to be 100%, Heat Pump is assumed to be 2.3 COP.
[219] IFTherms value is developed using computer models consistent with methodology for Waste Heat Factor for Energy.

Building Type - Space Type	Fixture Annual Operating Hours[216] (Annual Hours)	WasteHeat Cooling Energy Factor[217] (WHFe)	WasteHeat Electric Resistance Heating[218] (IFkWh)	WasteHeat Heat Pump Heating (IFkWh)	WasteHeat Gas Heating[219] (IFTherms)
Midrise Apartment Building - Common area	6138	1.14	0.44	0.19	0.019
Parking Garage	3465	1.00	0.00	0.00	0.00
Parking Garage – 24/7	8760	1.00	0.00	0.00	0.00
Public Order & Safety	6812	1.06	0.32	0.14	0.014
Restaurant – Fast Service	4235	1.12	0.27	0.12	0.012
Restaurant – Full Service	4235	1.11	0.22	0.10	0.009
Retail – Big box	5367	1.08	0.21	0.09	0.009
Retail - Small	3156	1.08	0.22	0.10	0.009
Warehouse	3127	1.04	0.26	0.11	0.011
C&I Weighted Average	3636	1.09	0.24	0.10	0.010

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

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

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

2.6.1 LED Bulbs and Fixtures (Available for Income Eligible and BSS programs)

DESCRIPTION

This measure provides savings assumptions for a variety of light emitting diode (LED) efficient lighting including lamps, bulbs, fixtures, and retrofit kits . The effective useful life varies dependent on the lighting category.

This measure was developed to be applicable to the following program types: TOS, EREP, 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 bulbs, lamps, fixtures, retrofit kits are to be certified or registered with at least one recognized independent agency. The following tables lists the requirements for three of those agencies.

Agency	Requirement	Version	Lighting Types
Design Lights Consortium Designlights.org	DLC Listed	Technical requirement versions: 4.0 to current Premium or Standard classification	lamps, fixtures, retrofit kits, LLLC
Design Lights Consortium Designlights.org	DLC Hort	Technical requirement versions: 1.0 to current	horticultural
ENERGYSTAR Energystar.gov	Certified	Version 2.1 to current	lamps, fixtures
UL Solutions Ul.com	Certified	UL Mark	lamps, fixtures, retrofit kits, horticultural, LLLC

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

DEFINITION OF BASELINE EQUIPMENT

For RF and EREP installations, the baseline is the lamp or fixture being replaced. A midlife baseline adjustment occurs at the end of the remaining useful life, approximated at 1/3 of the EUL. Deemed fixture wattages are provided in Table 2 LED New and Baseline Assumptions:.

For TOS installations, the baseline is determined by the Federal Energy Efficiency Standards, expressed in minimum lumens per watt.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Actual incremental costs should be used if available. For default values, refer to the reference tables below.

LOADSHAPE

Lighting BUS
Ext Lighting BUS
Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$	= Actual wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.
$Watts_{EE}$	= Actual wattage of LED fixture purchased / installed. If unknown, use default provided in “LED New and Baseline Assumptions.”
Hours	= Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 2.6 by Building Type. If hours or Building Type are unknown, use the C&I Average value.
WHFe	= Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 2.6 for each Building Type. If building is un-cooled, the value is 1.0.

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

Heating Penalty:

If electrically heated building:[220]

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

Where:

IF_{kWh}	= Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements

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

due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6. If unknown, use the C&I Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001899635[221] for indoor lighting
= 0.0000056160 for exterior lighting
= 0.0001379439 for exterior 24/7 lighting

NATURAL GAS ENERGY SAVINGS

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

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

Where:

IF_{Therms} = Lighting-HVAC Interaction Factor for gas heating impacts.[222] This factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6. If unknown, use the C&I Average value.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

[221] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"
[222] Negative value because this is an increase in heating consumption due to the efficient lighting.

REFERENCE TABLES [223]

Table 2 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	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	$11/ft
	LED Undercabinet Shelf-Mounted Task Light Fixtures	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	$11/ft
	LED Refrigerated Case Light, Horizontal or Vertical	4.0 / ft	5'T8	15.2 / ft	$11/ft
	LED Freezer Case Light, Horizontal or Vertical	4.0 / ft	6'T12HO	18.7 / ft	$11/ft
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp,<2400 lumens	13.7	32w T8	28.0	$15
	LED 2' Linear Replacement Lamp	8.6	17w T8	15.0	$13
	LED 4' Linear Replacement Lamp, ≥2400 lumens	24.7	40WT8HO	41.8	$13
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	22.4	2-Lamp 32w T8 (BF < 0.89)	57.0	$53
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	34.2	3-Lamp 32w T8 (BF < 0.88)	84.5	$69
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	29.9	2-Lamp 32w T8 (BF < 0.89)	57.0	$55
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	42.1	3-Lamp 32w T8 (BF < 0.88)	84.5	$76
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	51.5	4-Lamp 32w T8 (BF < 0.88)	112.6	$104
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	19.2	1-Lamp 32w T8 (BF <0.91)	29.1	$22
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	30.8	2-Lamp 32w T8 (BF < 0.89)	57.0	$75
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	40.2	3-Lamp 32w T8 (BF < 0.88)	84.5	$83
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	17.6	1-Lamp 32w T8 (BF <0.91)	29.1	$10
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	28.0	2-Lamp 32w T8 (BF < 0.89)	57.0	52
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	39.2	3-Lamp 32w T8 (BF < 0.88)	84.5	$78
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	49.9	T5HO 2L-F54T5HO - 4'	120.0	$131
	LED Surface & Suspended Linear Fixture, > 7500 lumens	90.6	T5HO 3L-F54T5HO - 4'	180.0	$173
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	51.8	3-Lamp T8HO Low-Bay	157.0	$43
	LED High-Bay Fixtures, 10,001-15,000 lumens	89.2	4-Lamp T8HO High-Bay	196.0	$32

[223] IL TRM V13, Measure 4.5.4 LED Fixture Wattage, TOS Baseline and Incremental Cost Assumptions", which aggregated data from CLEAResults, DLC, VEIC and others.

LED Category	EE Measure		Baseline		Incremental Cost
	Description	$Watts_{EE}$	Description	$Watts_{BASE}$	
	LED High-Bay Fixtures, 15,001-20,000 lumens	118.5	6-Lamp T8HO High-Bay	294.0	$62
	LED High-Bay Fixtures, > 20,000 lumens	171.4	8-Lamp T8HO High-Bay	392.0	$51
	LED High-Bay Fixtures, 20,001-30,000 lumens	230.5	750 Watt Metal Halide	850	$114
	LED High-Bay Fixtures, 40,001-50,000 lumens	306.2	1000 Watt Metal Halide	1080	$166
	LED High-Bay Fixtures, >50,000 lumens	443.7	1500 Watt Metal Halide	1610	$284
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	12.9	1L T8	29.1	$18
	LED Ag Interior Fixtures, 2,001-4,000 lumens	29.7	2L T8	57.0	$48
	LED Ag Interior Fixtures, 4,001-6,000 lumens	45.1	3L T8	121.0	$57
	LED Ag Interior Fixtures, 6,001-8,000 lumens	59.7	4L T8	159.0	$88
	LED Ag Interior Fixtures, 8,001-12,000 lumens	84.9	200W Pulse Start Metal Halide	227.3	$168
	LED Ag Interior Fixtures, 12,001-16,000 lumens	113.9	320W Pulse Start Metal Halide	363.6	$151
	LED Ag Interior Fixtures, 16,001-20,000 lumens	143.7	350W Pulse Start Metal Halide	397.7	$205
	LED Ag Interior Fixtures, > 20,000 lumens	193.8	(2) 320W Pulse Start Metal Halide	727.3	$356
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	31.0	100W Metal Halide	113.6	$68
	LED Exterior Fixtures, 5,001-10,000 lumens	64.0	175W Pulse Start Metal Halide	198.9	$60
	LED Exterior Fixtures, 10,001-15,000 lumens	101.0	250W Pulse Start Metal Halide	284.1	$129
	LED Exterior Fixtures, 15,001-30,000 lumens	141.0	400W Pulse Start Metal Halide	454.5	$156
	LED Exterior Fixtures, 30,001-40,000 lumens	236.0	750W Metal Halide	850	$446
	LED Exterior Fixtures, >40,000 lumens	295.0	1000W Metal Halide	1080	$629

LED Component Costs and Lifetimes:[224]

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	50,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Interior Directional	LED Track Lighting	50,000	$39.00	70,000	$47.50	2,500	$12.71	40,000	$11.00
	LED Wall-Wash Fixtures	50,000	$30.75	70,000	$47.50	2,500	$8.86	40,000	$14.40
LED Display Case	LED Display Case Light Fixture	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	50,000	$9.75/ft	70,000	$11.88/ft	2,500	$6.70	40,000	$5.63
LED Display Case	LED Refrigerated Case Light, Horizontal or Vertical	50,000	$8.63/ft	70,000	$9.50/ft	15,000	$1.13	40,000	$8.00
	LED Freezer Case Light, Horizontal or Vertical	50,000	$7.88/ft	70,000	$7.92/ft	12,000	$0.94	40,000	$6.67
LED Linear Replacement Lamps Replacement	LED 2' Linear Replacement Lamp	50,000	$5.76	70,000	$13.67	30,000	$6.17	40,000	$11.96
	LED 4' Linear Replacement Lamp,<2400 lumens	50,000	$8.57	70,000	$13.67	24,000	$6.17	40,000	$11.96
	LED 4’ Linear Replacement Lamp, ≥2400 lumens	50,000	$8.57	70,000	$13.67	18,000	$6.17	40,000	$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$78.07	70,000	$40.00	24,000	$26.33	40,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$89.23	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$96.10	70,000	$40.00	24,000	$12.33	40,000	$35.00

[224] Costs for baseline and LED lamps sourced from Illinois TRM V13, which aggregated data from the Design Light Consortium (DLC) Qualifying Product Lists, Efficiency Vermont projects, PGE refrigerated case study.

LED Category	EE Measure Description	EE Measure: Lamp Life (hrs)	EE Measure: Total Lamp Replace Cost	EE Measure: LED Driver Life (hrs)	EE Measure: Total LED Driver Replace Cost	Baseline: Lamp Life (hrs)	Baseline: Total Lamp Replace Cost	Baseline: Ballast Life (hrs)	Baseline: Total Ballast Replace Cost
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$114.37	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$137.43	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$65.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$100.44	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$108.28	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	50,000	$62.21	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$93.22	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$114.06	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$152.32	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	50,000	$183.78	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	50,000	$90.03	70,000	$62.50	18,000	$64.50	40,000	$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$122.59	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	50,000	$157.22	70,000	$62.50	18,000	$129.00	40,000	$117.50
	LED High-Bay Fixtures, > 20,000 lumens	50,000	$228.52	70,000	$62.50	18,000	$172.00	40,000	$142.50
	LED High-Bay Fixtures, 20,001-30,000 lumens	50,000	$294.00	70,000	$62.50	15,000	$82.00	40,000	$143.00

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	LED High-Bay Fixtures, 40,001-50,000 lumens	50,000	$324.00	70,000	$62.50	15,000	$88.00	40,000	$149.00
	LED High-Bay Fixtures, >50,000 lumens	50,000	$382.00	70,000	$62.50	15,000	$96.00	40,000	$200.00
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	50,000	$41.20	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$65.97	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$80.08	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$105.54	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$179.81	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$190.86	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$237.71	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$331.73	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	50,000	$73.80	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$124.89	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	$214.95	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Exterior Fixtures, 15,001-30,000 lumens	50,000	$321.06	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Exterior Fixtures, 30,001-40,000 lumens	50,000	$546.00	70,000	$62.50	15,000	$82.00	40,000	$143.00

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	LED Exterior Fixtures, >40,000 lumens	50,000	$722.00	70,000	$62.50	15,000	$88.00	40,000	$149.00
	LED Exterior Fixtures, ≤ 5,000 lumens	50,000	$870.00	70,000	$62.50	15,000	$96.00	40,000	$200.00
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$73.80	70,000	$62.50	15,000	$58.00	40,000	$102.50

MEASURE CODE:

2.6.2 LED Screw Based Omnidirectional Bulb (Available for Income Eligible and BSS programs)

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.[225]

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent.[226] A midlife adjustment example is provided but not applied to measures installed prior to 2022.

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

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

[226] A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

Actual incremental costs should be used if available. If unavailable, assume $3.26 (baseline cost of $1.80 and efficient cost of $5.06).[227]

Loadshape

Lighting BUS
Ext Lighting BUS
Miscellaneous BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed

$Watts_{EE}$ = Actual wattage of LED purchased/installed. If unknown, use default provided below.[228]

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each Building Type in the Lighting Reference Table in Section 2.6. If unknown, use the C&I Average value.

ISR = In-Service Rate represents the percentage of reported lamps or fixtures that is installed and operating and varies with the program delivery approach. Use 100% for programs with direct installation and/or installation verification procedures (e.g., verification inspections for a sample of projects); use 98.7% for program delivery

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[227] 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.

[228] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, $Watts_{EE}$ is based upon the ENERGY STAR® minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at "cerified-light-bulbs-2015-06-18.xlsx." These assumptions should be reviewed regularly to ensure they represent the available product.

without installation verification.[229] The ISR may also be set to 100% if the installation verification is embedded in other evaluation adjustments.

Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$ LED	Delta Watts
250	309	25	4.0	21
310	749	29	6.7	22.3
750	1,049	43	10.1	32.9
1,050	1,489	53	12.8	40.2
1,490	2,600	72	17.4	54.6
2,601	3,000	150	43.1	106.9
3,001	3,999	200	53.8	146.2
4,000	6,000	300	76.9	223.1

Mid-Life Baseline Adjustment Example

During the lifetime of a standard omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes to a CFL equivalent in 2020 due to the EISA backstop provision (except for <310 and 2600+ lumen lamps), the annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule. However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

For example, for 43W equivalent LED lamp installed in 2016, the full savings (as calculated above in the Algorithm) should be claimed for the first four years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) should be claimed for the remainder of the measure life.[230&231]

[229] ISR is based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate). These evaluation results are from a retail-based lighting program with multiple delivery channels including point-of-sale markdown, online website, coupons, and social marketing distribution.
[230] These adjustments should be applied to kW and gas impacts as well.
[231] Calculated with EISA requirement of 45lumens/watt.

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	Watts EE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020[208]	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
250	309	280	4.0	25	21	25	21	100.0%
310	749	530	6.7	29	22.3	9.4	2.7	12.1%
750	1049	900	10.1	43	32.9	13.4	3.3	10.0%
1050	1489	1270	12.8	53	40.2	18.9	6.1	15.2%
1490	2600	2045	17.4	72	54.6	24.8	7.4	13.6%
2,550	3,000	2,775	43.1	150	106.9	150	106.9	100.0%
3,001	3,999	3,500	53.8	200	146.2	200	146.2	100.0%
4,000	6,000	5,000	76.9	300	223.1	300	223.1	100.0%

<u>Heating Penalty:</u>

If electrically heated building:[232]

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

Where:

IF_{kWh} = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001899635[233] for indoor lighting
= 0.0000056160 for exterior lighting
= 0.0001379439 for exterior 24/7 lighting

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):[232]

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

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

[233] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

Where:

IF_{Therms} = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the falling EISA-Qualified backdrop provision, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:[234]

Incandescent / Halogen	CFL	LED ALamp
$1.80	$2.20	$5.06

The present value of replacement lamps and annual levelized replacement costs using utilities' average real discount rate of 6.91% are presented below:

Location	PV of replacement costs for period			Levelized annual replacement cost savings		
	2016 - 2017	2017 - 2018	2018 - 2019	2016 - 2017	2017 - 2018	2018 - 2019
C&I Average	$18.66	$14.70	$10.46	$2.04	$1.60	$1.14

Note: incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows. If unknown Building Type, assume C&I Average:

[234] All cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report," February 2016 page 19, https://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf

Building Type	Replacement Period (years)[235]	Replacement Cost
Large Office	0.32	$1.80[236]
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:

[235] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA-qualified halogen/incandescent is 1000 hours (manufacturers are simply using a regular incandescent lamp with halogen fill gas rather Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC)).

[236] 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.

2.6.3 LED Exit Sign (Available for Income Eligible and BSS programs)

This measure characterizes the savings associated with installing a new LED exit sign (or retrofit kit) in place of a CFL or incandescent exit sign in a commercial building. LED exit signs use less power (≤ 5 watts), have a significantly longer lifetime, and have less maintenance costs compared to incandescent or CFL exit signs.[237]

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.[238]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Actual program delivery costs should be used if available. If not, use the full cost of $39[239] for a new LED exit sign and $25 for a retrofit kit, plus $6.25 in labor,[240] for a total measure cost of $45.25 and $31.25, respectively.

LOADSHAPE

Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[241]

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

Where:

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

[238] 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.

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

[240] 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.

[241] 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).

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

Baseline Type	$Watts_{BASE}$
Incandescent (dual sided)	50 W [242]
Incandescent (single sided)	25 W
CFL (dual sided)	14 W [243]
CFL (single sided)	7 W

$Watts_{EE}$ = Actual wattage if known; if unknown assume 2W for singled sided and 4W for dual sided.[244]

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 2.6 for each Building Type. If building is un-cooled, the value is 1.0.

Heating Penalty

If electrically heated building:[245]

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

Where:

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

Summer Coincident Peak Demand Savings

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

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242 Average incandescent single sided (5W, 10W, 15W, 20W, 25W, 34W, 40W, 50W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: https://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf (See rows 9-22 middle of page# B-26)

243 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: https://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf (See rows 1-4,7,8 top of page# B-26)

244 Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: https://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf (See last two rows on page# B-26)

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

Where:

ΔkWh = Electric energy savings, including cooling savings, as calculated above.

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

NATURAL GAS ENERGY SAVINGS

Heating penalty if fossil fuel heated building (or if heating is unknown):[246]

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

Where:

IF_{Therms} = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.6 for each Building Type.

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M cost adjustment savings should be calculated using the following component costs and lifetimes.

Component	Baseline Measure	
	Cost[247]	Life (yrs) [248]
CFL lamp	$8.91	0.63 years
Incandescent lamp	$7.39	0.14 years

MEASURE CODE:

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

[247] 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.

[248] ENERGY STAR® “Save Energy, Money and Prevent Pollution with LED Exit Signs” states that CFL bulbs for exit signs typically have an average rated life of 5,000-6,000 hours. Given 24/7 run time, assume a CFL in an exit sign will require replacement every 0.63 years (5,500 hours/8,766 hours).

2.6.4 LED Specialty Lamp (Available for Income Eligible and BSS programs)

DESCRIPTION

This characterization provides savings assumptions for LED directional, decorative, and globe lamps. This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the EISA requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. However, in 2019, the Department of Energy issued two final rules and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. As of 10/15/2020, the 45 lumen per watt EISA standard is not effective.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR® labeled based upon the ENERGY STAR® specification v2.0 which will become effective on 1/2/2017.(https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_spec_v2.pdf).
Qualification could also be based on the Design Light Consortium's qualified product list.[249]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:[250]

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

[250] 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

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

Where:

$Watts_{Base}$ = Based on bulb type and lumens of LED bulb installed. See table below.

$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:[251]

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each Building Type in the Lighting Reference Table in Section 2.6. If unknown, use the C&I Average value.

ISR = In Service Rate represents the percentage of reported lamps or fixtures that is installed and operating and varies with the program delivery approach. Use 100% for programs with direct installation and/or installation verification procedures (e.g., verification inspections for a sample of projects); use 98.7% for program delivery without installation

[251] $Watts_{EE}$ 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.

verification.[252] The ISR may also be set to 100% if the installation verification is embedded in other evaluation adjustments.

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$	Delta Watts
Directional	250	349	25	5.6	19.4
	350	399	35	6.3	28.7
	400	599	40	7.5	32.5
	600	749	60	9.7	50.3
	750	999	75	12.7	62.3
	1000	1250	100	16.2	83.8
Decorative	70	89	10	1.8	8.2
	90	149	15	2.7	12.3
	150	299	25	3.2	21.8
	300	499	40	4.7	35.3
	500	699	60	6.9	53.1
Globe	250	349	25	4.1	20.9
	350	499	40	5.9	34.1
	500	574	60	7.6	52.4
	575	649	75	13.6	61.4
	650	1099	100	17.5	82.5
	1100	1300	150	13.0	137.0

Heating Penalty:

If electrically heated building:[253]

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

Where:

IF_{kWh} = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

[252] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate). These evaluation results are from a retail-based lighting program with multiple delivery channels including point-of-sale markdown, online website, coupons, and social marketing distribution.

[253] 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[254] for indoor lighting
= 0.0000056160 for exterior lighting
= 0.0001379439 for exterior 24/7 lighting

Other factors as defined above.

NATURAL GAS SAVINGS

Heating penalty if fossil fuel heated building (or if heating fuel is unknown):[255]

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

Where:

IF_{Therms} = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 2.6 and based upon Building Type. If unknown, use the C&I Average value.

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M cost should be applied as follows:

[254] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"
[255] Ibid.

Installation Location	Replacement Period (years)[256]	Replacement Cost[257]
Large Office	0.32	Decorative: $6.31 Directional: $3.92
Medium Office	0.32	
Small Office	0.35	
Warehouse	0.35	
Stand-alone Retail	0.29	
Strip Mall	0.27	
Primary School	0.29	
Secondary School	0.29	
Supermarket	0.27	
Quick Service Restaurant	0.16	
Full Service Restaurant	0.16	
Hospital	0.26	
Outpatient Health Care	0.26	
Small Hotel - Building	0.27	
Large Hotel - Building	0.27	
Midrise Apartment - Building	0.35	
C&I Average	0.30	

MEASURE CODE:

[256] 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).
[257] Incandescent costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report,” Itron, February 28, 2014.

2.6.5 Lighting Power Density (Available for Income Eligible and BSS programs)

Description

This measure entails the installation of efficient lighting systems in either new construction or during substantial renovation of commercial buildings that triggers compliance with code. This methodology applies to situations where code specifies maximum lighting power density allowances (W/ft^2). Either the Building Area Method or Space-by-Space (not recognized by IECC 2009) method as defined in IECC 2009, 2012, 2015, 2018, 2021, or 2024 can be used for calculating the Interior Lighting Power Density (LPD).[258] The measure consists of a design that has a lower LPD than code requires.

This measure was developed to be applicable to the following program types: NC and TOS. The measure is application for any project for which the project requires compliance with building code. If applied to other program types, the measure savings should be verified.

Definition of Efficient Equipment

In order for this characterization to apply, the lighting system must be more efficient than the baseline energy code maximum lighting power density in watts/square foot for either the interior space or exterior space.the interior space.

Definition of Baseline Equipment

The baseline is assumed to be the maximum lighting power density that meets the building code recognized by the local jurisdiction. In the absence of local energy building codes, and for areas with an IECC code version prior to 2018, the IECC 2018 is the baseline. For illustrative purposes in this characterization, IECC 2009, 2012, 2015, and 20182018, 2021 and 2024, are highlighted to demonstrate the methodology.

Deemed Lifetime of Efficient Equipment

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

Deemed Measure Cost

The actual incremental cost over a baseline system should be collected from the customer if possible or quantified using an alternative suitable source.

Loadshape

Lighting BUS
Ext Lighting BUS
Miscellaneous BUS

Algorithm

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[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

CALCULATION OF SAVINGS

ENERGY SAVINGS

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

Where:

WSF_{base} = Baseline lighting watts per square foot or linear foot as determined by building or space type. IECC example whole building analysis values are presented in the Reference Tables below.[259]

WSF_{EE} = The actual installed lighting watts per square foot or linear foot.

SF = Provided by customer based on square footage of the building area applicable to the lighting design for new building.

Hours = Annual site-specific hours of operation of the lighting equipment collected from the customer or selected from the Reference Table in Section 2.8 if unavailable.

WHF_e = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 2.8 for each Building Type. If building is not cooled, the value is 1.0.

Heating Penalty

If electrically heated building:[260]

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

Where:

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh *x CF

Where:

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

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[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

= 0.0001899635[261] for indoor lighting
= 0.0000056160 for exterior lighting
= 0.0001379439 for exterior 24/7 lighting

Other factors as defined above.

NATURAL GAS ENERGY SAVINGS

Heating interactive loss is calculated as:

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

Where:

IF_{Therms} = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 2.8 for each Building Type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

REFERENCE TABLES

Lighting Power Density Values from IECC 2009, 2012 and 20152015, 2018, 2021 for Interior Commercial New Construction and Substantial Renovation Building Area Method. The IECC 2024 has not been published as of June 2024.The IECC 2015 values are provided for comparison, as the base models for developing the LPD standard did not include LED lighting.

Building Area Type [262]	IECC 2009 2015 Lighting Power Density (w/ft^2)	IECC 2012 2018 Lighting Power Density (w/ft^2)	IECC 2015 2021 Lighting Power Density (w/ft^2)
Automotive facilityAutomotive Facility	0.80.80.80.9	0.710.710.710.9	0.750.750.750.80
Convention centerConvention Center	1.011.011.011.2	0.760.760.761.2	0.640.640.641.01
CourthouseCourt House	1.011.011.011.2	0.90.90.91.2	0.790.790.791.01
Dining: bar lounge/leisureDining: Bar Lounge/Leisure	1.011.011.011.3	0.90.90.91.3	0.80.80.81.01
Dining: cafeteria/fast toodDining: Cafeteria/Fast Food	0.90.90.91.4	0.790.790.791.4	0.760.760.760.9
Dining: familyDining: Family	0.950.950.951.6	0.780.780.781.6	0.710.710.710.95
Dormitory Dormitory	0.570.570.571.0	0.610.610.611.0	0.530.530.530.57
Exercise centerExercise Center	0.840.840.841.0	0.650.650.651.0	0.720.720.720.84
Fire station Fire station	0.670.670.671.0	0.530.530.530.8	0.560.560.560.67
GymnasiumGymnasium	0.940.940.941.1	0.680.680.681.1	0.760.760.760.94
Health care clinicHealthcare – clinic	0.90.90.91.0	0.820.820.821.0	0.810.810.810.90
Hospital Hospital	1.051.051.051.2	1.051.051.051.2	0.960.960.961.05
Hotel/MotelHotel	0.870.870.871.0	0.750.750.751.0	0.560.560.560.87
LibraryLibrary	1.191.191.191.3	0.780.780.781.3	0.830.830.831.19
Manufacturing facilityManufacturing Facility	1.171.171.171.3	0.90.90.91.3	0.820.820.821.17
Motion picture theaterMotel	0.760.760.761.0	0.830.830.831.0	0.440.440.440.87
Multiple FamilyMotion Picture Theater	0.510.510.511.2	0.680.680.681.2	0.450.450.450.76
MuseumMultifamily	1.021.021.020.7	1.061.061.060.7	0.550.550.550.51
OfficeMuseum	0.820.820.821.1	0.790.790.791.1	0.640.640.641.02
Parking garageOffice	0.210.210.211.0	0.150.150.150.9	0.180.180.180.82

[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

PenitentiaryParking Garage	0.810.810.810.3	0.750.750.750.3	0.690.690.690.21
Performing arts theaterPenitentiary	1.391.391.391.0	1.181.181.181.0	0.840.840.840.81
Police stationPerforming Arts Theater	0.870.870.871.6	0.80.80.81.6	0.660.660.661.39
Post officePolice Station	0.870.870.871.0	0.670.670.671.0	0.650.650.650.87
Religious buildingPost Office	1111.1	0.940.940.941.1	0.670.670.670.87
RetailReligious Building	1.261.261.261.3	1.061.061.061.3	0.840.840.841.0
School/universityRetail[263]	0.870.870.871.5	0.810.810.811.4	0.720.720.721.26
Sports arenaSchool/University	0.910.910.911.2	0.870.870.871.2	0.760.760.760.87
Town hallSports Arena	0.890.80.891.1	0.80.710.81.1	0.690.750.690.91
TransportationTown Hall	0.70.71.1	0.610.611.1	0.50.50.89
WarehouseTransportation	0.660.661.0	0.480.481.0	0.450.450.70
WorkshopWarehouse	1.191.190.8	0.90.90.6	0.910.910.66
	0.81.4	0.711.4	0.751.19

Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method

[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

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

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m^2.

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

2.6.6 Lighting Controls

DESCRIPTION

The lighting controls measure is applicable to the installation of occupancy sensors, daylighting sensors, networked lighting controls (NLC) and luminaire level lighting controls (LLLC). Associated energy savings depends on the building type, location area covered, type of lighting, activity, occupancy pattern and control strategies.

This measure relates to the installation of lighting controls with a new or existing interior lighting system, that are not required by local building energy codes.

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 measure characterization applies to fixture-mounted occupancy sensors, remote mounted occupancy sensors, networked lighting controls (NLC) and LED fixtures equipped with light level luminaire control (LLLC). For LLLC fixtures, this measure applies to the control strategies (trimming the base wattage, dimming, occupancy, daylighting). The base watt reduction for LLLC fixtures over the existing or code based fixture is not characterized by this measure, but by measure 2.6.1 LED Bulbs and Fixtures. Also, not characterized for LLLC fixtures are HVAC temperature and humidity setback sensing.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with only manual controls or no controls. When controls are installed with new fixtures, replacing existing fixtures, the controlled wattage is based on the new system.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for occupancy sensors and daylight sensor is assumed to be 10 years.[264]

The expected measure life for NLC and LLLC controls is assumed to align with the fixture life, at 15 years.

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

[264] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 (See page 1-3).

Lighting control type	Cost
Full cost of fixture mounted occupancy sensor, <200W	$65 per sensor[265]
Full cost of fixture mounted occupancy sensor, >200W	$138 per sensor
Full cost of remote (ceiling) mounted occupancy sensor	$105 per sensor
Luminaire lighting level controls with fixture	$53 per fixture[266]
Network lighting controls, less than 10,000 SF	$0.86 per SF[267]
Network lighting controls, 10,000 SF to 100,000 SF	$0.59 per SF
Network lighting controls, more than 100,000 SF	$0.44 per SF

LOADSHAPE

Lighting BUS
Miscellaneous BUS
Ext Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \sum (kW_{Controlled} x\ Hours\ x(ESF_{Occ} + ESF_{Trim} + ESF_{Other})x(WHF_e - IF_{heat}))$$

Where:

ΔkWh = Summation of controlled watts, hours of use, savings factors, waste heater factor for each unique usage area

$kW_{Controlled}$ = Lighting load controlled, kilowatts.
=Actual, default from table below may be used for fixture or remote occupancy sensing. NLC and LLC to use actual only.

Lighting Control Type	Default kW controlled [268]
Fixture-mounted occupancy sensor	0.138 (per fixture)
Remote (ceiling) mounted occupancy sensor	0.338 (per control)
Network, Luminaire level control	Custom

Hours = Annual operating hours per unique usage area.

[265] Ameren DSM participant reported costs, 266 participants, 1/1/2019 through 7/1/2024, weighted average of 14,228 sensor cost with installation.
[266] NEEA, Northwest Energy Alliance, Table 11 page 11, Average of three systems, "2022 Luminaire Level Lighting Controls Incremental Cost Study", (March 2023), https://neea.org/img/documents/2022-Luminaire-Level-Lighting-Controls-Incremental-Cost-Study.pdf
[267] Lawrence Berkeley National Laboratory, Energy Solutions, for the California Energy Commission (April 2019), Average incremental cost of three building types by area, Page 62-63 Table 18 to 20, https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-041.pdf
[268] Efficiency Vermont Technical Reference Manual 12.31.2018, Page 47; https://puc.vermont.gov/sites/psbnew/files/doc_library/Vermont%20TRM%20Savings%20Verification%202018%20Version_FINAL.pdf

=Actual, if unknown the hours by Building Type may be applied.

ESF_{Occ} = Energy Savings Factor (represents the percentage reduction to the operating hours for occupancy sensing from the non-controlled baseline lighting system).
=Actual, if unknown, the default values below.

ESF_{Trim} =Energy Savings Factor for high end trim adjustment or tuning with Network Lighting Controls with or without Luminaire Lighting Level Controls (represents percentage reduction to the base fixture wattage)
=(Fixture full wattage – Trimmed wattage)/Full wattage

ESF_{Other} =Energy Savings Factor for NLC with additional strategies beyond occupancy sensing or scheduling. Includes daylight harvesting, dimming, luminaire level lighting control, personal control.
=Actual, if unknown the default values below may be used.

Lighting Strategy by Equipment Type	Energy Savings Factor [269]
Occupancy Sensing – Fixture, Remote, NLC, LLC	0.24
High End Trim - NLC	0.11[270]
High End Trim – NLC + LLLC	0.28
Other strategies – NLC + LLLC	0.10

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the table , "C&I Lighting Deemed Hours and Waste Heat Factors by Building Type".

IF_{heat} = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the table , "C&I Lighting Deemed Hours and Waste Heat Factors by Building Type".

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh \times CF$$

Where:

ΔkWh = As calculated above

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[269] Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Page & Associates Inc. 2011 (Page 1).
https://eta.lbl.gov/publications/meta-analysis-energy-savings-lighting.
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.

[270] NEEA, Northwest Energy Efficiency Alliance, Table 10 page 56, "Energy Savings from Networked Lighting Control Systems With and Without Luminaire Level Lighting Controls", https://neea.org/img/documents/Energy-Savings-from-Networked-Lighting-Control-Systems-With-and-Without-LLLC.pdf. The Table 10 Control Factor values for NLC and NLC + LLLC , were set as incremental values from a typical occupancy sensor savings factor of 0.24. The sum of all ESF total the reported values of 0.63 for NLC + LLLC and 0.35 for NLC.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor.
= 0.0001899635[271] for indoor lighting
= 0.0001379439 for Miscellaneous
= 0.0000056160 for exterior lighting

Natural Gas Energy Savings

If gas heated building (or unknown), the heating penalty is:

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

$$\Delta Therms = \sum (kW_{Controlled} * Hours * (ESF_{Occ} + ESF_{Trim} + ESF_{Other}) * (-IF_{heat}))$$

Where:

IF_{Therms} = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the table , "C&I Lighting Deemed Hours and Waste Heat Factors by Building Type".

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

271 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.7 Miscellaneous

2.7.1 Heat Pump Pool Heater

DESCRIPTION

This measure applies to the installation of a heat pump pool heater in place of a standard electric pool heater on an outdoor pool at a commercial location.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new, standard efficiency electric resistance pool heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[272]

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.[273]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Q_{PoolHeating}$ = Required annual heat transfer to pool water (kWh), calculated as follows:[274]
For an uncovered pool: [53.075 x (SQFT)] + 1631.1
For a pool that is regularly covered when not in use: [8.079 x (SQFT)] + 1295.4

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[272] Measure life is for a high-efficiency pool heater, from 2017 Michigan Energy Measures Database (row 246).

[273] Measure cost based on "The Definitive Guide to Heating Your Swimming Pool," page 7, AquaCal, July 2013. https://www.thepoolworks.com/pdfs/The-Definitive-Guide-To-Heating-Your-Swimming-Pool.pdf . Electric resistance pool heaters can be purchased for less than $2,000, and heat pump pool heaters cost between $2,000 and $4,000

[274] Based on the results of a swimming pool energy calculation tool found at http://noanderson.com/services/swimming-pool-energy-temperature-calculator/energy-temperature-calculator/. Results use St. Louis weather-related assumptions and assume a pool season of May through October (per Energy Star® guidelines), with a water temperature of 80 degrees Fahrenheit.

Where SQFT is the total surface area of the pool.

Eff_{Base} = Efficiency of electric resistance pool heater

= 100%

Eff_{EE} = Efficiency (COP) of heat pump pool heater

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \times CF$$

Where:

ΔkWh = Calculated value above.

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

= 0.0001379439[275]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[275] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.7.2 Computer Server

DESCRIPTION

This measure estimates savings for an energy efficient computer server with that has been certified to ENERGY STAR® (ES) Version 4.0.

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 4.0**.** The measure characterization includes computer server, blade systems (one or more blade servers), resilient server, and multi-node server. Power supply efficiency must meet the PSU criteria for 10%,20%, 50% and 100% load. The power supply must also meet the power factor criteria for ENERGY STAR® Version 4.0. The server must also meet the active state efficiency score requirements, which include the CPU efficiency, memory efficiency and storage efficiency. The table lists the minimum active efficiency by server type and installed processors.

DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR® qualified computer server.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.[276]

DEEMED MEASURE COST

The actual incremental cost of the equipment should be used, if unknown, the following estimates may be used.

Number Installed Processors	Equipment	Incremental cost[277]
1	Rack	$331
	Tower	$323
	Resilient	$5000
2	Rack	$452
	Tower	$668
	Blade or Multi-Node	$1225
	Resilient	$5000
≥3	Rack	$452
	Blade or Multi-Node	$1225

[276] 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.

[277] Internet online manufacturer product pricing difference for rack and tower, resilient and blade servers estimated with 20% incremental cost for ENERGY STAR certified equipment. Local file: "Server incremental cost.xlsx"

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[278]

Annual energy savings are based on the number of installed processor and equipment type, as estimated by the ENERGY STAR® Computer Server Analysis calculator, with the results summarized in the following table[279]:

Number Installed Processors	Equipment	Minimum Score Eff_{Active}	Electric Savings kWh
1	Rack	26.4	1,459
	Tower	24.4	723
	Resilient	6.6	1,474
2	Rack	30.4	2,542
	Tower	26.5	2,028
	Blade or Multi-Node	29.1	1,574
	Resilient	6.0	0
≥3	Rack	31.9	10,218
	Blade or Multi-Node	26.8	3,903

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

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[279] ENERGY STAR® , "Computer Servers Final Data and Analysis Package", Energy and Cost Savings worksheet, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.energystar.gov%2Fsites%2Fdefault%2Ffiles%2Fasset%2Fdocument%2FENERGY%2520STAR%2520Version%25204.0%2520Computer%2520Servers%2520Final%2520Data%2520and%2520Analysis%2520Package.xlsx&wdOrigin=BROWSELINK

= 0.0001379439 [280]

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:

[280] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.8 Motors and Pumps

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. The measure includes induction, reluctance, electronically commutated, and permanent magnet motors. Fire pump motors are excluded.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a 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 for early replacements, or the Federal Energy Standards for normal replacements. [281]

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 18 years.[282]

Deemed Measure Cost

Actual incremental costs should be used if available. If actual costs are unknown, use default installed cost from table below.[283]

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

[281] DOE|Motors|https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431
[282] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for electric motors.("Updated 2014 EUL table" rows 40,52,131,134,627)
[283] Installed costs from 2015-2016 Demand-Side Management Plan, Xcel Energy https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM-2015-16-DSM-Plan.pdf (page 440).

Motor Size (HP)	Installed Cost
40	$3,716
50	$4,073
60	$5,128
75	$5,888
100	$7,392
125	$9,076
150	$9,401
200	$11,250
250	$13,958
300	$17,744
350	$25,653

LOADSHAPE

Motors BUS

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%[284]

0.746 = Conversion factor from HP to kWh

η_{Bmotor} = Actual efficiency of existing motor for early replacement
=Federal Energy Standards for normal replacement

$\eta_{EEmotor}$ = Efficient motor nominal/nameplate motor efficiency
= Actual

Hours = Annual hours of operation for motor; see table below for HVAC motors

[284] 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. (see page 1)

Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC)[285]

Motor Size (HP)	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
1	82.50%	85.50%	77.00%	82.50%	85.50%	77.00%
1.5	86.50%	86.50%	84.00%	87.50%	86.50%	84.00%
2	87.50%	86.50%	85.50%	88.50%	86.50%	85.50%
3	88.50%	89.50%	85.50%	89.50%	89.50%	86.50%
5	89.50%	89.50%	86.50%	89.50%	89.50%	88.50%
7.5	90.20%	91.00%	88.50%	91.00%	91.70%	89.50%
10	91.70%	91.70%	89.50%	91.00%	91.70%	90.20%
15	91.70%	93.00%	90.20%	91.70%	92.40%	91.00%
20	92.40%	93.00%	91.00%	91.70%	93.00%	91.00%
25	93.00%	93.60%	91.70%	93.00%	93.60%	91.70%
30	93.60%	94.10%	91.70%	93.00%	93.60%	91.70%
40	94.10%	94.10%	92.40%	94.10%	94.10%	92.40%
50	94.10%	94.50%	93.00%	94.10%	94.50%	93.00%
60	94.50%	95.00%	93.60%	94.50%	95.00%	93.60%
75	94.50%	95.00%	93.60%	94.50%	95.40%	93.60%
100	95.00%	95.40%	93.60%	95.00%	95.40%	94.10%
125	95.00%	95.40%	94.10%	95.00%	95.40%	95.00%
150	95.40%	95.80%	94.10%	95.80%	95.80%	95.00%
200	95.40%	95.80%	95.00%	95.80%	96.20%	95.40%
250	95.40%	95.80%	95.00%	95.80%	96.20%	95.80%
300	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%
350	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%

[285] For 1-200 HP motors, baseline efficiency is from NEMA MG 1 Table 12-12. For motors over 200 hp, baseline efficiency is from NEMA MG 1 Table 12-11.

Annual Hours of Use for HVAC Motors[286]

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours	Fan Motor Run Hours
Large Office	5,233	6,385	6,753
Medium Office	3,437	5,921	6,968
Small Office	3,715	3,774	6,626
Warehouse	4,587	1,292	6,263
Stand-alone Retail	4,040	2,713	6,679
Strip Mall	3,908	2,548	6,687
Primary School	4,754	5,160	5,906
Secondary School	5,594	5,279	6,702
Supermarket	4,868	4,255	6,900
Quick Service Restaurant	4,231	3,378	7,679
Full Service Restaurant	4,595	4,897	7,664
Hospital	8,760	8,717	8,760
Outpatient Health Care	8,760	8,689	8,760
Small Hotel - Building	3,533	7,976	8,760
Large Hotel - Building	5,538	8,308	8,760
Midrise Apartment - Building	5,197	4,347	8,728
Nonresidential Average	4,411	3,539	6,773

SUMMER COINCIDENT PEAK DEMAND SAVINGS[287]

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[288]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

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[286] 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.

[287] 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.

[288] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

2.8.2 Pool Pump

Description

This measure applies to the installation of a variable frequency drive (VFD) on an existing single-speed pool pump at a commercial location. VFDs save energy by reducing the speed of the pool pump motor to match the pool's required flow rate. Additionally, VFD's soft-starting extends motor life by reducing wear.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new VFD meeting program requirements. The hydraulic horsepower must exceed 2.5 HHP, which is approximately equal to a 5 hp motor, as their minimum efficiency is regulated by the dedicated pool pump (DPPP) standard.

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.[289]

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.[290]

Loadshape

Motors BUS

Algorithm

Calculation of Savings

Electric Energy Savings

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

[289] EUL set to 10 years based on 2021 comparison with other TRM values; Database for Energy Efficient Resources (2014). http://www.deeresources.com/. ("Updated 2014 EUL table, row 592)

[290] Costs from 2017 Michigan Energy Measures Database ("Commercial" tab row 356).

Where:

1,747 = Average annual energy savings per pool pump motor horsepower (kWh/HP)[291]

HP = Pool pump motor horsepower

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

Summer Coincident Peak Demand Savings

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

Where:

kWh = Electric energy savings, as calculated above.

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

= 0.0001379439[292]

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

[291] 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 (page "i" and 22 https://www.etcc-ca.com/sites/default/files/reports/et13sce1170_comm_vfd_pool_pumps_final.pdf).

[292] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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.[293]

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.

[293] https://pooltimerdoor.com/how-much-does-it-cost-to-replace-a-pool-timer/

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[294]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[294] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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.[295]

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

[295] Martin, N. et al., Emerging Energy-Efficient Industrial Technologies: New York State Edition, American Council for an Energy Efficient Economy (ACEEE) Page 126, March 2001 (as stated in the OH State TRM, page 269).

ELECTRIC ENERGY SAVINGS

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

Where:

HP_{motor}	= Installed nameplate motor horsepower = Actual
0.746	= Conversion factor from horsepower to kW (kW/hp)
LF / η_{motor}	= Combined as a single factor since efficiency is a function of load = 0.65[296]
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%.[297]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh \times CF$$

Where:

CF	= Summer Coincident Peak Factor for measure = 0.0001379439[298]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[296] "Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings," ACEEE 1994 Summer Study Conference, Asilomar, CA (page 3.95 Table 3).

[297] 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.

[298] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

DESCRIPTION

This measure applies to VFDs installed on HVAC chilled water distribution pumps, hot water distribution pumps, condenser water pumps and cooling tower fans. Back-up pumps/fans do not qualify for this measure. There is a separate measure for HVAC supply and return fans. The VFD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a pump or fan motor that does not have a VFD. The hydronic system that the VFD is applied to must have a variable or reduced load. Installation is to include the necessary control points and parameters (example: differential pressure, differential temperature, return water temperature) as determined by a qualified engineer.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.[299]

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.[300] The tables values can also be extrapolated with:

Incremental cost = 300 x Hp+ $1,500.

[299] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for electronic building controls. California Database for Energy Efficiency Resources (DEER) 2014 Estimated Useful Life (EUL) Table Update. ("Updated 2014 EUL table" row 108) Consistent with Ameren Missouri program assumptions.
[300] TRC, Ameren MO C&I participant self reported cost data for completed projects (2019 to 2024).

HP	Cost
1-2.5 HP	1,593
2.6-5 HP	2,383
6-10 HP	3,610
11-20 HP	8,786
21-50 HP	13,082
51-75 HP	18,867
75-100 HP	21,760
>100 HP	23,116

LOADSHAPE

Cooling BUS
Heating BUS
HVAC BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = BHP /EFFi x Hours x ESF

Where:

BHP = System Brake Horsepower
= Nominal motor HP x Motor load factor)
Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.[301] 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.[302] When available, actual hours should be used.

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

[301] 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 (page 24).

[302] Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each Building Type. "Heating and Cooling Run Hours" are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each Building Type. This may over claim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

Annual Hours of Use for VFD Pumps and Fans

Building Type	Heating Run Hours	Cooling Run Hours
Large Office	5233	6385
Medium Office	3437	5921
Small Office	3715	3774
Warehouse	4587	1292
Stand-alone Retail	4040	2713
Strip Mall	3908	2548
Primary School	4754	5160
Secondary School	5594	5279
Supermarket	4868	4255
Quick Service Restaurant	4231	3378
Full Service Restaurant	4595	4897
Hospital	8760	8717
Outpatient Health Care	8760	8689
Small Hotel - Building	3533	7976
Large Hotel - Building	5538	8308
Midrise Apartment - Building	5197	4347
Nonresidential Average	4411	3539

ESF for VFD Pumps and Fans

Application	ESF
Hot Water Pump	0.249[303]
Cooling Water Pump	0.358[304]
Cooling Tower Fan	0.502[305]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.000910684[306] Cooling Water Pumps
= 0.000443983 Hot Water Pumps
= 0.000443983 Cooling Tower Fans

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

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[303] VEIC, workpaper to support VFD savings,Local file: "VSD ESF Calculation.xlsx"
[304] VEIC, workpaper to support VFD savings,Local file: "VSD HVAC Pump Savings.xlsx"
[305] VEIC, workpaper to support VFD savings,Local file: "VSD ESF Calculation.xlsx"
[306] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.8.6 Variable Frequency Drives for HVAC Supply and Return Fans

Description

This measure applies to VFDs installed on HVAC supply fans and return fan. Back-up fans do not qualify for this measure. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

Definition of Efficient Equipment

The VFD is applied to an HVAC fan motor that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (example: differential pressure, temperature, or volume). Savings are based on the application of VFDs to a range of baseline system conditions, including no control, inlet guide vanes, outlet guide vanes, relief dampers, and throttling valves.

Definition of Baseline Equipment

The TOS baseline is a new motor installed without a VFD or other methods of control. The RF baseline is an existing motor operating as is. RF baselines may or may not include guide vanes, throttling valves, or other methods of control.

Installations of new equipment with VFDs which are required by regional code adoption should not claim savings.

Deemed Lifetime of Efficient Equipment

The expected measure life for HVAC application is 15 years.[307]

Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.[308] The tables values can also be extrapolated with:

Incremental cost = 300 x Hp+ $1,500.

[307] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for electronic building controls (page 38.3).
[308] TRC, Ameren MO C&I participant self reported cost data for completed projects (2019 to 2024).

HP	Cost
1-2.5 HP	1,593
2.6-5 HP	2,383
6-10 HP	3,610
11-20 HP	8,786
21-50 HP	13,082
51-75 HP	18,867
75-100 HP	21,760
>100 HP	23,116

LOADSHAPE

HVAC BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[309]

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

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

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

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

Where:

ΔkWh_{fan}	= Fan-only annual energy savings
ΔkWh_{total}	= Total project annual energy savings
kWh_{Base}	= Baseline annual energy consumption (kWh/yr)
$kWh_{Retrofit}$	= Retrofit annual energy consumption (kWh/yr)
0.746	= Conversion factor for HP to kWh
HP	= Nominal horsepower of controlled motor
LF	= Load Factor; Motor Load at Fan Design CFM (Default = 65%)[310]
ηmotor	= Installed nominal/nameplate motor efficiency = Actual. If unknown, default can be assumed as a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor, with efficiency indicated in the table below.

[309] 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.

[310] 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 (page 42).

$RHRS_{Base}$ = Annual operating hours for fan motor based on Building Type.
%FF = Percent of time at flow fraction
PLR_{Base} = Part load ratio for a given flow fraction range based on the baseline flow control type (see table below)
$PLR_{Retrofit}$ = Part load ratio for a given flow fraction range based on the retrofit flow control type (see table below)
E_{energy} = HVAC interactive effects factor for energy (default = 15.7%)[311]

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 = 0.004439830[312]

[311] Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications." (page 123) A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

[312] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

2.8.7 Efficient Pumps

Description

The Federal Energy Efficiency Standards set minimum energy ratings for clean water pumps. The types of pumps characterized in this measure include clean water commercial & industrial pumps, circulator pumps and dedicated purpose pool pumps. The Federal Energy Efficiency Standards for C&I clean water pumps was effective January 27, 2020. The standards for circulator pumps are effective May 2028, but are included in the measure characterization. The Federal Energy Efficiency Standards for dedicated purpose pool pump with VFD motor, setting a minimum weighted energy factor (WEF) effective date was July 19, 2021. The measure requires exceeding the minimum standard by 10% or more of the rated efficiency. The measure does not include fire pumps.

Definition of Efficient Equipment

In order for this characterization to apply, the C&I pump is

- Clean water pump
- Flow rate of ≥25 gpm (BEP, full impeller diameter); 1 to 200 hp
- Electric motor driven
- Variable load pump energy index (PEI_{VL}) or constant load pump energy index (PEI_{CL}) <0.90 with varying C-values.

The motor and motor controls may be included in the system energy rating.
The following formula may be used to convert the PEI to the Energy Rating, ER.

$$Energy\ Rating = (1 - PEI)\ x\ 100$$

For circulator pumps

- Hydraulic horsepower ≤2.5 HHP.
- Flow rate of ≥25 gpm (BEP, full impeller diameter)
- Circulator Energy Index, CEI <0.90.

For dedicated purpose pool pumps

- Hydraulic horsepower ≤2.5 HHP. (HHP is approximately ½ of total motor hp, THP)
- Flow rate of ≥25 gpm (BEP, full impeller diameter)
- Weighted energy factor (WEF) exceeds the minimum standard by 10% or more

Definition of Baseline Equipment

In order for this characterization to apply, the baseline pump is assumed to be an efficient pump meeting Federal Energy Efficiency Standards for pumps.

Pump Type	Efficiency Units	Efficiency Value	Applicability
C&I variable load	PEI_{VL}	1.0	By C-value
C&I constant load	PEI_{CL}	1.0	By C-value
Self prime pool pump	WEF, kgal/kWh	-2.3 x hhp + 6.59	0.711 ≤ hhp<2.5
Circulator pump	CEI	1.0	≥25 gpm

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to 20 years.[313]

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
Cooling BUS
HVAC BUS

Algorithm

Calculation of Savings

Electric Energy Savings

Pumps with efficiency expressed in ER units.

$$\Delta\, kWh = \frac{ER}{100}\; x\; Pump\; Motor\; (hp) x\; 0.746\; \frac{kW}{hp}\; x\; Annual\; Hours$$

Where:

ER = Energy rating of pump (may include motor and controls)
= Actual, as listed by the Hydraulic Institute[314]

LF = Load Factor; Motor Load at Fan/Pump Design CFM
= 75%[315]

0.746 = Conversion factor from HP to kWh

[313] ASHRAE, Chapter 38: Owning and Operating Costs, Table 4, "Heating, Ventilating and Air Conditioning Applications", (2023 edition) for base mounted pumps.
[314] Hydraulic Institute, https://er.pumps.org/ratings/search
[315] 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. (page # 1)

η_{Bmotor} = Actual efficiency of existing motor, or if unknown, use federal baseline nominal/nameplate motor efficiency as shown in table below.

$\eta_{EEmotor}$ = Efficient motor nominal/nameplate motor efficiency
= Actual

Hours = Annual hours of operation for motor
=Actual, or if unknown,; see table in 2.8.1 for Annual Hours of Use for HVAC motors

Pumps with efficiency expressed in WEF units.

$$\Delta\, kWh = \left(\frac{1}{WEF_{base}} - \frac{1}{WEF_{eff}}\right) x\ Volume\ x\ Turnover\ x\ OpenDays$$

Where:

WEF_{base} =Federal Energy Efficiency Standard
= -2.3 x hydraulic horsepower + 6.59,

WEF_{eff} = Weighted energy factor, kgal/kWh
= Actual

Volume = Pool volume, 1,000 gallons

Turnover = Pool water turnover per day, actual
= 4.0 if unknown[316]

Open Days = Annual days pool is open requiring filtration

[316]CA eTRM, Six hour or less complete pool water turnover for public pools, “VSD for Pool & Spa Pump”, VSDforPool&SpaPump|ETRM(caetrm.com) https://clearcomfort.com/why-is-swimming-pool-circulation-important/#:~:text=Circulating%20your%20pool%20disperses%20any,to%20disinfect%20your%20entire%20pool.

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh \times CF$$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.000910684[317] Cooling Water Pumps
= 0.000443983 Hot Water Pumps
= 0.0001379439 Process Pumps

Natural Gas Energy Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code:

[317] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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 5.0, Effective December 22, 2022) [318]

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.026V + 0.8	≤ 0.21V+ 0.9
15 ≤ V < 30	≤ 0.05V + 0.45	≤ 0.12V + 2.248
30 ≤ V < 50	≤ 0.05V + 0.45	≤ 0.2578V – 1.8864
V ≥ 50	≤ 0.025V + 1.6991	≤ 0.14V + 4.0
Glass Door		
0 < V < 15	≤ 0.095V + .445	≤ 0.232V + 2.36
15 ≤ V < 30	≤ 0.05V + 1.12	≤ 0.232V + 2.36
30 ≤ V < 50	≤ 0.076V + 0.34	≤ 0.232V + 2.36
V ≥ 50	≤ 0.105V – 1.111	≤ 0.232V + 2.36
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.05V + 0.28	≤ 0.057V + 0.55

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 and meets the Federal Energy Efficiency Standards

[318] ENERGY STAR® | Commercial Refrigerators & Freezers | https://www.energystar.gov/products/commercial_food_service_equipment/commercial_refrigerators_freezers/key_product_criteria

for units built as of March 2017 for TOS. Existing, working equipment may use the value in the baseline table determined by the manufacturing date.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[319]

Deemed Measure Cost

The incremental capital cost for this measure varies by size as shown in the table below:

Measure	Incremental Cost [320]
Commercial Glass Door Freezers less than 15 ft^3	$50
Commercial Glass Door Freezers 15 to 30 ft^3	$100
Commercial Glass Door Freezers 30 to 50 ft^3	$300
Commercial Glass Door Freezers more than 50 ft^3	$500
Commercial Glass Door Refrigerators less than 15 ft^3	$50
Commercial Glass Door Refrigerators 15 to 30 ft^3	$200
Commercial Glass Door Refrigerators 30 to 50 ft^3	$450
Commercial Glass Door Refrigerators more than 50 ft^3	$700
Commercial Solid Door Freezers less than 15 ft^3	$100
Commercial Solid Door Freezers 15 to 30 ft^3	$350
Commercial Solid Door Freezers 30 to 50 ft^3	$500
Commercial Solid Door Freezers more than 50 ft^3	$600
Commercial Solid Door Refrigerators less than 15 ft3	$150
Commercial Solid Door Refrigerators 15 to 30 ft3	$200
Commercial Solid Door Refrigerators 30 to 50 ft3	$250
Commercial Solid Door Refrigerators more than 50 ft3	$350
Horizontal Closed - Solid or Glass Door Refrigerator (all volumes)	$0
Horizontal Closed - Solid or Glass Door Freezer (all volumes	$0

Loadshape

Refrigeration BUS

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below.[321]

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

[319] ENERGY STAR® | Commercial Food Service Calculator | Freezer Calcs, Refrigerator Calcs worksheets | https://www.energystar.gov/cfs/calculator/

[320] https://www.energystar.gov/sites/default/files/2024-03/CFS%20Equipment%20Calculator.xlsx

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

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	Daily Energy, kWh[322]	
	Manufactured 1/1/2010-3/27/2017	Manufactured 3/28/2017 to Current or TOS
Solid Door Refrigerator	0.10V + 2.04	0.05V + 1.36
Glass Door Refrigerator	0.12V + 3.34	0.1V + 0.86
Solid Door Freezer	0.40V + 1.38	0.22V + 1.38
Glass Door Freezer	0.75V + 4.10	0.29V + 2.95

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR®
= Actual, if unknown calculated as shown in the Efficient Equipment table using the actual refrigerated volume (V)

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[323]

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

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[322] Federal Energy Efficiency Standards | Commercial Refrigerators and Freezers | https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-C

[323] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.9.2 Refrigerated Beverage Vending Machine

Description

This measure applies to new ENERGY STAR®, Class A or Class B refrigerated vending machines. ENERGY STAR® vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR®, Class A or Class B[324] refrigerated vending machine meeting energy consumptions requirements as determined by equipment type (Class A or Class B).

ENERGY STAR® Requirements (Version 4.0, Effective April 2020) [325]

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.[326]

Deemed Measure Cost

The incremental cost of this measure is $125.[327]

Loadshape

Refrigeration BUS

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[324] 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."

[325] ENERGY STAR® | Refrigerated Vending Machines Key Product Criteria, https://www.energystar.gov/products/vending_machines/key_product_criteria

[326] Average of measure lives recognized by Ameren Missouri (10 years) and KCPL (14 years). Also consistent with ENERGY STAR® ® commercial refrigerator lifetime ("Refrigerator Calcs" tab row 42).

[327] Serving Up Savings: The New Value Equation for Energy Efficient Vending Machines (Average of $100 for Tier II on pag 4-211 and $150 for a kit to refurbish an old machine on page 4-216. https://www.aceee.org/files/proceedings/2006/data/papers/SS06_Panel4_Paper18.pdf .

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.

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

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline vending machine
= Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWhBase [328]
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
= Actual, if unknown calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWhEE[329]
Class A	≤ 0.0523V + 2.432
Class B	≤ 0.0657V + 2.844

V = Refrigerated volume[330] (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[331]

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[328] 33010 CFR §431.296 - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

[329] ENERGY STAR® | Refrigerated Vending Machines Key Product Criteria, https://www.energystar.gov/products/vending_machines/key_product_criteria

[330] 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.

[331] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

MEASURE CODE:

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.[332]

DEEMED MEASURE COST

Actual incremental costs should be used if available. The incremental capital cost $150 per door.[333]

LOADSHAPE

Refrigeration BUS

Algorithm

CALCULATION OF SAVINGS

[332] Database for Energy Efficient Resources (2014). http://www.deeresources.com/. ("Updated 2014 EUL table, cell D35).

[333] TRC, Ameren DSM participants for anti-sweat heater controls, 2014 to 2024. Loca file: "Door heat controls cost 2014 to 2024.xlsx"

ELECTRIC ENERGY SAVINGS

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

Where:

kW_{Base} = Per door electric energy consumption of door heater without controls
= Assume 0.130 kW per door[334]

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%[335]

$\%ON_{Control}$ = Effective run time with anti-sweat door heater controls
= Actual or if unknown, use 45.6% [335]

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)[336]

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[337]

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

[334] 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.

[335] The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 69, Table 37.

[336] 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.

[337] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

NATURAL GAS ENERGY SAVINGS

N/A

MEASURE CODE:

2.9.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers/Freezers

DESCRIPTION

This measure consists of replacement of an existing, uncontrolled, and continuously operating standard efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins.

This measure achieves savings by installing a more efficient motor, thereby moving the same amount of air with less energy requirements. Additionally, less waste heat is produced, resulting in a decreased refrigeration load.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure applies to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an electronically commutated motor (ECM). Savings assume that efficient motors operate continuously.

DEFINITION OF BASELINE EQUIPMENT

The baseline is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[338]

DEEMED MEASURE COST

The measure cost is assumed to be $$358 per motor for a walk in cooler and $208 walk in freezer, labor cost was assumed equal for a code compliant motor and ECM motor, .[339]

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

338 Database for Energy Efficient Resources (2014). https://www.deeresources.com/("Updated 2014 EUL table, cell D52).

339 CA eTRM,, “High Efficiency Fan “, Southern California Edison, “SWCROO4-02Cost analysis.xlsx” (2022),Equipment cost for ECM motor

from controllers, however for the purposes of this measure only those associated with the ECM upgrade are considered.

ELECTRIC ENERGY SAVINGS

$\Delta kWh = Savings\ per\ motor\ x\ motors$

Where:

Savings per motor[340] = based on the motor rating of the ECM motor – see table below.

Motors = number of fan motors replaced

Evaporator Fan Motor Rating (of ECM)	Annual kWh Savings/motor
16W	408
1/15 - 1/20HP	1,064
1/5HP	1,409
1/3HP	1,994
1/2HP	2,558
3/4HP	2,782

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001379439[341]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

340 See reference workbook "ECM Savings.xlsx" for derivation.

341 Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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.[342]

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.[343]

Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening.[344]

Loadshape

Refrigeration BUS

Algorithm

Calculation of Savings

[342] 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. https://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

[343] Database for Energy Efficient Resources (2014). http://www.deeresources.com/. ("Updated 2014 EUL table, cell D50).

[344] 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 "NR - Commercial Refrigeration" tab cells E18 & G18 ,

ELECTRIC ENERGY SAVINGS[345]

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

Where:

ΔkWh/SQFT = Average annual kWh savings per square foot of infiltration barrier. Based on application type, as indicated by the table below.[346]

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

Type	Pre-Existing Curtains	Energy Savings ΔkWh/sq ft
Supermarket - Cooler	Yes	40
Supermarket - Cooler	No	120
Supermarket - Freezer	Yes	170
Supermarket - Freezer	No	490
Convenience Store - Cooler	Yes	10
Convenience Store - Cooler	No	20
Convenience Store - Freezer	Yes	10
Convenience Store - Freezer	No	30
Restaurant - Cooler	Yes	10
Restaurant - Cooler	No	20
Restaurant - Freezer	Yes	30
Restaurant - Freezer	No	110
Refrigerated Warehouse	Yes	50
Refrigerated Warehouse	No	150

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

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

[345] 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].

[346] NW Council, https://rtf.nwcouncil.org/measure/strip-curtains/, "ComGroceryStripCurtain_v3_1.xlsm" savings calculator, Local files: Revised effectiveness against infiltration value to 0.58 for existing curtains.

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001357383[347]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[347] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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 2015. An efficient window would have specifications not exceeding these values.

Characteristic	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.[348]

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.[349]

LOADSHAPE

[348] Database for Energy Efficient Resources (2014). http://www.deeresources.com/. ("Updated 2014 EUL table, cell D21).
[349] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports (Page C-5-2).

Cooling BUS
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.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

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:

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

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

Where:

CFM_{PRE} = Infiltration at natural conditions as estimated by blower door testing before window upgrade
= Actual

CFM_{POST} = Infiltration at natural conditions as estimated by blower door testing after window upgrade
= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Table 1, HVAC End Use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{0}F] during cooling season between outdoor air temperature and assumed 75^{0}F indoor air temperature – see table below

0.018 = Specific Heat Capacity of Air (Btu/ft^3 °F)

LM = Latent Multiplier to account for latent cooling demand [350]
= 3.0 for St. Louis, MO

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

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

Weather Basis (City based upon)	$OA_{AVG,cooling}$ [°F][351]	$\Delta T_{AVG,cooling}$ [°F]
St Louis, MO	83.0	8.0

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

Where:

U_{BASE} = U-factor value of baseline window assembly (Btu/ft².°F.h)
= Dependent on Weather Basis and window type. See baseline description for values.

U_{EFF} = U-factor value of the efficient window assembly (Btu/ft².°F.h)
= Actual.

A_{window} = Area of insulated window (including visible frame and glass) (ft²)

Other variables as defined above.

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

Where:

$SHGC_{BASE}$ = Solar Heat Gain Coefficient of the baseline window assembly (fractional)

$SHGC_{EFF}$ = Solar Heat Gain Coefficient of the efficient window assembly (fractional)

$\Psi_{cooling}$ = Incident solar radiation during the cooling season (Btu/ft²):[352]
= 40,996 for St. Louis, MO

Other variables as defined above.

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the window upgrade is:

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

$$Infiltration_{heating} = (CFM_{PRE} - CFM_{POST}) \times 60 \times EFLH_{heating} \times \Delta T_{AVG,heating} \times 0.018 / (3{,}412 \times \eta_{heating})$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Table 1, HVAC end use

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

3,412 = Conversion from Btu to kWh.

351 Onebuilding.org|MO TMYx weather data|https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDMO_Missouri-. 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.

352 See "Windows SHG.xlsx" for derivation ("Summary" tab cell E3).

$\eta_{heating}$ = Efficiency of heating system
= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100% Other variables as defined above.

Weather Basis	$OA_{AVG,heating}$ [°F][353]	$\Delta T_{AVG,heating}$ [°F]
St Louis, MO	46.4	8.6

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

Where:

Variables as defined above.

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

Where:

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

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.000910684[354] Cooling
=0.000443983 HVAC (heating and cooling combined)

NATURAL GAS SAVINGS

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

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

$$Infiltration_{gasheat} = (CFM_{PRE} - CFM_{POST}) \times 60 \times EFLH_{heating} \times \Delta T_{AVG,heating} \times 0.018 / (100{,}000 \times \eta_{heat})$$

$$Conduction_{gasheat} = (U_{BASE} - U_{EFF}) \times A_{window} \times EFLH_{heating} \times \Delta T_{AVG,heating} / (100{,}000 \times \eta_{heat})$$

$$Solar_{gasheat} = (SHGC_{BASE} - SHGC_{EFF}) \times A_{window} \times \Psi_{Heating} / (100{,}000 \times \eta_{heat})$$

Where:

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[353] Onebuilding.org|MO TMYx weather https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDMO_Missouri- . Heating Season defined as September 17th through April 13th.

[354] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

2.10.2 Ceiling and Wall Insulation

Description

Energy and demand saving are realized through reductions in the building cooling and heating loads.

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

In order for this characterization to apply, the baseline is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of IECC. For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2015:

	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

COOLING BUS
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

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

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWhheating = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$R_{existing}$ = Assembly heat loss coefficient with existing insulation [(hr-^{0}F-ft^2)/Btu]

R_{new} = Assembly heat loss coefficient with new insulation [(hr-^{0}F-ft^2)/Btu]

Area = Area of the surface in square feet.

CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.
= 100% if Spray Foam or External Rigid Foam
= 50% if studs and cavity insulation[355]

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Table 1, HVAC End Use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{0}F] during cooling season between outdoor air temperature and assumed 75^{0}F indoor air temperature

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Table 1, HVAC end use

[355] 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.”

$\Delta T_{AVG,heating}$ = Average temperature difference [^{0}F] during heating season between outdoor air temperature and assumed 55^{0}F heating base temperature
3,412 = Conversion from Btu to kWh.
$\eta_{heating}$ = Actual COP efficiency of heating system

Weather Basis (City based upon)	OA_{AVG},cooling [°F][356]	ΔT_{AVG},cooling [°F]	OA_{AVG},heating [°F][357]	ΔT_{AVG},heating [°F]
St Louis, MO	83.0	8.0	46.4	8.6

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.

$\Delta kWh_{heating} = \Delta Therms \times Fe \times 29.3$

Where:

ΔTherms = Gas savings calculated with equation below.
Fe = Percentage of heating energy consumed by fans, assume 3.14%[358]
29.3 = Conversion from therms to kWh

Summer Coincident Peak Demand Savings

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

Where:

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004439830[359] Cooling
=0.000443983 HVAC

Natural Gas Savings

[356] Onebuilding.org|MO TMYx weather https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDMO_Missouri-. 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.
[357] Onebuilding.org|MO TMYx weather https://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html#IDMO_Missouri- . Heating Season defined as September 17th through April 13th.
[358] 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.
[359] Ameren Missouri TRM Volume 1 - Appendix G: "Table 2 – Commercial and Industrial End Use Category Monthly Shapes and Coincident Peak Factors"

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 Table 1, HVAC end use

$\Delta T_{AVG,heating}$ = Average 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: