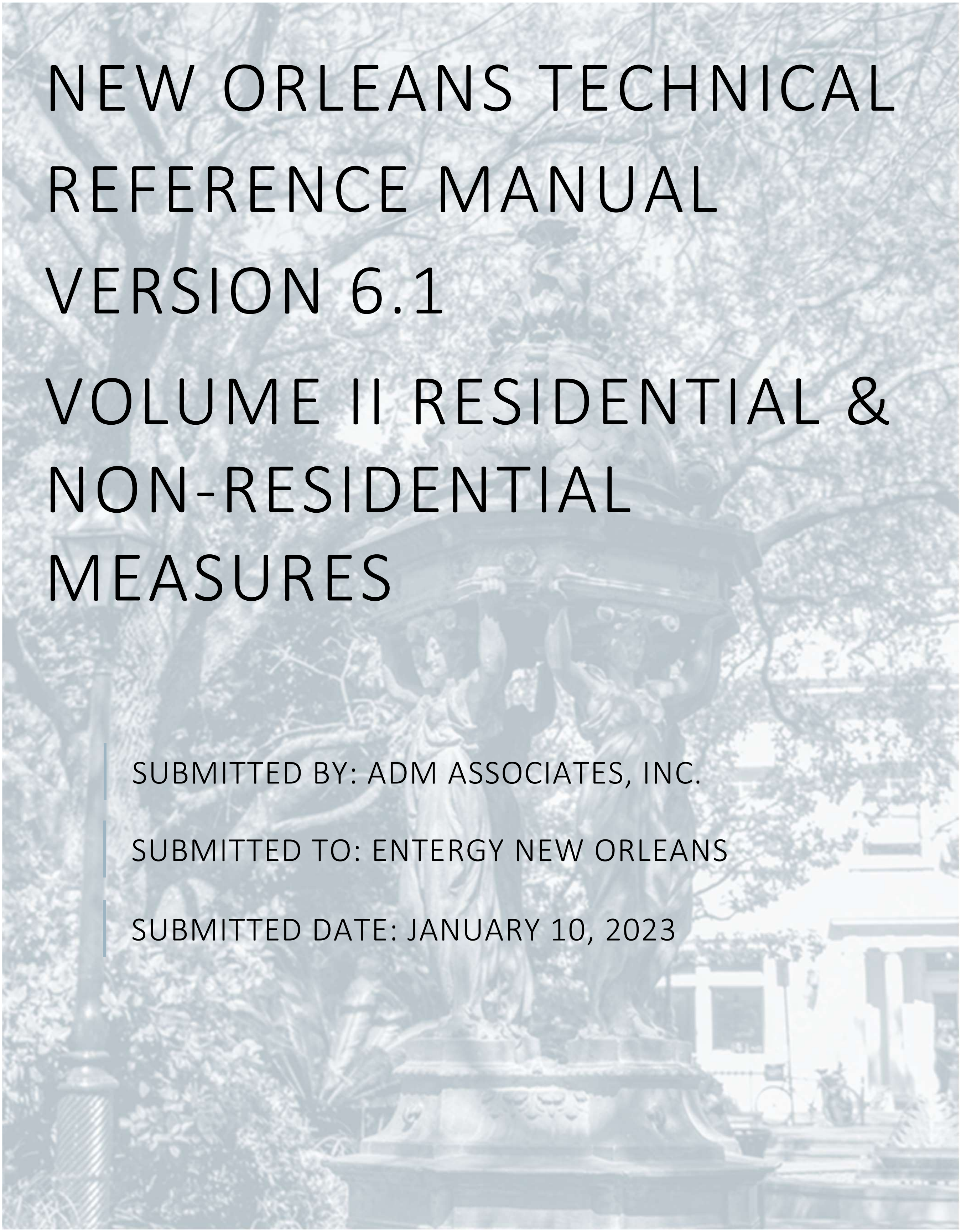

NEW ORLEANS TECHNICAL REFERENCE MANUAL VERSION 6.1

VOLUME II RESIDENTIAL & NON-RESIDENTIAL MEASURES

SUBMITTED BY: ADM ASSOCIATES, INC.

SUBMITTED TO: ENTERGY NEW ORLEANS

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ACRONYMS/ABBREVIATIONS

Table1 Acronyms/Abbreviations

Acronym	Term
AC	Air Conditioner
AOH	Annual operating hours
APS	Advanced Power Strip
AR&R	Appliance Recycling & Replacement
BP	Behavioral Program
BYOT	Bring Your Own Thermostat
C&I	Commercial and Industrial
CEE	Consortium for Energy Efficiency
CF	Coincidence factor
CFL	Compact fluorescent lamp (bulb)
CFM	Cubic feet per minute
CRE	Commercial Real Estate
DI	Direct install
DLC	Direct Load Control
DLC	Design Lights Consortium
EER	Energy efficiency ratio
EFLH	Equivalent full-load hours
EISA	Energy Independence and Security Act
EL	Efficiency loss
EM&V	Evaluation, Measurement, and Verification
ES	ENERGY STAR
EUL	Estimated Useful Life
GPM	Gallons per minute
HDD	Heating degree days
HID	High intensity discharge
HOU	Hours of Use
HP	Heat pump
HPwES	Home Performance with ENERGY STAR
HSPF	Heating seasonal performance factor
HVAC	Heating, Ventilation, and Air Conditioning
IEER	Integrated Energy Efficiency Ratio
IEF	Interactive Effects Factor
IPLV	Integrated part load value
IQW	Income Qualified Weatherization
ISR	In-Service Rate
kW	Kilowatt
kWh	Kilowatt-hour

Acronym	Term
LCDR	Large Commercial Demand Response
LCIS	Large Commercial & Industrial Solutions
LCA	Lifecycle Cost Adjustment
LED	Light Emitting Diode
M&V	Measurement and Verification
MFS	Multifamily Solutions
MW	Megawatt
MWh	Megawatt-hour
NC	New Construction
NTG	Net-to-Gross
PCT	Participant Cost Test
PFI	Publicly Funded Institutions
PY	Program Year
QA	Quality Assurance
QC	Quality Control
RCA	Refrigerant charge adjustment
RIM	Ratepayer Impact Measure
RLA	Retail Lighting and Appliances
ROB	Replace on Burnout
RR	Realization Rate
RUL	Remaining Useful Life
SCDR	Small Commercial Demand Response
SCIS	Small Commercial & Industrial Solutions
SEER	Seasonal Energy Efficiency Ratio
SK&E	School Kits and Education
TA	Trade Ally
TPE	Third-Party Evaluator
TPI	Third-Party Implementer
TRC	Total Resource Cost Test
TRM	Technical Reference Manual
UCT	Utility Cost Test
VFD	Variable Frequency Drive

SAVINGS TYPES

Table 2 Savings Types

Savings Types	Definition
Energy Savings (kWh)	The change in energy (kWh) consumption that results directly from program-related actions taken by participants in a program.
Demand Reductions (kW)	The time rate of energy flow. Demand usually refers to electric power measured in kW (equals kWh/h) but can also refer to natural gas, usually as Btu/hr., kBtu/hr., therms/day, etc.
Expected / *Ex ante* Gross	The change in energy consumption and/or peak demand that results directly from program-related actions taken by participants in a program, regardless of why they participated.
Verified / *Ex post* Gross	Latin for "from something done afterward" gross savings. The energy and peak demand savings estimates reported by the evaluators after the gross impact evaluation and associated M&V efforts have been completed.
Net / *Ex post* Net	Verified / *ex post* gross savings multiplied by the net-to-gross (NTG) ratio. Changes in energy use that are attributable to a particular program. These changes may implicitly or explicitly include the effects of free-ridership, spillover, and induced market effects.
Annual Savings	Energy and demand savings expressed on an annual basis, or the amount of energy and/or peak demand a measure or program can be expected to save over the course of a typical year. The TRM provides algorithms and assumptions to calculate annual savings and are based on the sum of the annual savings estimates of installed measures or behavior change.
Lifetime Savings	Energy savings expressed in terms of the total expected savings over the useful life of the measure. Typically calculated by multiplying the annual savings of a measure by its EUL. The TRC Test uses savings from the full lifetime of a measure to calculate the cost-effectiveness of programs.

1. RESIDENTIAL MEASURES

1.1 Appliances

1.1.1 ENERGY STAR® CLOTHES WASHERS

1.1.1.1 Measure Description

This measure involves the installation of a residential ENERGY STAR® clothes washer > 2.5 ft^3 in a new construction or replacement-on-burnout application. This measure applies to all residential applications.

1.1.1.2 Baseline and Efficiency Standards

The baseline standard for deriving savings from this measure is the current federal minimum efficiency levels.

The efficiency standard is the ENERGY STAR requirements for clothes washers.

Efficiency performance for clothes washers is characterized by Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF). The units for IMEF are ft^3/kWh/cycle. Units with higher IMEF values are more efficient. The units for IWF are gallons/cycle/ft^3. Units with lower IWF values will use less water and are therefore more efficient.

Table 1-1 ENERGY STAR Clothes Washer – Baseline and Efficiency Levels

Clothes Washer Configuration	ENERGY STAR Efficiency Level Effective 2/5/2018
Top Loading	IMEF ≥ 2.06 IWF ≤ 4.3
Front Loading	IMEF ≥ 2.76 IWF ≤ 3.2

1.1.1.3 Estimated Useful Life

The EUL of this measure is 14 years according to the US DOE.

1.1.1.4 Deemed Savings Values

For retrofit situations, baseline and efficiency case energy consumption is based on the configuration of the replaced unit and new unit (top loading or front loading). For new construction applications, a top loading clothes washer is assumed as the baseline and the efficient equipment is either top loading or front loading.

Table 1-2 ENERGY STAR Clothes Washer – Deemed Savings

Baseline Configuration	Efficient Configuration	Water Heater Fuel Type	Dryer Fuel Type	kWh Savings	kW Savings
Top Loading	Top Loading	Gas	Gas	23	0.005
		Gas	Electric	62	0.015
		Electric	Gas	114	0.027
		Electric	Electric	153	0.036
Top Loading	Front Loading	Gas	Gas	38	0.009
		Gas	Electric	122	0.029
		Electric	Gas	191	0.045
		Electric	Electric	275	0.065
Front Loading	Front Loading	Gas	Gas	6	0.002
		Gas	Electric	148	0.035
		Electric	Gas	32	0.008
		Electric	Electric	173	0.041

Energy savings for this measure were derived using the ENERGY STAR Clothes Washer Savings Calculator[1]. Unless otherwise specified, all savings assumptions are extracted from the ENERGY STAR calculator. The baseline and ENERGY STAR efficiency levels are set to those matching Table 1-1. The calculator determines savings based on whether an electric or gas water heater is used. Calculations are also conducted based on whether the dryer is electric or gas. For applications using an electric water heater and an electric dryer, the savings are calculated as follows:

$$kWh_{savings} = \left(E_{conv,machine} + E_{conv,WH} + E_{conv,dryer}\right) - \left(E_{ES,machine} + E_{ES,WH} + E_{ES,dryer}\right)$$

Where:

$E_{conv,machine}$= Conventional machine energy (kWh)

$E_{conv,WH}$= Conventional water heating energy (kWh)

$E_{conv,dryer}$= Conventional dryer energy (kWh)

[1] The ENERGY STAR Clothes Washer Savings Calculator can be found on the ENERGY STAR website on the right hand side of the page at: https://www.energystar.gov/products/heating_cooling/guide/savings-calculator

$E_{ES,machine}$= ENERGY STAR machine energy (kWh)

$E_{ES,WH}$= ENERGY STAR water heating energy (kWh)

$E_{ES,dryer}$=ENERGY STAR dryer energy (kWh)

1.1.1.4.1 Energy Savings

Energy savings for the above factors can be determined using the following algorithms.

$E_{conv,machi} = \frac{MCF \times RUEC_{conv} \times LPY}{RLPY}$ $E_{conv,WH} = \frac{WHCF \times RUEC_{conv} \times LPY}{RLPY}$ $E_{conv,dryer} = \left(\frac{CAP \times LPY}{IMEF_{FS}} - \frac{RUEC_{conv} \times LPY}{RLPY}\right) \times DUF$ $E_{ES,machine} = \frac{MCF \times RUEC_{ES} \times LPY}{RLPY}$ $E_{ES,WH} = \frac{WHCF \times RUEC_{ES} \times LPY}{RLPY}$ $E_{ES,dryer} = \left(\frac{CAP \times LPY}{IMEF_{ES}} - \frac{RUEC_{ES} \times LPY}{RLPY}\right) \times DUF$

Where:

MCF= Machine electricity consumption factor = 20%

$WHCF$= Water heating electricity consumption factor = 80%

$RUEC_{conv}$= Rated unit electricity consumption (kWh/year) = 381 (Top Loading); 169 (Front Loading)

$RUEC_{ES}$ = Rated unit electricity consumption (kWh/year) = 230 (Top Loading); 127 (Front Loading)

CAP= Clothes washer capacity = 3.5 (ft^3)

$IMEF_{FS}$= Federal Standard Integrated Modified Energy Factor (ft^3/kWh/cycle)

$IMEF_{ES}$= ENERGY STAR Integrated Modified Energy Factor (ft^3/kWh/cycle)

LPY = Loads per year = 295

$RLPY$= Reference loads per year = 392

DUF= Dryer use factor = 91%

1.1.1.4.2 Demand Reductions

Demand reductions are calculated using the following equation:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Where:

AOH = Annual operating hours = LPY × d = 295 hours

CF = Coincidence factor = 0.07[2]

1.1.1.5 Incremental Cost

The incremental cost is $190 .

1.1.1.6 Future Studies

There are no planned studies for this measure at this time.

[2] Value from Clothes Washer Measure, Mid Atlantic TRM 2014. Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, p. 36.

1.1.2 ENERGY STAR DRYERS

1.1.2.1 Measure Description

This measure involves the installation of a residential ENERGY STAR dryers in a new construction or replacement-on-burnout application. This measure applies to all residential applications.

1.1.2.2 Baseline and Efficiency Standards[3]

The baseline standard for deriving savings from this measure is the current federal minimum efficiency levels. The efficiency standard is the ENERGY STAR requirements for dryers.

ENERGY STAR Clothes Dryers are more efficient than standard ones and save energy. They have a higher CEF (Combined Energy Factor) and may incorporate a moisture sensor to reduce excessive drying of clothes and prolonged drying cycles. ENERGY STAR Heat pump dryers or ventless dryers have higher CEF than conventional ENERGY STAR dryers.

Table 1-3 ENERGY STAR Dryer – Baseline and Efficiency Levels[4]

	Vented Gas Dryer	Ventless or Vented Electric, Standard ≥ 4.4 ft^3	Ventless or Vented Electric, Compact (120V) < 4.4 ft^3	Vented Electric, Compact (240V) < 4.4 ft^3	Ventless Electric, Compact (240V) < 4.4 ft^3	Heat Pump Clothes Dryer
ENERGYSTAR Required CEF	3.48	3.93	3.80	3.45	2.68	7.60
Federal standard CEF	2.84	3.11	3.01	2.73	2.13	3.11
Average load (in lbs.)	8.45	8.45	3.0	3.0	3.0	8.45
Default loads per year	283	283	283	283	283	283
Default capacity (in ft^3)	5.0	5.0	3.0	3.0	3.0	5.0

1.1.2.3 Estimated Useful Life

The EUL of this measure is 12 years according to the US DOE.

1.1.2.4 Deemed Savings Values

For retrofit situations, baseline and efficiency case energy consumption is based on the size of the replaced unit and new unit. For new construction applications.

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[3] Current federal standards for clothes dryers can be found on the DOE website at: https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36.

Current ENERGY STAR criteria for clothes dryers can be found on the ENERGY STAR website at: https://www.energystar.gov/products/appliances/clothes_dryers.

ENERGY STAR Most Efficient criteria for clothes washers can be found at: http://www.energystar.gov/ia/partners/downloads/most_efficient/2015/Final_ENERGY_STAR_Most_Efficient_2015_Recognition_Criteria_Clothes_Washers.pdf.

[4] The ENERGY STAR Clothes Dryer Savings Calculator can be found on the ENERGY STAR website on the right hand side of the page at: www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CW

Table 1-4 ENERGY STAR Clothes Dryer – Deemed Savings

Product Type	Energy Savings (kWh/yr)	Demand Reduction (kW)
Vented Electric, Standard (4.4 ft³ or greater capacity)	152.42	.0226
Vented Electric, Compact (120V) (less than 4.4 ft³ capacity)	55.71	.0083
Vented Electric, Compact (240V) < 4.4 ft³	61.66	.0092
Ventless Electric, Compact (240V) < 4.4 ft³	77.71	.0115
Heat Pump Clothes Dryer	431.56	.0641

Energy savings for this measure were derived using the *ENERGY STAR Dryer Savings Calculator*. Unless otherwise specified, all savings assumptions are extracted from the ENERGY STAR calculator.

The energy and demand savings are obtained through the following formulas:

$$\Delta kWh/yr = Cycles_{wash} \times \%_{dry/wash} \times Load_{avg} \times \left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right) \Delta kW_{peak} =$$

$$\frac{\left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right) \times Load_{avg}}{time_{cycle}} \times CF$$

Where:

$Cycles_{wash}$ = Number of washing machine cycles per year = 283 cycles/year

$Load_{avg}$ = Weight of average dryer load, in pounds per load = Standard Dryer: 8.45 lbs/load and Compact Dryer: 3.0 lbs/load[5] [6]

$\%_{\mathrm{dry/wash}}$ = Percentage of homes with a dryer that use the dryer every time clothes are washed = 95%

CEF_{base} = Combined Energy Factor of baseline dryer (lbs/kWh) = See Table 1-3[7]

CEF_{ee} = Combined Energy Factor of ENERGY STAR dryer (lbs./kWh) = See Table 1-3[8]

$time_{cycle}$ = Duration of average drying cycle in hours = 1 hour

CF - Coincidence Factor = 0.042[9]

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[5] Test Loads for Compact and Standard Dryer in Appendix D2 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers. http://www.ecfr.gov/cgi-bin/text-idx?SID=9d051184ada3b0d0b5b553f624e0ab05&node=10:3.0.1.4.18.2.9.6.14&rgn=div9

[6] 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Clothes Dryer Frequency from Table 7.3.3 for Electric Standard. http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee11&disposition=attachment&contentType=pdf

[7] Federal Standard for Clothes Dryers, Effective January 1, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36

[8] ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Draft%20Version%201.0%20Clothes%20Dryers%20Specification_0.pdf

[9] Central Maine Power Company. "Residential End-Use Metering Project". 1988. Using 8760 data for electric clothes dryers, calculating the CF according to the PJM peak definition.

1.1.2.5 Incremental Cost

The incremental cost of high efficiency clothes dryers is detailed in Table 1-5.

Table 1-5 ENERGY STAR Clothes Dryer Incremental Costs

Product Type	Incremental Cost
Vented Electric, Standard: (4.4 ft^3 or greater capacity)	$40[10]
Vented Electric, Compact (120V): (less than 4.4 ft^3 capacity)	$40
Vented Electric, Compact: (240V) < 4.4 ft^3	$40
Ventless Electric, Compact: (240V) < 4.4 ft^3	$40

1.1.2.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. Thus, savings are calculated using ENERGY STAR default values. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents. Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

[10] ENERGY STAR Appliance Calculator: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwihkoHI8f3OAhVW5mMKHe72Du4QFggeMAA&url=https%3A%2F%2Fwww.energystar.gov%2Fsites%2Fdefault%2Ffiles%2Fasset%2Fdocument%2Fappliance_calculator.xlsx&usg=AFQjCNFAy5-mu5GR3BjLp4MR1LqrOHegCA&sig2=8l5MGUh1_bJy3lSl9wAWIA

1.1.3 ENERGY STAR DISHWASHERS

1.1.3.1 Measure Description

This measure involves the installation of an ENERGY STAR dishwasher in a new construction or replacement-on-burnout situation. This measure applies to all residential applications.

1.1.3.2 Baseline and Efficiency Standards

The baseline for this measure is the current federal standard as displayed in the table below.

Table 1-6 ENERGY STAR Criteria for Dishwashers[11]

	ENERGY STAR Criteria		
	Capacity	**Annual Energy Consumption kWh/Year**	**Gallons/Cycle**
Standard Model Size (Effective On 1/26/2016)[12]	> 8 place settings + 6 serving pieces	AECbase + AECadderconnected AECbase: 270 AECadderconnected: 0.05 × AECbase	< 3.5
Compact Model Size (Effective On 1/26/2016)	< 8 place settings + 6 serving pieces	< 203	< 3.1

1.1.3.3 Estimated Useful Life

The EUL of this measure is 15 years according to the US DOE.

1.1.3.4 Deemed Savings Values

Deemed savings are per installed unit based on the water heating fuel type.

Table 1-7 ENERGY STAR Dishwashers – Deemed Savings Values

	Water Heater Fuel Type	kW Savings	kWh Savings
Standard Model Size	Gas	0.0005	5
Standard Model Size	Electric	0.0011	12

1.1.3.4.1 Energy Savings

Energy savings for this measure were derived using the ENERGY STAR Dishwasher Savings Calculator. The baseline and ENERGY STAR efficiency levels are set to those matching Table 1-6.

$$kWh_{Savings} = \left(E_{conv,machine} + E_{conv,WH}\right) - \left(E_{ES,machine} + E_{ES,WH}\right)$$

[11] ENERGY STAR criteria for dishwashers can be found on the ENERGY STAR website at: www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers

[12] ENERGY STAR efficiency requirements as of January 26, 2016 are defined on their website at www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf

Where:

$E_{conv,machine}$= Conventional machine energy (kWh)

$E_{conv,WH}$= Conventional water heating energy (kWh)

$E_{ES,machine}$= ENERGY STAR machine energy (kWh)

$E_{ES,WH}$= ENERGY STAR water heating energy (kWh)

Algorithms to calculate the above parameters are defined as:

$$E_{conv,machine} = MCF \times RUEC_{conv}$$

$$E_{conv,WH} = WHCF \times RUEC_{conv}$$

$$E_{ES,machine} = MCF \times RUEC_{ES}$$

$$E_{ES,WH} = WHCF \times RUEC_{ES}$$

1.1.3.4.2 Demand Reductions

Demand reductions can be derived using the following:

$$kW_{Savings} = \frac{kWh_{Savings}}{AOH} \times CF$$

Where:

MCF= Machine electricity consumption factor = 44%

$WHCF$= Water heating electricity consumption factor = 56%

$RUEC_{conv}$= Rated unit electricity consumption = 307 (kWh/year)

$RUEC_{ES}$ = Rated unit electricity consumption = 295 (kWh/year)

CPY = Cycles per year = 215

d = Average wash cycle duration = 2.1 hours[13]

AOH = Annual operating hours = CPY × d = 451.5 hours

CF = Coincidence factor = 0.036[14]

$\eta_{gas\ WH}$= Gas water heater efficiency = 75%

1.1.3.5 Incremental cost

The incremental cost of ENERGY STAR Dishwashers is $10 .

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[13] Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/dishwashers.htm. Information available for subscribers only.

[14] Hendron, R. & Engebrecht, C. 2010, , National Renewable Energy Laboratory (NREL). "Building America Research Benchmark Definition: Updated December" US U.S. DOE. January 2010. p. 14 (peak hour of 4 PM was applied). http://www.nrel.gov/docs/fy10osti/47246.pdf

1.1.3.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. Thus, savings are calculated using ENERGY STAR default values. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents. Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

1.1.4 ENERGY STAR WATER COOLERS

1.1.4.1 Measure Description

This measure entails the replacement of an inefficient water cooler unit with an ENERGY STAR unit.

The categories of coolers considered are Cook & Cold / Cold Only units; and Hot and Cold units. Within these categories are three configurations Top-loading; Bottom-loading; or Point-of-Use (POU). Top-loading and Bottom-loading are units in which a 3 gallon or a 5 gallon bottle can easily be installed. POU water coolers are bottle-less units that are installed directly to a water line. This chapter provides deemed savings for top and bottom-loading units; POU models are not eligible at this time.

1.1.4.2 Baseline and Efficiency Standards

The previous energy consumption baseline and the current energy efficient energy consumption baseline for the two types of water coolers is shown in Table 1-8.

Table 1-8 Energy Consumption Baseline and ENERGY STAR Efficiency Criteria

Criteria	Water Cooler Category		kWh Per Day
Standard	Cook & Cold		≤ 0.29 kWh/day
	Cold Only		
	Hot and Cold		≤ 2.19 kWh/day
ENERGY STAR	Cold Only and Cook & Cold		≤ 0.16 kWh/day
	Hot and Cold Units - Conditioned Storage[15]	Low Capacity	≤ 0.68 kWh/day
		High Capacity	≤ 0.80 kWh/day
	Hot and Cold Units - On Demand		≤ 0.18 kWh/day

1.1.4.3 Estimated Useful Life

According to ENERGY STAR the EUL is 10 years.

1.1.4.4 Deemed Savings Values

Calculated deemed energy savings are shown in Table 1-9.

Table 1-9 Deemed kWh Savings and kW Reductions for Water Cooler Replacement

Water Cooler Category		Annual kWh Savings	Peak kW Savings
Cold Only and Cook & Cold		47.5	0.005
Hot and Cold Units - Conditioned Storage	Low Capacity	551.5	0.062
	High Capacity	507.7	0.057
Hot and Cold Units - On Demand		734.2	0.082

[15] Point-of-Use and bottled water coolers are included in this category

1.1.4.4.1 Energy Savings

Energy savings are based on the reduction of energy consumption resulting from replacing an inefficient water cooler unit with an energy-efficient unit and are calculated as follows:

$$kWh_{Savings} = \left(kWh_{base} - kWh_{efficient}\right) \times 365.25$$

Where:

kWh_{base} = Baseline daily kWh consumption of energy-inefficient unit (Table 1-8)

$kWh_{efficient}$ = Daily kWh consumption of energy-efficient ENERGY STAR model (Table 1-8)

365 = The number of days in a year water cooler is operating

For example, if an inefficient Cold Only water cooler were to be replaced with a Cold Only ENERGY STAR labeled efficient unit having an energy consumption rate of 0.16 kWh/day, then the annual energy savings would be

$$kWh_{Savings} = (0.29 - 0.16) \times 365 = 47.45\ kWh$$

$$kW_{savings} = kWh_{savings} \times Energy\ to\ Demand\ Factor\ (ETDF)$$

Where:

$ETDF = 0.0001119 \frac{kW}{kWh/_{year}}$ [16]

Continuing the example calculation shown in the previous subsection, the peak demand reduction is:

$$kW_{savings} = 47.45\ {}^{kWh}/_{year} \times 0.0001119 \frac{kW}{kWh/_{year}} = 0.0053\ kW$$

1.1.4.5 Incremental Cost

The TPE conducted a market study of currently available ENERGY STAR and non-ENERGY STAR water coolers to determine incremental pricing. Prices were collected from New Orleans retail websites. The range of models in the “Cook & Cold” category was very limited (particularly for ENERGY STAR-qualifying models). Due to low measure incremental costs, the TPE recommends incentivizing the measure through mid-stream channels.

[16] Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf

Table 1-10 Water Cooler Cost Summary

Type	Efficiency Level	Average Cost
Hot & Cold	Standard	\$182.36 (n=22)
	ENERGY STAR	\$188.81 (n=28)
Cook & Cold	Standard	\$123.18 (n=6)
	ENERGY STAR	\$127.52 (n=2)

- The incremental cost of an ENERGY STAR Cook & Cold or a Cold Only unit is \$4.34.
- The incremental cost of an ENERGY STAR Hot and Cold unit is \$6.45.

Due to low measure incremental costs, the TPE recommends incentivizing the measure through mid-stream channels.

1.1.4.6 Future Studies

At the time of authorship of this chapter, this measure was not implemented in the Energy Smart program. Future EM&V should be conducted to update this measure to align with any new federal standards, as well as to establish a net-to-gross ratio. If program administrators obtain additional cost data for Cook & Cold systems, this should be provided so that the incremental cost for this measure category can be updated with a more robust sample size.

1.1.5 ENEGRY STAR AIR PURIFIERS

1.1.5.1 Measure Description

This measure involves the installation of an ENERGY STAR certified room air purifier. An air purifier, also known as an air cleaner, is defined as a portable electric appliance that removes dust and fine particles from indoor air.

1.1.5.2 Baseline and Efficiency Standards

The baseline equipment is assumed to be a conventional unit. The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below:

- Must produce a minimum 30 Clean Air Delivery Rate (CADR) for Smoke to be considered under this specification. Minimum Performance Requirement is expressed in Smoke CADR/Watt and it shall be greater than or equal to the Minimum Smoke CADR/Watt Requirement shown in the table below:

  Table 1-11 CADR/W Requirement

Clean Air Delivery Rate (CADR)	CADR/W
30 ≤ Smoke CADR < 100	1.9
100 ≤ Smoke CADR < 150	2.4
150 ≤ Smoke CADR < 200	2.9
200 ≤ Smoke CADR	2.9

- "Partial On Mode" Requirements are to be calculated as per Section 3.4.1 of the Energy Star Eligibility Criteria Standby Power Requirement: = Measured standby power shall not exceed 2 Watts.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb).

1.1.5.3 Estimated Useful Life

The EUL of this measure is 9 years according to ENERGY STAR.

1.1.5.4 Deemed Savings Values

The table below summarizes the deemed kWh and kW based on clean air delivery rate.

Table 1-12 ENERGY STAR Air Purifiers Deemed Savings

Clean Air Delivery Rate (CADR)	Energy Savings (kWh)	Demand Reduction (kW)
30 ≤ Smoke CADR < 100	133	0.015
100 ≤ Smoke CADR < 150	229	0.026
150 ≤ Smoke CADR < 200	302	0.034
200 ≤ Smoke CADR	570	0.065

1.1.5.5 Incremental Cost

ENERGY STAR Air Purifiers incremental cost is outlined in the table below.

Table 1-13 ENERGY STAR Air Purifier Incremental Cost[17]

Clean Air Delivery Rate (CADR)	CADR used in calculation (midpoint)	Average Incremental Cost ($)
30 ≤ Smoke CADR < 100	1.9	8.44
100 ≤ Smoke CADR < 150	2.4	22.33
150 ≤ Smoke CADR < 200	2.9	92.34
200 ≤ Smoke CADR	2.9	44.50

1.1.5.6 Future Studies

There are no future studies planned for this measures at this time.

[17] ENERGY STAR V2 Room Air Cleaners Data Package (October 11, 2019). See file “ENERGY STAR V2 Room Air Cleaners Data Package_GH 05122020_VEIC.xlsx”

1.1.6 ENERGY STAR CEILING FANS

1.1.6.1 Measure Description

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating at the low, medium, and high settings than standard ceiling fans as well ENERGY STAR qualified lighting for those with light kits included. Due to EISA Phase II, savings calculations and deemed values do not consider lighting savings.

1.1.6.2 Baseline and Efficiency Standards

Current ENERGY STAR efficiency standards for ceiling fans are shown in Table 1-14 below.

Table 1-14 ENERGY STAR Ceiling Fan Standards

Type	Size (diameter) (in.)	Minimum Efficiency (cfm/W)	Minimum High Speed Airflow (cfm)
Ceiling Fan	D ≤ 36 inches	≥ 0.72*D + 41.93	≥ 1767
	36 inches < D < 78 inches	≥ 2.63*D - 26.83	$\geq 250*\pi*(D/24)^2$
	D ≥ 78 inches		≥ 8296
Hugger Ceiling Fan	D ≤ 36 inches	≥ 0.31*D + 36.84	≥ 1414
	36 inches < D < 78 inches	≥ 1.75*D - 15	$\geq 200*\pi*(D/24)^2$
	D ≥ 78 inches		≥ 6637

Savings are based on a comparison between ENERGY STAR fans and standard efficiency ceiling fan meeting the January 21, 2020, Federal efficiency requirements.[18]

1.1.6.3 Estimated Useful Life

The EUL for ceiling fans is 10 years.[19]

1.1.6.4 Deemed Savings

Deemed savings are calculated for fan-only ceiling fans.

Table 1-15 ENERGY STAR Ceiling Fan – Deemed Savings

Product Type (Fan Only)	Diameter, D (inches)	kWh Savings	kW Reduction
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0	0
	36 < D < 78	25	0.002
	D ≥ 78	34	0.002
Hugger Ceiling Fan	36 < D < 78	36	0.003

[18] Energy and water conservation standards and their compliance dates.10 C.F.R. § 430.32.

[19] Lifetime estimate is sourced from the ENERGY STAR Ceiling Fan Savings Calculator

The energy savings are obtained through the following formula:

$$\Delta kWh = \Delta W_{fan} \times \frac{1\ kW}{1000\ W} \times HOU_{fan} \times 365.25 \frac{days}{yr}$$

$$\Delta kW = \Delta W_{fan} \times \frac{1\ kW}{1000\ W} \times CF$$

Where:

ΔW_{fan} = Difference in wattage between standard and ENERGY STAR fan

Table 1-16 Differences in Fan Wattage

Ceiling Fan Type	**Diameter, D (inches)**	ΔW_{fan}
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0
	36 < D < 78	23
	D ≥ 78”	31
Hugger Ceiling Fan[20]	36 < D < 78	33

HOU_{fan} = fan daily hours of use (hours/day) = 3 hours/day

CF = Demand Factor= 0.091[21]

1.1.6.5 Incremental Cost

The incremental cost of a three-lamp ENERGY STAR Ceiling Fan is $46[22].

1.1.6.6 Future Studies

At the time of authorship of the TRM, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using ENERGY STAR default values. If this measure is added to Energy Smart programs, the evaluation should include a review of the models actually incented through the program. The key parameters to be examined include:

- Content of the lighting included with the fan;
- Rated wattage of the fans at low, medium, and high speeds.

Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

[20] The ENERGY STAR 4.0 specifications allow for hugger ceiling fans with blade spans of ≤ 36” and ≥ 78”, however, as of August 2022, there are no ENERGY STAR qualified products meeting those criteria. They were therefore omitted from this characterization.

[21] EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.

[22] ENERGY STAR Lighting Fixture and Ceiling Fan Calculator. Updated September 2013

1.1.7 ADVANCED POWER STRIPS

1.1.7.1 Measure Description

This measure involves the installation of a multi-plug Advanced Power Strip (APS, also known as "Smart Strips") that has the ability to automatically disconnect specific loads depending on the power draw of a specified load.

There are two categories of smart strips:

- Tier 1: Tier 1 advanced power strips have a master controls socket arrangement and will shut off items plugged into the controlled power-saver sockets when the sense that the appliance plugged into the master socket has been turned off. The power-saving functions of the control sockets is not used when the master appliance is turned on.
- Tier 2: Tier 2 advanced power strips manage both active and standby consumption. Tier 2 smart strips manage standby power consumption by turning off devices from a control event; this could be a TV or other item powering off, which then powers off the controlled outlets to save energy. Active power consumption is managed by monitoring a user's engagement or presence in a room either by infrared remote signals or motion sensing. After a period of inactivity, the Tier 2 unit will shut off controlled outlets.

1.1.7.2 Expected Useful Life

- For Tier 1 advanced power strips, the EUL is 10 years .
- For Tier 2 advanced power strips, there has not been a study performed to validate EUL. Until better data is available, they should default to using the current EUL of Tier 1 devices, 10 years.

1.1.7.3 Baseline & Efficiency Standard

The baseline case is the absence of an APS, where peripherals are plugged in to a traditional surge protector or wall outlet. The efficiency standard case is the presence of an APS, with all peripherals plugged into the APS.

1.1.7.4 Estimated Useful Life

The EUL is 10 years according to the NYSERDA Advanced Power Strip Research Report from August 2011.

1.1.7.5 Deemed Savings Values

Deemed Savings for Residential APS are found in the table below.

Table 1-17 Deemed Savings for Residential APS

Tier	Size	Usage	kW Savings	kWh Savings
1	5-plug	Unspecified	.0056	48.9
		Entertainment	.0077	62.1
		Computer	.0037	35.8
	7-plug	Unspecified	.0067	57.7
		Entertainment	.0092	74.5
		Computer	.0045	42.9
2	5-plug	Unspecified	.0194	204.2
		Entertainment	.0316	307.4
		Computer	.0172	100.9

1.1.7.5.1 Calculation of Deemed Savings

Energy and demand savings for a 5-plug APS in use in a home office or for a home entertainment system are calculated using the following algorithm, where kWh saved are calculated and summed for all peripheral devices:

(i) Tier 1

$$\Delta kWh/yr. = \frac{(kW_{comp\ idle} \times HOU_{comp\ idle}) + (kW_{TVidle} \times HOU_{TV\ idle})}{2} \times 365 \frac{\boldsymbol{days}}{\boldsymbol{yr}} \times ISR\ = 48.9\ kWh\ (5\text{-}plug);\ 57.7\ kWh$$

$$\Delta \text{kWh/yr. entertainment center} = \boldsymbol{kW_{TV\ idle}} \times \boldsymbol{HOU}\ _{\boldsymbol{TV\ idle}} \times 365 \frac{\boldsymbol{days}}{\boldsymbol{yr}} \times \text{ISR} = 62.1\ \text{kWh (5-plug); 74.5 kWh (7-plug)}$$

$$\Delta \text{kWh/yr. computer} = kW_{Comp\ idle} \times HOU\ _{Comp\ idle} \times 365 \frac{days}{yr} \times \text{ISR} = 35.8\ \text{kWh(5-plug); 42.9 (7-plug)}$$

$$\Delta \text{kW}_{\text{peak}}\ \text{unspecified use} = \frac{\text{CF} \times (\text{kW}_{\text{comp idle}} + \text{kW}_{\text{TV idle}})}{2} \times \text{ISR}\ = 0.0056\ \text{kW (5-plug); 0.0067 kW (7-plug)}$$

$$\Delta \text{kW}_{\text{peak}}\ \text{entertainment center} = \text{CF} \times \text{kW}_{\text{TV idle}} \times \text{ISR} = 0.0077\ \text{kW (5-plug); 0.0092 kW (7-plug)}$$

$$\Delta \text{kW}_{\text{peak}}\ \text{Computer} = \text{CF} \times \text{kW}_{\text{Comp idle}} \times \text{ISR} = 0.0037\ \text{kW (5-plug); 0.0045 kW (7-plug)}$$

(ii) Tier 2

$$\Delta \text{kWh unspecified use} = \frac{(\text{kWh}_{\text{comp}} + \text{kWh}_{\text{TV}})}{2} \times \text{ESF} \times \text{ISR} = 204.2\ \text{kWh}$$

$$\Delta \text{kWh entertainment center} = \text{kWh}_{\text{TV}} \times \text{ESF} \times \text{ISR} = 307.4\ \text{kWh}$$

ΔkWh Computer = $\mathrm{kWh_{Comp}} \times \mathrm{ESF} \times \mathrm{ISR}$ = 100.9 kWh

$\Delta \mathrm{kW_{peak}}$ unspecified use = $\frac{\mathrm{CF} \times (\Delta \mathrm{kWh}_{\mathrm{comp}} + \Delta \mathrm{kWh}_{\mathrm{entertainment}})}{2 \times 8760 \frac{\mathrm{hours}}{\mathrm{yr}}} \times \mathrm{ISR}$ =0.0194 kW

$\Delta \mathrm{kW_{peak}}$ entertainment center = $\frac{\mathrm{CF} \times \Delta \mathrm{kWh}_{\mathrm{entertainment}}}{8760 \frac{\mathrm{hours}}{\mathrm{yr}}} \times \mathrm{ISR}$ = 0.0316 kW

$\Delta \mathrm{kW_{peak}}$ Computer = $\frac{\mathrm{CF} \times \Delta \mathrm{kWh}_{\mathrm{computer}}}{8760 \frac{\mathrm{hours}}{\mathrm{yr}}} \times \mathrm{ISR}$ = 0.0172 kW

Table 1-18 APS Parameters

Parameter	Unit	Value	Source
kWcomp idle, Idle kW of computer system	kW	.0049 (5-plug) .00588 (7-plug)	Footnotes 23, 24, & 25
HOUcomp idle, Daily hours of computer idle time	Hours/day	20	23
kWTV idle, Idle kW of TV system	kW	. 0085 (5-plug) .00102 (7-plug)	23, 25
HOUTV idle, Daily hours of TV idle time	Hours/day	20	23
kWhTV, Annual kWh of TV system	kWh	602.8	25
kWhcomp, Annual kWh of computer system	kWh	197.9	25

[23] "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes", Energy Center of Wisconsin, May 2010.

[24] "Smart Plug Strips", ECOS, July 2009.

[25] "Advanced Power Strip Research Report", NYSERDA, August 2011"

Parameter	Unit	Value	Source
ISR, In-Service-Rate	%	1.0	
CF, Coincidence Factor	%	Entertainment Center = .90 Computer System= .763 Unspecified = .832	Footnote 26
ESF, Energy Savings Factor. Percent of baseline energy consumption saved by installing the measure	%	Entertainment Center = .51	Footnote 27

1.1.7.6 Incremental Cost

The incremental cost for APS systems is as follows:

- Tier (1) – 5-plug: $16
- Tier (1) – 7-plug: $26
- Tier (2): $65

1.1.7.7 Net-to-Gross

The NTG is 80% for direct installation applications.

1.1.7.8 Future Studies

At the time of authorship of the TRM, this measure has low participation numbers in Energy Smart programs. As a result, savings are calculated using values cited from evaluation reports completed on behalf of the New York State Energy Research & Development Authority (NYSERDA) and Wisconsin Focus on Energy. If participation reached 1% of residential Energy Smart program savings, the evaluation should include fieldwork to support in-service rates and to document an inventory of the equipment actually installed into the APS by New Orleans residents.

[26]C F Values of Standby Losses for Entertainment Center and Home Office in Efficiency Vermont TRM, 2013, pg. 16. Developed through negotiations between Efficiency Vermont and the Vermont Department of Public Service

[27] "Tier 2 Advanced Power Strip Evaluation for Energy Saving Incentive," California Plug Load Research Center, 2014.

1.1.8 ENERGY STAR DEHUMIDIFIERS

1.1.8.1 Measure Description

This measure is portable and whole-house humidifiers which meet the minimum qualifying efficiency standard set forth by the current ENERGY STAR Version 5.0 (effective 10/31/2019) and ENERGY STAR Most Efficient 2019 Criteria (effective 01/01/2019) that are purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

1.1.8.2 Baseline and Efficiency Standards

1.1.8.2.1 Definition of Efficient Equipment

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as defined in the table below.

Table 1-19 ENERGY STAR Dehumidifier Standard

Equipment Specification	Capacity (pints/day)	Federal Standard Criteria (L/kWh)
Portable Dehumidifier	Up to 25	≥ 1.57
	≤ 25.01 to ≤ 50	≥ 1.80
	≥ 50.01	≥ 3.30
Equipment Specification	**Product Case Volume (cubic feet)**	**Federal Standard Criteria (L/kWh)**
Whole-home Dehumidifier	Up to 8	≥ 2.09
	≥ 8.01	≥ 3.30

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

1.1.8.2.2 Definition of Baseline Equipment

The baseline condition for this measure is a new dehumidifier that meets the federal efficiency standards. The Federal Standard for Dehumidifiers as of June 13, 2019, are defined in the below.

Table 1-20 Federal Minimum Standards for Dehumidifiers[28]

Equipment Specification	Capacity (pints/day)	Federal Standard Criteria (L/kWh)
Portable Dehumidifier	Up to 25	≥ 1.30
	≤ 25.01 to ≤ 50	≥ 1.60
	≥ 50.01	≥ 2.80

[28] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf

Equipment Specification	Product Case Volume (cubic feet)	Federal Standard Criteria (L/kWh)
Whole-home Dehumidifier	Up to 8	≥ 1.77
	≥ 8.01	≥ 2.41

1.1.8.3 Estimated Useful Life

The EUL of a portable dehumidifier is 11 years and a whole house dehumidifier is 19 years.

1.1.8.4 Deemed Savings Values

Energy savings and demand reductions for residential dehumidifiers are based on the energy consumption. The following subsections outline deemed calculations for energy savings and demand reductions, respectively.

1.1.8.4.1 Energy Savings

$$\Delta kWh = \left[\frac{(Avg\ Cap * 0.473)}{24} \times Hours\right] \times \left[\left(\frac{1}{L/kWh_{Base}}\right) - \left(\frac{1}{L/kWh_{Eff}}\right)\right]$$

Where:

Avg Cap = Average capacity of the unit (pints/day)

= Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average.

0.473 = Constant to convert Pints to Liters

24 = Constant to convert Liters/day to Liters/hour

Hours = Run hours per year

= 1632[29]

L/kWh = Liters of water per kWh consumed, as provided in tables above

Estimated annual kWh use for each capacity class are presented below in the table below.

[29] ENERGY STAR Dehumidifier Calculator; 24-hour operation over 68 days of the year.

Table 1-21 Annual Energy Savings by Capacity Range

Portable Dehumidifiers					Annual Use		
Capacity Range	**Capacity Used**	**Federal Standard**	**ENERGY STAR**	**ENERGY STAR Most Efficient**[30]	**Federal Standard**	**ENERGY STAR**	**ENERGY STAR Most Efficient**
(pints/day)	(pints/day)	(≥L/kWh)	(≥L/kWh)	(≥L/kWh)	(kWh)	(kWh)	(kWh)
Up to 25	25	1.3	1.57	2.2	619	512	366
≥ 25.01 to ≤ 50	41.1	1.6	1.8	2.2	827	735	691
≥ 50.01	76.6	2.8	3.3	N/A	880	747	N/A
Whole House					**Federal Standard**	**ENERGY STAR**	**ENERGY STAR Most Efficient**
(cubic feet)	(pints/day)[31]	(≥L/kWh)	(≥L/kWh)	(≥L/kWh)	(kWh)	(kWh)	(kWh)
Up to 8	Up to 59.2	1.77	2.09	2.3	1,076	911	828
> 8	> 59.2	2.41	3.3	N/A	790	577	N/A

Deemed annual kWh savings for each capacity class are presented below in the table below.

Table 1-22 Annual Energy Savings by Capacity Range

System Type	Capacity Range	Capacity Used	ENERGY STAR Savings (kWh)	ENERGY STAR Most Efficient Savings(kWh)
Portable (Pints/Day)	Up to 25	25	106	253
	>25 to ≤ 50	41.1	92	225
	> 50	76.6	133	N/A
Whole House (Cubic Feet)	Up to 8	59.2	165	248
	> 8	59.2	213	N/A

[30] ENERGY STAR 2019 Most Efficient Criteria exclude the following products from eligibility; dehumidifiers with capacity of 75 pints/day or higher, portable dehumidifiers with capacity of 50.01 pints/day or higher, and whole home dehumidifiers with case volume greater than 8.0 cubic feet.

[31] The capacity and relative weighting of the whole-home dehumidifiers was sourced from the average capacity of portable dehumidifiers as there were no whole-home dehumidifiers on the ENERGY STAR Qualified Products List, as accessed in May 2019. See "Dehumidifier Calcs_05062019.xls.

1.1.8.4.2 Demand Reductions

$$\Delta kW = (\Delta kWh/Hours) * CF$$

Where:

Hours = Annual operating hours

=1632 hours[32]

CF = Summer Peak Coincidence Factor for measure

= 0.37[33]

Demand results for each capacity range are presented below in the table below.

Table 1-23 Demand Reductions by Capacity Range

System Type	Capacity Range	Peak kW Savings	
		ENERGY STAR	ENERGY STAR Most Efficient
Portable (Pints/Day)	Up to 25	0.024	0.057
	>25 to ≤50	0.021	0.051
	> 50	0.03	N/A
Whole House (Cubic Feet)	Up to 8	0.037	0.056
	> 8	0.048	N/A

1.1.8.5 Incremental Measure Cost

The incremental cost for an ENERGY STAR unit is assumed to be $10.29 and for an ENERGY STAR Most Efficient unit is $75.

1.1.8.6 Future Studies

At the time of authorship of the TRM, this measure was not implemented in Energy Smart programs. Thus, savings are calculated using ENERGY STAR default values. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents. If there is notable participation from this measure, primary research may be conducted to develop a New Orleans-specific estimate of days per year of operation to override the ENERGY STAR estimate of 68 days per year.

Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

[32] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

[33]Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

1.1.8.7 ENERGY STAR Pool Pumps

1.1.8.8 Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR certified variable speed or multi-speed pool pump. This measure applies to all residential applications; however, pools that serve multiple tenants in a common area are not eligible for this measure.

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that is basically two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings. Therefore, multi-speed pumps must have a minimum size of 1 horsepower (HP) to be eligible for this measure.

1.1.8.9 Baseline and Efficiency Standards

The baseline condition is a 0.5-3 horsepower (HP) standard efficiency single-speed pool pump.

The high efficiency condition is a 0.5-3 HP ENERGY STAR certified variable speed or multi-speed pool pump.

1.1.8.10 Estimated Useful Life

According to DEER 2014 the EUL for this measure is 10 years.

1.1.8.11 Deemed Savings Values

Deemed savings are per installed unit based on the pump horsepower.

Table 1-24 Variable Speed Pool Pumps – Deemed Savings Values

Pump HP	kW Savings	kWh Savings
0.5	0.24	1,713
0.75	0.28	1,860
1	0.36	2,063
1.5	0.47	2,465
2	0.52	2,718
2.5	0.57	2,838
3	0.72	3,364

Table 1-25 Multi-Speed Pool Pumps – Deemed Savings Values

Pump HP	kW Savings	kWh Savings
1	0.30	1,629
1.5	0.40	1,945
2	0.41	1,994
2.5	0.46	2,086
3	0.54	2,292

1.1.8.11.1 Energy Savings

Energy savings for this measure were derived using the *ENERGY STAR Pool Pump Savings* Calculator .

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

Where:

kWh_{conv}= Conventional single-speed pool pump energy (kWh)

kWh_{ES}= ENERGY STAR variable speed pool pump energy (kWh)

Algorithms to calculate the above parameters are defined as:

$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hour\ _{conv} \times days}{EF_{conv} \times 1000}$ $hours_{conv} = \frac{V_{pool} \times PT}{PFR_{conv} \times 60}$ $kWh_{ES} = kWh_{HS} +$

kWh_{LS} $kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$ $kWh_{LS} = \frac{PFR_{LS} \times 60 \times hou\ \ _{LS} \times days}{EF_{LS} \times 1000}$ $PFR_{LS} =$

$\frac{V_{pool}}{t_{turnover} \times 60}$ kWh_{HS} = ENERGY STAR variable speed pool pump energy at high speed (kWh)

kWh_{LS} = ENERGY STAR variable speed pool pump energy at low speed (kWh)

$hours_{conv}$ = Conventional single-speed pump daily operating hours (Table 1-26)

$hours_{HS,VS}$ = ENERGY STAR variable speed pump high speed daily operating hours = 2 hours

$hours_{LS,VS}$ = ENERGY STAR variable speed pump low speed daily operating hours = 10 hours

$hours_{HS,MS}$ = ENERGY STAR multi-speed pump high speed daily operating hours = 2 hours

$hours_{LS,VS}$ = ENERGY STAR multi-speed pump low speed daily operating hours (Table 1-27)

$days$ = Operating days per year = 7 months x 30.4 days/month = 212.8 days (default)

PFR_{conv} = Conventional single-speed pump flow rate (gal/min) (Table 1-26)

$PFR_{HS,VS}$ = ENERGY STAR variable speed pump high speed flow rate = 50 gal/min (default)

$PFR_{LS,VS}$ = ENERGY STAR variable speed pump low speed flow rate (gal/min) = 30.6 (default)

$PFR_{HS,MS}$ = ENERGY STAR multi-speed pump high speed flow rate (gal/min) (Table 1-27)

$PFR_{LS,MS}$ = ENERGY STAR multi-speed pump low speed flow rate (gal/min) (Table 1-27)

EF_{conv} = Conventional single-speed pump energy factor (gal/W·hr) (Table 1-26)

$EF_{HS,VS}$ = ENERGY STAR variable speed pump high speed energy factor = 3.75 gal/W·hr (default)

$EF_{LS,VS}$ = ENERGY STAR variable speed pump low speed energy factor = 7.26 gal/W·hr (default)

$EF_{HS,MS}$ = ENERGY STAR multi-speed pump high speed energy factor (gal/W·hr) (Table 1-27

$EF_{LS,MS}$ = ENERGY STAR multi-speed pump low speed energy factor (gal/W·hr) (Table 1-27)

V_{pool} = Pool volume = 22,000 gal (default)

PT = Pool turnovers per day = 1.5 (default)

$t_{turnover,VS}$ = Variable speed pump time to complete 1 turnover = 12 hours (default)

$t_{turnover,MS}$ = Multi-speed pump time to complete 1 turnover (Table 1-27)

60 = Constant to convert between minutes and hours

1000 = Constant to convert W to kW

Table 1-26 Conventional Pool Pumps Assumptions

Pump HP	$hours_{conv}$	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
0.5	11.0	50.0	2.71
0.75	10.4	53.0	2.57
1	9.2	60.1	2.40
1.5	8.6	64.4	2.09
2	8.5	65.4	1.95
2.5	8.1	68.4	1.88
3	7.5	73.1	1.65

Table 1-27 ENERGY STAR Multi-Speed Pool Pumps Assumptions

Pump HP	$t_{,turnover,MS}$	$hours_{MS,LS}$	$PFR_{HS,MS}$ (gal/min)	$EF_{HS,MS}$ (gal/W·h)	$PFR_{LS,MS}$ (gal/min)	$EF_{LS,MS}$ (gal/W·h)
1	11.8	9.8	56.0	2.40	31.0	5.41
1.5	11.5	9.5	61.0	2.27	31.9	5.43
2	11.0	9.0	66.4	1.95	33.3	5.22
2.5	10.8	8.8	66.0	2.02	34.0	4.80
3	9.9	7.9	74.0	1.62	37.0	4.76

1.1.8.11.2 Demand Reductions

Demand savings can be derived using the following:

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hou\quad_{conv}} - \left(\frac{kWh_{HS}+kWh_{LS}}{hours_{HS}+hour\ _{LS}}\right)\right] \times \frac{CF}{days}$$

Where:

CF = Coincidence factor[34] = 0.31

[34] Southern California Edison (SCE) Design & Engineering Services, 2008., *"Pool Pump Demand Response Potential, DR 07.01 Report."* June 2008. Derived from Table 16 assuming a peak period of 2-6 PM.

1.1.8.12 Incremental Cost

The incremental cost for ENERGY STAR Pool Pumps is :

- $549 for Variable Speed
- $235 for Multi-Speed

1.1.8.13 Future Studies

This measure has low-to-moderate participation in Energy Smart programs. If measure savings reach a minimum of 500,000 kWh in a program year, the TPE recommends a metering study to validate usage assumptions. Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

1.1.9 ENERGY STAR REFRIGERATORS

1.1.9.1 Measure Description

This measure involves replace-on-burnout or early retirement of an existing refrigerator and installation of a new, full-size (7.75 ft^3 or greater) ENERGY STAR refrigerator. This measure applies to all residential or small commercial applications.

To qualify for early retirement, the ENERGY STAR unit must replace an existing, full-size, working unit that is at least six years old. For early retirement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

1.1.9.2 Baseline and Efficiency Standards[35]

For ROB, the baseline for refrigerators is the DOE minimum efficiency standards for refrigerators, effective September 15, 2014.

For an individual refrigerator early retirement program, the baseline for refrigerators is assumed to be the annual unit energy consumption of the refrigerator being replaced, as reported by the Association of Home Appliance Manufacturers (AHAM) refrigerator database , adjusted for age according to the formula in the Measure Savings Calculations section. AHAM energy use data includes the average manufacturer-reported annual kilowatt hour usage, by year of production. This data dates back to the 1970s.

Alternatively, the baseline annual kilowatt hour usage of the refrigerator being replaced may be estimated by metering for a period of at least three hours using the measurement protocol specified in the US DOE report, “Incorporating Refrigerator Replacement into the Weatherization Assistance Program.”

To determine annual kWh of the refrigerator being replaced, use the formula:

$$kWh/yr = \frac{WH \times 8{,}760}{h \times 1{,}000}$$

Where:

WH = the watt-hours metered during a time period

h = measurement time period (hours)

8,760 = hours in a year

1,000 watt-hours = 1 kWh

[35] Current federal standards for refrigerators can be found on the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Current ENERGY STAR criteria for refrigerators can be found on the ENERGY STAR website at: www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators

For the early retirement application, all new refrigerators must replace refrigerators currently in use, and all replaced refrigerators must be dismantled in an environmentally-safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators.

Newly-installed refrigerators must meet current ENERGY STAR efficiency levels. All newly-installed refrigerators must be connected to an adequately-sized electrical receptacle and be grounded in accordance with the National Electric Code (NEC).

Minimum efficiency requirements for ENERGY STAR refrigerators are set at 10% more efficient than required by the minimum federal government standard. The standard varies depending on the size and configuration of the refrigerator. See Table 1-28.

Configuration Codes (Table 1-28):

- BF: Bottom Freezer
- SD: Refrigerator Only – Single Door
- SR: Refrigerator/Freezer – Single Door
- SS: Side-by-Side
- TF: Top Freezer
- TTD: Through the Door (Ice Maker)
- A: Automatic Defrost
- M: Manual Defrost
- P: Partial Automatic Defrost
- AV = Adjusted Volume[36]

Table 1-28 Formulas to Calculate the ENERGY STAR Refrigerator Criteria[37]

Product Category	Federal Standard (kWh/YR)	Maximum Energy Usage (kWh/YR)[38]	Ice (Y/N)	Defrost	Adjusted Volume	kWh	kW
Refrigerator-only—manual defrost	6.79 × AV + 193.6	6.111 × AV + 174.24	Y, N	M	20.8	33.48	0.0077
Refrigerator-freezers—manual or partial automatic defrost	7.99 × AV + 225.0	7.191 × AV + 202.5	Y, N	M, P	24.51	42.08	0.0097

[36] Adjusted Volume (AV) can be found for ENERGY STAR certified refrigerators on their website under the "advanced view" option. https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Refrigerators/p5st-her9. Scroll to the right until you reach the column named "Adjusted Volume".

[37] Available for download at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[38] Ten percent more efficient than baseline, as specified in the ENERGY STAR appliance calculator.

Product Category	Federal Standard (kWh/YR)	Maximum Energy Usage (kWh/YR)[38]	Ice (Y/N)	Defrost	Adjusted Volume	kWh	kW
Refrigerator-only-automatic defrost	7.07 × AV + 201.6	6.363 × AV + 181.44	Y, N	A	15.75	31.30	0.0072
Built-in refrigerator-only-automatic defrost	8.02 × AV + 228.5	7.218 × AV + 205.65	Y, N	A	16.97	36.46	0.0084
Refrigerator-freezers-automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.965 × AV + 285.3	N	A	18.36	47.95	0.0111
Built-in refrigerator-freezers-automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	8.46 × AV + 303.21	N	A	17.57	50.21	0.0073
Refrigerator-freezers-automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	7.965 × AV + 360.9	Y	A	24.6	61.87	0.0143
Built-in refrigerator-freezers-automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	9.40 × AV + 420.9	8.46 × AV + 378.81	Y	A	21.67	62.46	0.0091
Refrigerator-freezers-auto defrost w bottom-mounted freezer with an automatic icemaker with TTD ice service	9.25 × AV + 475.4	8.325× AV + 427.86	Y	A	32.34	77.45	0.0179

Product Category	Federal Standard (kWh/YR)	Maximum Energy Usage (kWh/YR)[38]	Ice (Y/N)	Defrost	Adjusted Volume	kWh	kW
Built-in refrigerator-freezers-automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.83 × AV + 499.9	8.847 × AV + 449.91	Y	A	21.67	71.29	0.0164
Refrigerator-freezers-automatic defrost with side-mounted freezer without an automatic icemaker	8.51 × AV + 297.8	7.659 × AV + 268.02	N	A	30.44	55.68	0.0128
Built-in refrigerator-freezers-automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	9.198 × AV + 321.66	N	A	33.71	70.19	0.0102
Refrigerator-freezers-automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	7.659 × AV + 343.62	Y	A	30.44	64.08	0.0093
Built-in refrigerator-freezers-automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	9.198 × AV + 397.26	Y	A	34.06	78.95	0.0182
Refrigerator-freezers-automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.686 × AV + 389.52	Y	A	33.06	71.51	0.0165

Product Category	Federal Standard (kWh/YR)	Maximum Energy Usage (kWh/YR)[38]	Ice (Y/N)	Defrost	Adjusted Volume	kWh	kW
Built-in refrigerator-freezers-automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	10.25 × AV + 502.6	9.225 × AV + 452.34	Y	A	33.6	84.70	0.0195
Refrigerator freezers-automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.263 × AV + 210.33	N	A	17.8	37.73	0.0087
Built-in refrigerator-freezers-automatic defrost with top-mounted freezer without an automatic icemaker	9.15 × AV + 264.9	8.235 × AV + 238.41	N	A	17.8	42.78	0.0062
Refrigerator-freezers-automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	8.07 × AV + 317.7	7.263 × AV + 285.93	Y	A	21.22	48.89	0.0071
Built-in refrigerator-freezers-automatic defrost with top-mounted freezer without an automatic ice maker with TTD ice service	9.15 × AV + 348.9	8.235 × AV + 314.01	Y	A	21.22	54.31	0.0079
Refrigerator-freezers-automatic defrost with top-mounted freezer with TTD ice service	8.40 × AV + 385.4	7.56 × AV + 346.86	Y	A	21.22	56.36	0.0082

1.1.9.3 Estimated Useful Life

According to the Department of Energy Technical Support Document, the EUL of High Efficiency Refrigerators is 17 years .

1.1.9.4 Deemed Savings Values

Deemed peak demand and annual energy savings should be calculated as shown below. Note that these savings calculations are different depending on whether the measure is replace-on-burnout or early retirement.

1.1.9.4.1 Energy Savings

(i) Replace-on-Burnout

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Where:

$kWh_{baseline}$ = Federal standard baseline average energy usage (Table 1-28)

kWh_{ES}= ENERGY STAR average energy usage (Table 1-28)

(ii) Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL); and
- The remaining time in the EUL period (17 – RUL).

For the RUL:

$$kWh_{savings} = kWh_{pre} - kWh_{ES}$$

kWh_{pre} refers to manufacturer data or a measured consumption that is adjusted using the applicable degradation and in-situ adjustment factors.

$$kWh_{pre} = kWh_{manf} \times (1 + \mathrm{PDF})^{n}$$

For the remaining EUL period:

Calculate annual savings as you would for a replace-on-burnout project using the equation below. Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kwh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

Where:

kWh_{NAECA}= NAECA baseline average energy usage (Table 1-28)

kWhpre = Adjusted manufacturer energy usage

kWh_{ES} = ENERGY STAR average energy usage (Table 1-28)

kWh_{manf} = annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database[39]

PDF = Performance Degradation Factor 0.0125/year. Refrigerator energy use is expected to increase at a rate of 1.25% per year as performance degrades over time[40]

n = age of replaced refrigerator (years)

RUL = Remaining Useful Life (Table 1-29)

EUL = Estimated Useful Life = 17 years

1.1.9.4.2 Demand Savings

Since refrigerators operate 24/7, average kW reduction is equal to annual kWh divided by 8,760 hours per year. As shown below, this average kW reduction is multiplied by temperature and load shape adjustment factors to derive peak period kW reduction.

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760\ hrs} \times \text{TAF} \times \text{LSAF}$$

Where:

TAF = Temperature Adjustment Factor[41] = 1.188

LSAF = Load Shape Adjustment Factor[42] = 1.074

(i) Derivation of RULs

ENERGY STAR refrigerators have an estimated useful life of 17 years. This estimate is consistent with the age at which 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 1-1.

[39] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

[40] 2009 Second Refrigerator Recycling Program NV Energy – Northern Nevada Program Year 2009; M&V, ADM, Feb 2010, referencing Cadmus data on a California program, February 2010.

[41] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group, 2004, *"Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study"*. July 29. Factor to adjust for varying temperature based on site conditions, p. 47.

[42] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group, 2004, "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29. Used load shape adjustment for "hot days" during the 4PM hour, pp. 45-48.

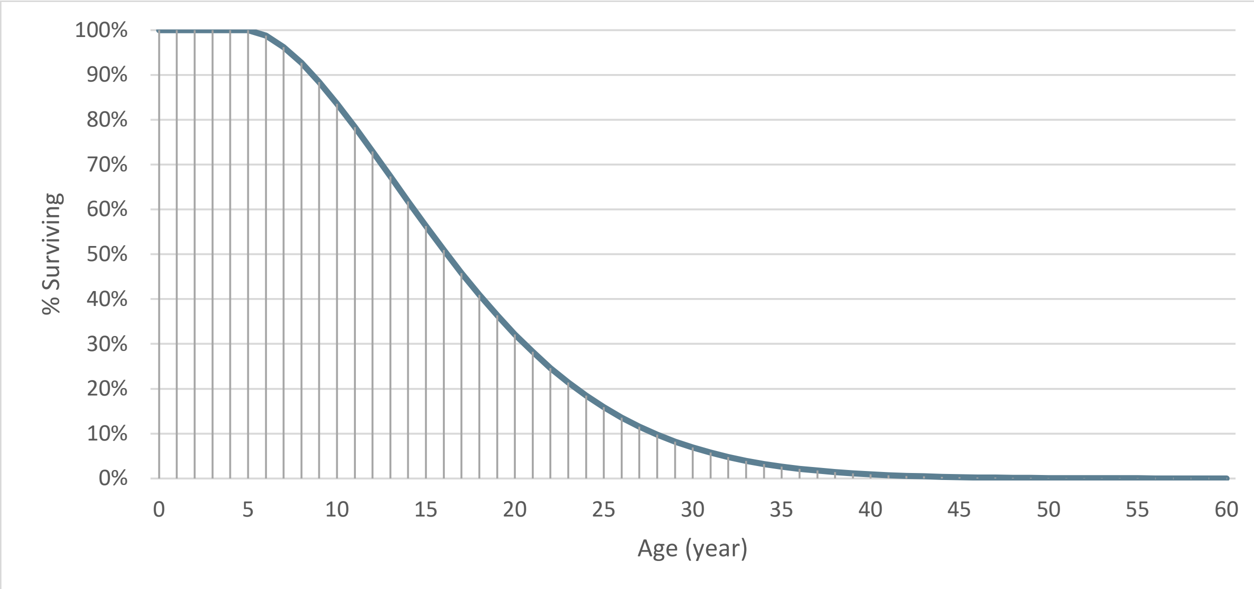

Figure 1-1 Survival Function for ENERGY STAR Refrigerator[43]

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 1-1. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Table 1-29 Remaining Useful Life (RUL) of Replaced Refrigerator[44]

Age of Replaced Refrigerator (years)	RUL (years)	Age of Replaced Refrigerator (years)	RUL (years)
6	10.3	15	6.0
7	9.6	16	5.8
8	8.9	17	5.5
9	8.3	18	5.3
10	7.8	19	5.1
11	7.4	20	4.9
12	7.0	21	4.8
13	6.6	22	4.6
14	6.3	23 +	0.0

[43] U.S. DOE, Technical Support Document, 2011, "Residential Refrigerators, Refrigerator-Freezers, and Freezers, 8.2.3 Product Lifetimes." September 15. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

[44] Use of the early retirement baseline is capped at 22 years, representing the age at which 75 percent of existing equipment is expected to have failed. Equipment older than 22 years should use the ROB baseline.

1.1.9.5 Incremental Cost

The incremental cost for efficient refrigerators is $40 for ENERGY STAR units and $140 for CEE Tier II units. For early retirement, incremental cost is calculated using:

- Full installed cost of the refrigerator: program-actual purchase price should be used. If not available, use $451 for ENERGY STAR and $551 for CEE Tier 2 units .
- Present value of replacement cost of a baseline refrigerator after the RUL of the initial replaced unit is exhausted. This unit costs $411 at the time of purchase, and should be discounted by the number of years of RUL. If RUL is unknown, use 4 years. Default discount rate is 10% . This results in a deferred replacement cost of $281.
- Overall incremental cost of early retirement is then calculated as:
  - ENERGY STAR: $451 - $281 = $70
  - CEE Tier II: $170

1.1.9.6 Net-to-Gross

The NTG for this measure is 44% .

1.1.9.7 Future Studies

There are no future studies planned for this measures at this time.

1.1.10ENERGY STAR FREEZERS

1.1.10.1 Measure Description

This measure is for the purchase of a freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). An ENERGY STAR freezer must be at least 10 percent more efficient than the minimum federal government standard.

1.1.10.2 Baseline and Efficiency Standards

The baseline equipment is assumed to be a model that meets the federal minimum standard for energy efficiency. Efficient equipment is defined as a freezer meeting the efficiency specifications of ENERGY STAR, as defined below.

Table 1-30 ENERGY STAR Freezer Specifications

Equipment	Volume	Criteria
Full Size Freezer	7.75 cubic feet or greater	At least 10% more energy efficient than the minimum federal government standard (NAECA).
Compact Freezer	Less than 7.75 cubic feet and 36 inches or less in height	At least 20% more energy efficient than the minimum federal government standard (NAECA).

The standard varies depending on the size and configuration of the freezer (chest freezer or upright freezer, automatic or manual defrost) and is defined in the table below.

Energy usage specifications are defined in the table below (note, AV is the freezer Adjusted Volume and is calculated as 1.73*Total Volume).

Table 1-31 Energy Usage Specifications

Product Category	Volume (cubic feet)	Assumptions after September 2014	
		Federal Baseline Maximum Energy Usage in kWh/year[45]	**Maximum Energy Usage in kWh/year[46]**
Upright Freezers with Manual Defrost	7.75 or greater	5.57*AV + 193.7	5.01*AV + 174.3
Upright Freezers with Automatic Defrost	7.75 or greater	8.62*AV + 228.3	7.76*AV + 205.5

[45] See Department of Energy Federal Standards.

[46] See Version 5.0 ENERGY STAR specification.

Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	7.29*AV + 107.8	6.56*AV + 97.0
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	8.65*AV + 225.7	7.79*AV + 203.1
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	10.17*AV + 351.9	9.15*AV + 316.7
Compact Chest Freezers	<7.75 and 36 inches or less in height	9.25*AV + 136.8	8.33*AV + 123.1

1.1.10.3 *Estimated Useful Life*

The EUL of this measure is 22 years .

1.1.10.4 *Deemed Savings Values*

1.1.10.4.1 Energy Savings

$$kWh_{savings} = kWh_{base} - kWh_{efficient}$$

Where:

kWh_{base} = Baseline kWh consumption per year as calculated in algorithm provided in table above.

$kWh_{efficient}$ = ENERGY STAR kWh consumption per year as calculated in algorithm provided in table above.

1.1.10.4.2 Demand Savings

Demand savings should be calculated using the following formula:

$$kW_{savings} = kWh_{savings} \times Energy\ Demand\ Factor$$

Where:

$Energy\ Demand\ Factor$ = 0.0001614

The table below outlines the deemed savings for this measure.

Table 1-32 Deemed Energy Savings and Demand Reductions

Freezer Category	Average Unit Adj. Volume (Ft^3)	Conventional Usage (kWh/YR)	ENERGY STAR Usage (kWh/YR)	kWh Savings	kW Reduction
Upright Freezers with Manual Defrost	27.9	349.1	314.1	35.0	0.0057
Upright Freezers with Automatic Defrost	27.9	468.8	422.0	46.8	0.0076
Chest Freezers and all other Freezers except Compact Freezers	27.9	310.4	280.0	30.3	0.0049
Compact Upright Freezers with Manual Defrost	10.4	315.7	284.1	31.5	0.0051
Compact Upright Freezers with Automatic Defrost	10.4	457.7	411.3	46.4	0.0075
Compact Chest Freezers	10.4	233.0	209.7	23.3	0.0038

1.1.10.5 Incremental Cost

The incremental cost for this measure is $42 .

1.1.10.6 Future Studies

There are no future studies planned for this measure at this time.

1.1.11 REFRIGERATOR AND FREEZER RECYCLING

1.1.11.1 Measure Description

This measure involves early retirement and recycling of an inefficient but operational existing, full-size (7.75 ft^3 or greater) refrigerator/freezer in a residential application. Savings represent the entire estimated energy consumption of the existing unit and are applicable over the estimated remaining life of the existing unit. A part use factor is applied to account for those secondary units that are not in use throughout the entire year.

1.1.11.2 Baseline and Efficiency Standards

Without program intervention, the recycled refrigerator or freezer would have remained operable on the electrical grid. As a result, the baseline condition for early retirement programs is the status quo (continued operation) and the basis for estimating energy savings is the annual energy consumption of the refrigerator or freezer being retired.

1.1.11.3 Estimated Useful Life

It is difficult to determine the number of years that a recycled refrigerator would have continued to operate absent the program and, therefore, the longevity of the savings generated by recycling old-but-operable refrigerators through the program. According to the DOE Technical Support Document , the EUL of High Efficiency Refrigerators is 17 years. The EUL for a freezer is 12 years . Section C.1.12.3.1 details a survival analysis and the derivation of refrigerator and freezer RULs. Below, Table 1-33 has been taken from said section and presents RULs by refrigerator or and freezer age.

Table 1-33 Remaining Useful Life of Replaced Refrigerator[47]

Age of Replaced Refrigerator (years)	Refrigerator RUL (years)	Freezer RUL (years)
6	10.3	7.3
7	9.6	6.8
8	8.9	6.3
9	8.3	5.9
10	7.8	5.5
11	7.4	5.2
12	7	4.9
13	6.6	4.7
14	6.3	4.4
15	6	4.2
16	5.8	4.1
17	5.5	3.9
18	5.3	0
19	5.1	0
20	4.9	0
21	4.8	0

[47] Use of the early retirement baseline is capped at 22 years, representing the age at which 75 percent of existing equipment is expected to have failed. Equipment older than 22 years should use the ROB baseline.

22	4.6	0
23 +	0	0

If refrigerator or freezer age is unknown, use a measure life of 6 years for refrigerators, 4 years for freezers.

1.1.11.3.1 Derivation of RULs

The DOE Technical Support Document[48] estimates that high efficiency refrigerator useful life is 17 years. This estimate is consistent with the age at which 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 1-2.

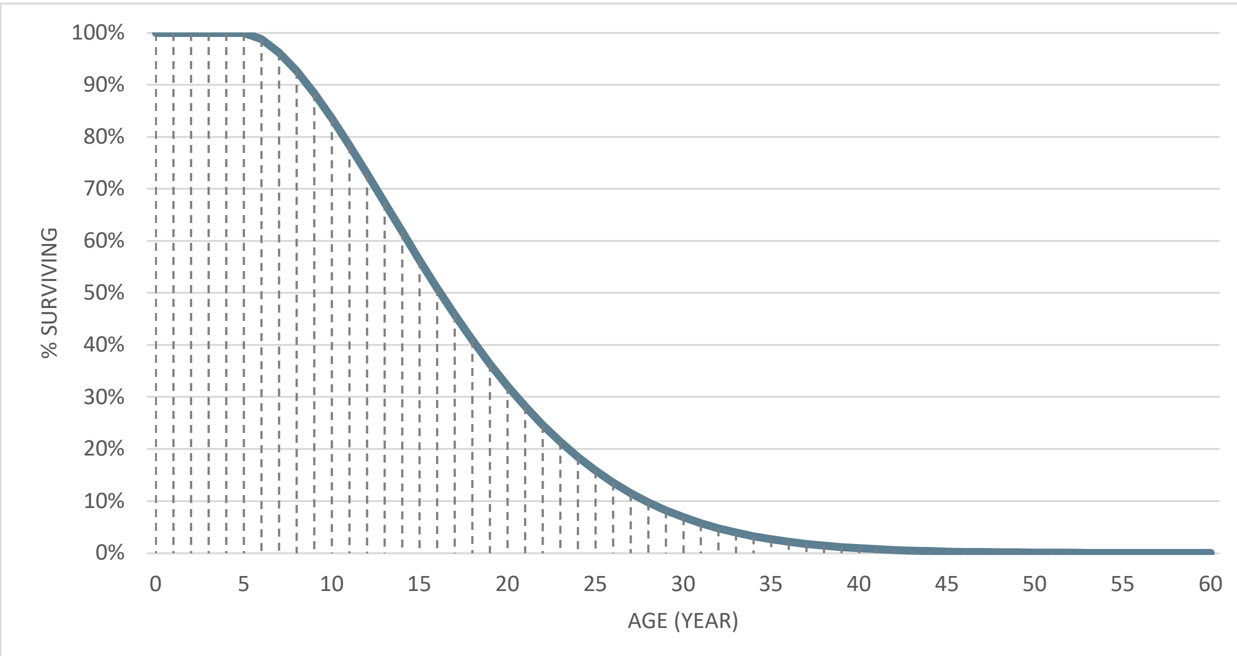

Figure 1-2 Survival Function for ENERGY STAR Refrigerators[49]

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 1-2. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced. To scale freezer RULs the TPE multiplied refrigerator RULs by the ratio of freezer/refrigerator EULs (12/17 = 0.706).

[48] *Ibid.*

[49] U.S. DOE, Technical Support Document, 2011, "Residential Refrigerators, Refrigerator-Freezers, and Freezers, 8.2.3 Product Lifetimes." September 15. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

1.1.11.4 Deemed Savings Values

Energy savings and demand reductions for retired refrigerators and freezers are based upon a linear regression model using equations and coefficients listed below.

1.1.11.4.1 Refrigerators

Table 1-34 displays the model coefficients and default inputs in the absence of program data. The coefficients presented are a combination of estimates from NREL, Illinois TRM V7.0, Texas TRM V6.1, and MidAtlantic TRM V8.0. Certain characteristics are 0-1 dummy indicators (such as whether a unit has side-by-side configuration). For these inputs, the Default Input is reflective of the average prevalence of that configuration the NREL UMP. For example, a default input of .323 for side-by-side indicates that 32.3% of units recycled could be expected to be side-by-side, based on prior research cited by the TPE.

Table 1-34 Savings Coefficients for Refrigerator Savings

Independent Variable	Estimated Coefficient[3]	Default Input[50]	kWh Impact
Intercept	0.750	1	273.75
Age (years)	0.032	17.10	199.73
Pre-1990	1.140	.081	33.70
Size (square feet)	0.067	19.00	464.65
Single Door	-1.085	.039	-15.44
Side-by-Side	0.957	.323	112.83
Primary Usage	0.477	.696	121.18
Unconditioned x CDD	0.007	.259*3,470	6.29
Unconditioned x HDD	-0.016	.259*1,058	-4.38
Total Unit Energy Consumption		1,192	
Part-Use Adjustment		93.2%	
Default kWh Savings		1,111	

$$\text{Savings}_{kWh} = [0.75 + (Age \times 0.032) + (Pre - 1990 \ \times 1.140) + (Size \ \times 0.067) +$$

$$(Single\ Door \times \ -1.085) + (Side - by - Side \times 0.957) + (Primary\ Usage \times 0.477) +$$

$$(Unconditioned\ CDD \ \times \ 0.007) + (Unconditioned\ HDD \times -0.016)] \times 365.25 \times 0.932$$

Where:

Age = Age of retired unit

Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)

Size = Capacity (cubic feet) of retired unit

Single Door = Single door dummy (=1 if one door, else 0)

[50] Unit inputs based on averages from Public Service Company of New Mexico 2016 EM&V Report, ADM Associates Inc. Weather inputs based on TMY3 estimates for CDD and HDD for New Orleans). https://www.pnm.com/documents/396023/3157050/2016+Independent+Measurement+and+Verification+Report%2C%20Part+1%2C%20ADM+Associates%2C%20Inc.pdf/011b6c03-4358-4396-acf8-73cd8a24009e

Side-by-Side = Side-by-side dummy (= 1 if side-by-side, else 0)

Primary Usage = Primary usage type (in absence of the program) dummy (= 1 if Primary, else 0)

Unconditioned x CDD = Weather interaction for units located in unconditioned spaces (=1*CDD). New Orleans CDD base 65 = 3,470

Unconditioned x HDD = Weather interaction for units located in unconditioned spaces (=1*HDD) New Orleans HDD base 65 = 1,058[3]

Part Use = To account for those units that are not running throughout the entire year.

For example: A resident decides to recycle a 20 square foot single door, non-side-by-side refrigerator. They originally purchased the unit in 1995 and has since been replaced, so this unit is now located in an unconditioned garage as extra food and beverage storage.

$$\text{Savings}_{kWh} = [0.75 + (24 \times 0.032) + (0 \ \times 1.140) + (20 \ \times 0.067) + (1 \times \ -1.085) + (0 \times 0.957) + (0 \times 0.477) + (1 \ \times \ 0.007) + (1 \times -0.016)] \times 365.25 \times 0.932 = 600.49 \text{ kWh}$$

1.1.11.4.2 Freezers

Table 1-35 Savings Coefficients for Freezer Savings

Independent Variable	Estimated Coefficient	Default Input	kWh Impact
Intercept	-0.296	1	-108.04
Appliance Age (years)	0.039	17.1	243.42
Pre-1990	0.486	0.081	14.37
Size (square feet)	0.104	15.9	603.56
Freezer Chest	0.122	0.119	5.30
Unconditioned x CDD	-0.002	.741*3470	-5.14
Unconditioned x HDD	0.024	.741*1,058	18.82
Total Unit Energy Consumption		772	
Part-Use Adjustment		85.5%	
Default kWh Savings		660	

$$\text{Savings}_{kWh} = [-0.296 + (Age \times 0.039) + (Pre - 1990 \ \times 0.486) + (Size \ \times 0.104) + (Freezer\ Chest \times \ 0.122) + (Unconditioned\ CDD \ \times \ -0.002) + (Unconditioned\ HDD \times 0.024)] \times 365.25 \times 0.855$$

Where:

$Freezer\ Chest$ = Chest freezer dummy (= 1 if chest freezer, else 0)

$$\text{Savings}_{kW} = \left(\frac{\Delta kWh}{8{,}760}\right) \times CF$$

Where:

CF = Coincident factor defined as summer kW/average kW

= 1.082 for Refrigerators

= 1.065 for Freezers

The coincident factor aggregates two adjustments:

- The duty cycle of the equipment during the peak period; and
- The declining efficiency of the compressor when subject to higher outside air temperatures.

The resulting aggregate effect is a coincidence factor > 1.0 for refrigerators and freezers.

Based on the default inputs specified in Table 1-34 and Table 1-35, the recommended default kW values are:

- Refrigerators: 1,111 / 8,760 * 1.082 = 0.137
- Freezers: 660 / 8,760 * 1.065 = 0.080

1.1.11.5 Incremental Cost

The incremental cost for this measure is the actual cost associated with the removal and recycling of the secondary refrigerator. If unknown, use $170 per unit .

1.1.11.6 Future Studies

This chapter is based on regression coefficients averaged from NREL, the Illinois TRM 7.0, the Texas TRM 6.1 and the Mid-Atlantic TRM 8.0 and citation of unit data from a refrigerator recycling evaluation completed on behalf of Public Service Company of New Mexico. It is recommended that program administrators collect the data needed to support energy savings estimates based on actual units recycled. Administrators should collect:

- Unit age;
- Size (cubic feet);
- Configuration (Refrigerators: side-by-side, single-door, top-freezer, bottom-freezer. Freezers: upright, chest);
- Location of use (conditioned versus unconditioned space); and
- Unit make and model number.

A net-to-gross study will be conducted in PY13, which will address the extent to which the units would have been disposed of by program participants in the absence of the program; free-ridership for refrigerator recycling addresses the question of “would the unit be plugged in in the absence of a program intervention”, and as a result the savings are program attributable if a participation would have otherwise kept it in use, gave it to a friend or relative, donated it to charity, or sold the unit.

If refrigerator/freezer cycling constitutes 5% or more of portfolio-level residential savings, the TPE would recommend an in-situ metering study to develop a New Orleans-specific unit energy consumption regression model.

1.2 Domestic Hot Water

1.2.1 WATER HEATHER REPLACEMENT

1.2.1.1 Measure Description

This measure involves:

- The replacement of electric water heaters by ENERGY STAR heat pump water heaters (HPWH);
- The replacement of either electric or gas water heaters by ENERGY STAR certified solar water heaters.

Systems greater than 55 gallons in capacity have an efficiency requirement that necessitates installation of a heat pump water heater or tank-less system.

Water heating deemed savings values are measured on an annual per-unit basis. Deemed savings variables include tank volume, estimated water usage, and rated uniform energy factor. Fuel substitution is not eligible for deemed savings. This measure applies to all residential applications.

1.2.1.2 Baseline and Efficiency Standards

The current baseline for electric and gas water heaters is the US DOE energy efficiency standard (10 CFR Part 430), which is consistent with the International Energy Conservation Code (IECC) 2009. Residential water heaters manufactured on or after April 16, 2015, must comply with the amended standards found in the Code of Federal Regulations, 10 CFR 430.32(d)[51]. An abbreviated account of the regulations that apply to qualifying water heater units are found in the table below.

Table 1-36 Title 10: 430.32 (d) Water Heater Standards

Product Class	Rated Storage Volume	Draw Pattern	Uniform Energy Factor (UEF)
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 − (0.0008 × Vr)
		Low	0.9254 − (0.0003 × Vr)
		Medium	0.9307 − (0.0002 × Vr)
		High	0.9349 − (0.0001 × Vr)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 − (0.0011 × Vr)
		Low	2.0440 − (0.0011 × Vr)
		Medium	2.1171 − (0.0011 × Vr)
		High	2.2418 − (0.0011 × Vr)
Instantaneous Electric Water Heater (tankless)	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

Where Vr[52] is the Rated Storage Volume which equals the water storage capacity of a water heater, in gallons, as certified by the manufacturer.

The new code requires that a "draw pattern" is to be determined to better calculate the energy factor associated with a water heater. The draw pattern is based on the first hour rating (FHR) of an installed

[51] https://www.govinfo.gov/content/pkg/CFR-2018-title10-vol3/pdf/CFR-2018-title10-vol3-part430.pdf (pg. 480)

[52] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17

water heater and is defined as the number of gallons of hot water the heater can supply per hour. The following three tables (Table 1-37, Table 1-38 and Table 1-39) provide the FHR ranges and corresponding draw patterns for different equipment types.

Table 1-37 Tank Water Heater Draw Pattern

New FHR Greater Than or Equal to:	New FHR Less Than:	Draw pattern
0 gallons	18 gallons	Very Small
18 gallons	51 gallons	Low
51 gallons	75 gallons	Medium
75 gallons	No Upper Limit	High

Table 1-38 Instantaneous Water Heater Draw Pattern

New Max GPM Greater Than or Equal to:	New Max GPM Rating Less Than:	Draw pattern
0 gallons/minute	1.7 gallons/minute	Very Small
1.7 gallons/minute	2.8 gallons/minute	Low
2.8 gallons/minute	4 gallons/minute	Medium
4 gallons/minute	No Upper Limit	High

Table 1-39 Heat Pump Water Heater Draw Pattern

Draw Volume	Draw Pattern
10 gallons	Very Small
38 gallons	Low
55 gallons	Medium
84 gallons	High

Current baseline Uniform Energy Factors (efficiencies) for various tank size electric storage water heaters are calculated and shown in Table 1-40. The estimated annual hot water usage for electric storage water heaters of various sizes is shown in Table 1-41.

Table 1-40 Calculated Electric Storage Water Heater Baseline Uniform Energy Factors

Uniform Energy Factors by Tank Size		Capacity (Gallons)				
		30	40	50	65	80
		≥ 20 gal and ≤ 55 gal			> 55 gal and ≤ 120 gal	
Electric Storage Water Heater	Very Small	0.8568	0.8488	0.8408	1.8521	1.8356
	Low	0.9164	0.9134	0.9104	1.9725	1.956
	Medium	0.9247	0.9227	0.9207	2.0456	2.0291
	High	0.9319	0.9309	0.9299	2.1703	2.1538

Table 1-41 Estimated Annual Hot Water Use (Gallons)

Tank Size (gal) of Replaced Water Heater	30	40	50	65	80
Estimated Annual Hot Water Usage	12,761	16,696	18,973	22,767	27,320

1.2.1.3 Estimated Useful Life

The EUL of this measure is dependent on the type of water heating. According to DEER 2014, the following measure lifetimes should be applied:

- 13 years for electric storage tank water heaters
- 10 years for Heat Pump Water Heaters
- 20 years for tank-less electric water heaters
- 15 years for solar water heaters

1.2.1.4 Deemed Savings Values

1.2.1.4.1 Water Heater

(i) Energy Savings

Calculated deemed energy savings are shown in Table 1-42. Water heater replacements that have tank sizes that fall between the range of 30-gallon to 50-gallon in volume generally produce adequate energy savings.

Table 1-42 Deemed Energy Savings for Water Heater Replacement

Water Heater System Type	HVAC System Type	Draw Pattern	Capacity (Gallons)				
			30	40	50	65	80
Heat Pump Water Heater	Gas Furnace	Very Small	1,351	1,790	2,059	709	867
		Low	1,236	1,624	1,854	620	757
		Medium	1,221	1,602	1,826	570	697
		High	1,208	1,583	1,801	494	605
	Heat Pump	Very Small	1,220	1,618	1,864	475	586
		Low	1,105	1,452	1,658	386	477
		Medium	1,090	1,430	1,631	336	417
		High	1,077	1,411	1,606	260	324
	Electric Resistance	Very Small	1,130	1,501	1,731	315	394
		Low	1,015	1,335	1,525	226	285
		Medium	1,000	1,313	1,497	177	225
		High	987	1,294	1,473	100	132
	Unconditioned	Very Small	1,260	1,670	1,923	546	671
		Low	1,144	1,504	1,718	457	562
		Medium	1,130	1,483	1,690	408	502
		High	1,117	1,464	1,666	331	409
Solar with Electric Backup	N / A	Very Small	1,611	2,130	2,446	1,173	1,423
		Low	1,496	1,964	2,240	1,083	1,314
		Medium	1,481	1,942	2,212	1,034	1,254
		High	1,468	1,923	2,188	958	1,161

(ii) Demand Reductions

Calculated deemed demand reductions are shown in Table 1-43.

Table 1-43 Deemed Demand Reductions for Water Heater Replacement

Water Heater System Type	HVAC System Type	Draw Pattern	Capacity (Gallons)				
			30	40	50	65	80
Heat Pump Water Heater	Gas Furnace	Very Small	0.1185	0.1570	0.1806	0.0622	0.0760
		Low	0.1084	0.1424	0.1626	0.0543	0.0664
		Medium	0.1071	0.1405	0.1601	0.0500	0.0612
		High	0.1060	0.1388	0.1580	0.0433	0.0530
	Heat Pump	Very Small	0.1070	0.1419	0.1635	0.0417	0.0514
		Low	0.0969	0.1274	0.1455	0.0338	0.0418
		Medium	0.0956	0.1254	0.1430	0.0295	0.0365
		High	0.0944	0.1238	0.1409	0.0228	0.0284
	Electric Resistance	Very Small	0.0991	0.1316	0.1518	0.0276	0.0345
		Low	0.0890	0.1171	0.1338	0.0198	0.0250
		Medium	0.0877	0.1152	0.1313	0.0155	0.0197
		High	0.0866	0.1135	0.1292	0.0088	0.0116
	Unconditioned	Very Small	0.1105	0.1465	0.1687	0.0479	0.0589
		Low	0.1004	0.1319	0.1507	0.0401	0.0493
		Medium	0.0991	0.1300	0.1482	0.0357	0.0440
		High	0.0979	0.1284	0.1461	0.0291	0.0359
Solar with Electric Backup	N / A	Very Small	0.1413	0.1868	0.2145	0.1029	0.1248
		Low	0.1312	0.1722	0.1965	0.0950	0.1152
		Medium	0.1299	0.1703	0.1940	0.0907	0.1100
		High	0.1288	0.1687	0.1919	0.0840	0.1018

1.2.1.4.2 Heat Pump Water Heater

(i) Energy Savings

The residential heat pump water heater (HPWH) measure involves the installation of an integrated ENERGY STAR HPWH. The HPWHs available through the ENERGY STAR product finder have an average UEF of 3.22.

The variables affecting deemed savings are storage tank volume, HPWH Energy Factor (EF), HPWH installation location (in conditioned or unconditioned space), and weather zone. This measure considers an air-conditioning energy savings (“Cooling Bonus”) and an additional space heating energy requirement (“Heating Penalty”) associated with the HPWH when it is installed inside conditioned space.

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times \left(\frac{1}{EF_{pre}} - \left(\frac{1}{(EF_{post} \times (1 + PA\%)} \times Adj\right)\right)}{3{,}412\ Btu/kWh}$$

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb.·°F

V = Estimated annual hot water use (gal) from Table 1-41

$T_{SetPoint}$ = Water heater set point (value = 123.61°F, based on on-site testing of New Orleans homes)

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F

EF_{pre} = Baseline Uniform Energy Factor from Table 1-40

EF_{post} = Uniform Energy Factor of new HPWH. ENERGY STAR average is 3.22

$PA\%$ = Performance Adjustment to adjust the HPWH EF relative to ambient air temperature per DOE guidance $= 0.00008 \times T_{amb}^3 + 0.0011 \times T_{amb}^2 - 0.4833 \times T_{amb} + 0.0857$. Assumed conditioned space, 73.4 degrees , PA% = 2.17%. For unconditioned space, 68.78 degrees , PA% = -1.92%

T_{amb}= Ambient temperature dependent on location of HPWH (Conditioned or Unconditioned Space) and Weather Zone from Table 1-44

Adj =HPWH-specific adjustment factor to account for Cooling Bonus and Heating Penalty on an annual basis, as well as backup electrical resistance heating which is estimated at 0.92 EF. Adjustment factors are listed in Table 1-45

$3{,}412\ Btu/kWh$ = conversion factor to convert BTU to kWh

The average ambient air temperatures listed in Table 1-44 are applicable to the installation locations for the HPWH. Unconditioned space is considered to be an unheated garage-like environment. This data is based on local ambient temperatures for each weather zone calculated from TMY3 weather data. The conditioned space temperatures assume thermostat settings of 78°F (cooling season) and 70°F (heating season), and a “balance point temperature” of 65°F. Unconditioned space ambient temperatures are adjusted from the local temperatures by seasonal factors to account for a garage-like setting.

Table 1-44 Average Ambient Temperatures and PA% Factors by Installation Location

	Conditioned Space	**Unconditioned Space**
$T_{ambient}$	73.4°F	68.9°F
PA% Factor	2.17%	- 1.91%

Table 1-45 HPWH Adjustment[53]

Water Heater Location	**Furnace Type**	**Adjustment Factor**
Conditioned Space	Gas	0.917
	Heat Pump	1.201
	Elec. Resistance	1.395
Unconditioned Space	N/A	1.070

[53] In order to facilitate an algorithmic approach: a spreadsheet model was created which modeled savings accounting for Cooling Bonus and Heating Penalty on an annual basis, as well as backup electrical resistance heating; HPWH Adjustment factors were derived to equate the results of this more extensive model to a simpler algorithm.

As an example, the following deemed electricity savings are applicable for the replacement of a 50-gallon electric storage tank water heater having a medium draw pattern, with a 50-gallon heat pump water heater using an ENERGY STAR model with an EF of 3.22 in conditioned space for a household using a gas furnace in New Orleans:

$$kWh_{Savings}$$

$$= \frac{8.33 \times 1 \times 18{,}973 \times (123.61 - 74.8) \times \left(\frac{1}{0.9207} - \left(\frac{1}{3.22 \times (1 + 0.0217355)} \times 0.917\right)\right)}{3{,}412\ Btu/kWh}$$

$$= 1{,}825.758 kWh$$

(ii) Demand Reductions

$$kW_{savings} = kWh_{savings} \times Ratio^{Peak\ kW}_{Annual\ kWh}$$

Where:

$Ratio^{Peak\ kW}_{Annual\ kW}$ Demand savings were calculated using the US DOE "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile. Based on this profile, the ratio of Peak kW to Annual kWh for domestic hot water usage was estimated to be 0.0000877 kW per annual kWh savings

For the HPWH example shown in equation above, peak demand savings is 1,826 kWh × 0.0000877 = 0.160 kW.

1.2.1.4.3 Solar Water Heating with Electric Backup

(i) Energy Savings

The residential solar water heater measure involves the installation of an ENERGY STAR certified solar water heater rated by the Solar Rating and Certification Corporation (SRCC). Solar water heaters available through the ENERGY STAR product finder have an average Solar Energy Factor (SEF) of 8.7 for electric backup.

The variables affecting deemed savings are SEF, LF, and weather zone.

The SRCC determines SEF based on standardized 1,500 Btu/ft^2-day solar radiation profile across the U.S. As solar insolation varies widely depending on geographic location, in order to derive more accurate estimates for a given locale, Localization Factors (LF) are used to adjust the SEF. The LF for the New Orleans weather zone have been calculated. The LF is based on the daily total insolation (1,598 in New Orleans), averaged annually, per a Satellite Solar Radiation model developed by the State University of New York (SUNY).

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{SEF\ x\ LF}\right)}{3412\,\frac{Btu}{kWh}}$$

Where:

ρ = Water density = 8.33 lb./gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal) from Table 1-41

$T_{SetPoint}$ = Water heater set point (default value = 122.24°F)

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F

EF_{pre} = Baseline Energy Factor

SEF = Solar Energy Factor of new water heater, default of 8.7

LF = Localization Factor for SEF of new water heater in New Orleans, 1.068

As an example, the following deemed electricity savings are applicable for replacement of a 50-gallon (High Draw) electric storage tank water heater with a 50-gallon solar water heater with electric backup using a model with an EF of 8.7 for a household in New Orleans:

$$kWh_{Savings} = \frac{8.33 \times 1 \times 18{,}973 \times (123.61 - 74.8) \times \left(\frac{1}{0.9209} - \frac{1}{(8.7\ \times\ 1.068)}\right)}{3{,}412\ Btu/kWh}$$

$$= 2{,}212.30\ kWh/yr$$

(ii) Demand Reductions

$$kW_{savings} = kWh_{savings} \times Ratio\,\frac{Peak\ kW}{Annual\ kWh}$$

Where:

$Ratio\,\frac{Peak\ kW}{Annual\ kWh}$ For the above example, peak demand savings is 2,188.00 kWh x 0.0000877 = 0.194 kW.

1.2.1.5 Incremental Cost

Incremental costs are as follows.

Table 1-46 Incremental Costs

Replacement Type	Size Category				
	30	40	50	65	80
Storage Tank - HPWH[54]	$582.99	$493.74	$404.37	$100.00	$138.38
Solar with Gas Back-up	$8,401[55]				

[54] CA DEER Workpaper SWWH014 – HPWH Res. (2019)

[55] California Solar Thermal Program: 2012 reported project costs.

1.2.1.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was implemented in Energy Smart programs. However, participation for this measure is currently too low to create reliable averages of measure characteristics. As a result, savings are calculated using ENERGY STAR default values.

If participation reached 1% of residential Energy Smart program savings, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents and the TPE recommends a metering study to support usage assumptions. Further, the TPE recommends a review of sizing changes from baseline to post-retrofit and an assessment of whether there needs to be consideration of snapback effects in HPWH retrofits.

If the measure is under consideration for increased emphasis in Energy Smart, the TPE recommends a market assessment to provide guidance as to the needs of New Orleans residents and plumbing contractors and to address savings potential.

Deemed parameters should be updated whenever DOE standards or other applicable codes warrant.

1.2.2 WATER HEATER JACKETS

1.2.2.1 Measure Description

This measure involves water heater jackets (WHJ) installed on water heaters located in an unconditioned space. These estimates apply to all weather regions. This measure applies to all residential applications.

1.2.2.2 Baseline and Efficiency Standards

Baseline is assumed to be the post-1991, storage-type water heater. WHJ must be installed on storage water heaters having a capacity of 30 gallons or greater. The manufacturer's instructions on the WHJ and the water heater itself should be followed. If electric, thermostat and heating element access panels must be left uncovered. If gas, follow WHJ installation instructions regarding combustion air and flue access.

Table 1-47 Water Heater Jackets – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Un-insulated water heater	Minimum insulation of R-6.7

1.2.2.3 Estimated Useful Life

The EUL of this measure is 13 years according to NEAT v.8.6.

1.2.2.4 Deemed Savings Values

Deemed savings are per installed jacket based on the jacket thickness, the type of water heating and the tank size.

Table 1-48 Water Heater Jackets – Electric Heating Deemed Savings Values

Approximate Tank Size (gal)	Electric Water Heating					
	kWh Savings			kW Savings		
	40	52	80	40	52	80
2" WHJ savings kWh	68	76	101	0.005	0.006	0.008
3" WHJ savings kWh	94	104	139	0.007	0.008	0.011

1.2.2.4.1 Calculation of Deemed Savings

Energy consumption for baseline units, with and without insulation jackets, was calculated using industry-standard energy-use calculation methodologies for residential domestic water heating. Variables in the calculations include the following:

- Water heater fuel type (electric or gas/propane)
- Baseline EF
- Estimated U-value of baseline unit
- Ambient temperature
- Tank volume
- Tank surface area
- Tank temperature

- Estimated hot water consumption

To estimate peak energy consumption, a load profile for residential water heating was developed from individual load profiles for the following end-uses: clothes washer, dishwasher, faucet, shower, sink-filling, bath, and other miscellaneous end-uses.

This end-use load shape data was calibrated using metered end-used data obtained from several utility end-use metering studies.

1.2.2.5 Incremental Cost

The incremental cost of a Water Heater Jacket is equal to the full installed cost. If the cost is unknown, use $35.

1.2.2.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values based on NEAT v.8.6 estimates.

In the PY13 evaluation of the Home Performance with Energy Star program, it is recommended that the percent of unjacketed water heaters is documented in order to inform whether water heater jackets warrant inclusion as a direct install measure.

1.2.3 WATER HEATER PIPE INSULATION

1.2.3.1 Measure Description

This measure requires water heater pipe insulation. Water heaters plumbed with heat traps are not eligible to receive incentives for this measure. New construction and water heater retrofits are not eligible for this measure, because they must meet current code requirements. This measure applies to all residential applications.

1.2.3.2 Baseline and Efficiency Standards

Baseline is assumed to be the typical gas or electric water heater with no heat.

All hot and cold vertical lengths of pipe should be insulated, plus the initial length of horizontal hot and cold water pipe, up to three feet from the transition, or until wall penetration, whichever is less.

Table 1-49 Water Heater Pipe Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Un-insulated hot water pipes	Minimum insulation thickness of ½”

1.2.3.3 Estimated Useful Life

The EUL of this measure is dependent on the type of water heater it is applied to. According to DEER 2014, the following measure lifetimes should be applied:

- 13 years for electric storage water heating
- 11 years for gas storage water heating
- 10 years for heat pump water heaters

1.2.3.4 Deemed Savings Values

The deemed savings per linear foot are detailed below.

Pipe Wrap – Deemed Savings Per Linear Foot

R-value	Pipe Diameter	kWh	kW
3	½”	25.32	.0029
	¾”	37.99	.0043

1.2.3.4.1 Energy Savings

$$Energy\ Savings = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient}\right) \times \left(\frac{1}{RE}\right) \times \frac{Hours_{Total}}{Conversion\ Factor}$$

Where:

U_{pre}= 1/(2.03[56]) = 0.49 BTU/h sq. ft. degree F

[56] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe and between the surface and air. Mark’s Standard Handbook for Mechanical Engineers, 8th edition.

U_{post}= 1/(2.03+$R_{Insulation}$)

$R_{Insulation}$= R-value of installed insulation

A = Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

$T_{Pipe}(°\mathrm{F})$ = Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambient}(°\mathrm{F})$ = 68.78°F (New Orleans)

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 0.79 for natural gas water heaters, or 2.2 for heat pump water heaters[57]

$Hours_{Total}$ = 8,760 hr per year[58,59]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating.

1.2.3.4.2 Demand Savings

Peak demand savings for hot water heaters installed in conditioned space can be calculated using the following formula for electric:

$$kW_{savings} = (U_{pre} - U_{post}) \times A \times (T_{Pipe} - T_{ambientMAX}) \times \left(\frac{1}{RE}\right) \times \frac{1}{3{,}412\ Btu/kWh}$$

Where:

U_{pre} = 1/(2.03) =0.49 BTU/h sq ft degree F

U_{post} = 1/(2.03+$R_{Insulation}$)

$R_{Insulation}$ = R-value of installed insulation

A = Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

$T_{Pipe}(°\mathrm{F})$ = Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambientMAX}(°\mathrm{F})$ =For water heaters installed in unconditioned basements, use an average ambient temperature of 75°F; for water heaters inside the thermal envelope, use an average ambient temperature of 78 °F

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[57] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

[58] Ontario Energy's Measures and Assumptions for Demand Side Management (DSM) Planning www.ontarioenergyboard.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[59] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Residential, Multi-Family, and Commercial/Industrial Measures http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf

RE = Recovery efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance or 2.2 for heat pump water heaters.

1.2.3.5 Incremental Cost

The incremental cost of a Water Heater Pipe Insulation is equal to the full installed cost. If the cost is unknown, use $3 per linear foot of insulation .

1.2.3.6 Future Studies

In the PY13 evaluation of the Home Performance with Energy Star program, it is recommended that the percent of uninsulated hot water lines is documented in order to inform whether pipe insulation warrant inclusion as a direct install measure

1.2.4 FAUCET AERATORS

1.2.4.1 Measure Description

This measure involves retrofitting aerators on kitchen and bathroom water faucets. The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable. This measure applies to all residential applications.

1.2.4.2 Baseline and Efficiency Standards

The 2.2 gallons per minute (GPM) baseline faucet flow rate is based upon the Energy Policy Act of 1992 (EPAct 92) and subsequent EPAct actions which limited faucet flows to 2.2 GPM . The US EPA WaterSense specification for faucet aerators is 1.5 GPM .

Table 1-50 Faucet Aerators – Baseline and Efficiency Standards

Baseline	Efficiency Standard
2.2 GPM	1.5 GPM maximum

The deemed savings values are for residential, retrofit-only installation of kitchen and bathroom faucet aerators.

1.2.4.3 Installation Requirements for Contractors / Trade Allies

Aerators that have been defaced so as to make the flow rating illegible are not eligible for replacement. For direct installation programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

1.2.4.4 Estimated Useful Life

The EUL of this measure is 10 years according to DEER 2014.

1.2.4.5 Deemed Savings Values

The table below summarizes the deemed kWh and kW for 1.5 GPM and 1.0 GPM faucet aerators, based on the algorithms in the subsections to follow.

Table 1-51 Faucet Aerators – Deemed Savings

Efficient GPM Rating	Water Heater Type	kWh	kW
1.5 GPM	Electric Resistance	26.80	0.0028
	Heat Pump	11.94	0.0012
1.0 GPM	Electric Resistance	44.66	0.0046
	Heat Pump	19.90	0.0021

1.2.4.5.1 Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the New Orleans are 74.8°F. The water main temperature data was approximated using the following formula .

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

Where:

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature, 68.8°F in New Orleans

R = 0.05

ΔT_{amb} = the average of maximum and minimum ambient air-dry bulb temperature for the month (Tmax + Tmin)/2 where Tmax = maximum ambient dry bulb temperature for the month, and Tmin = minimum ambient dry bulb temperature for the month

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.[60, 61, 62]

1.2.4.5.2 Estimated Hot Water Usage Reduction

$$Water\ consumption = \frac{\frac{Faucet\ Use\ per\ Person}{Day} \times Occupants\ per\ Home \times \frac{365\ Days}{Year}}{Faucets\ per\ Home}$$

Applying the formula to the values from Table 1-50 returns the following baseline and post water consumption.

- Baseline (2.2 GPM): 9.7 x 2.37 x 365 / 3.86 = 2,174
- Post (1.5 GPM): 8.2 x 2.37 x 365 / 3.86 = 1,838
- Post (1.0 GPM): 7.2 x 2.37 x 365 / 3.86 = 1,614

Gallons of water saved per year can be found by subtracting the post consumption in gallons per year per aerator from the baseline consumption.

- Gallons of water saved per year (1.5 GPM): 2,174 – 1,838 = 336
- Gallons of water saved per year (1.0 GPM): 2,174 – 1,614 = 560

Table 1-52 Estimated Aerator Hot Water Usage Reduction

Assumption Type	**Seattle Study[63]**	**Tampa Study[64]**	**East Bay Study**	**Average**	**Value used for New Orleans**
Faucet use gallons/person/day (baseline)	9.2	9.4	10.5	9.7	9.7
Faucet use gallons/person/day (1.5 GPM)	8.0	6.2	10.5	8.2	8.2

[60] Seattle Home Water Conservation Study, 2000. "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle%20Home%20Water%20Conservation%20Study

[61] Residential Indoor Water Conservation Study, 2003 "Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July. www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868

62 Tampa Water Department Residential Water Conservation Study, 2004, "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

[63] Average of pre-retrofit percent faucet hot water 72.7% on page 35, and post-retrofit percent faucet hot water 79.5% on page 53.

[64] Average of pre-retrofit percent faucet hot water 65.2% on page 31 and post-retrofit faucet hot water percentage 50.0% on page 54.

Assumption Type	Seattle Study[63]	Tampa Study[64]	East Bay Study	Average	Value used for New Orleans
Faucet use gallons/person/day (1.0 GPM)[65]	--	--	--	--	7.2
Occupants per home	2.54	2.92	2.56	2.67	2.37[66]
Faucets per home[67]	--	--	--	--	3.86
Gal./yr./faucet (baseline)	--	--	--	--	2,174
Gal./yr./faucet (1.5 GPM)	--	--	--	--	1,838
Gal./yr./faucet (1.0 GPM)	--	--	--	--	1,614
Percent hot water	76.10%[4]	Not listed	57.60%5	66.90%	66.9%
Water gallons saved/yr./faucet (1.5 GPM)	--	--	--	--	336
Water gallons saved/yr./faucet (1.0 GPM)	--	--	--	--	560

Based on the average percentage hot water shown in the table above, the average mixed water temperature across all weather zones was determined. The hot water temperature was found to be 122°F in a sample of 144 homes in New Orleans tested by the TPE. The mixed water temperature used in the energy savings calculation can be seen in the table below.

Table 1-53 Mixed Water Temperature Calculation

Average Water Main Temperature (°F)	Average Water Heater Setpoint Temperature (°F)	Percent Hot Water	Mixed Water Temperature (°F)
74.8	122.695	66.9%	106.8

1.2.4.5.3 Energy Savings

$$Annual\ Energy\ Savings\ = \frac{\rho \times C_P \times V \times (T_{Mixed} - T_{Supply}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor}$$

Where:

ρ = Water density = 8.33 lb/gal

C_P = Specific heat of water = 1 BTU/lb·°F

V = Gallons of water saved per year per faucet from Table 1-52

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[65] This value is a linear extrapolation of gallons per person per day from the baseline (2.2 GPM) and the 1.5 GPM case.

[66] 2010-2014, US Census Bureau. http://www.census.gov/quickfacts/table/PST045215/2255000

[67] Faucets per home assumed to be equal to one plus the number half bathrooms and full bathrooms per home, taken from 2009 RECS, Table HC2.10.

T_{Mixed} = Mixed water temperature, 106.8°F, from Table 1-53

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters[68].

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

1.2.4.5.4 Demand Reductions

Demand reductions for homes with electric water heating were calculated using the following formula:

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kW}^{Peak\ kW}$$

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$

This value is taken from the DOE domestic hot water use study. The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower bath and sink hot water use. An average was calculated using peak hours of 3 PM to 6 PM to generate an average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.

1.2.4.5.5 Example Calculation of Deemed Savings Values

Deemed savings values are per faucet aerator installed.

Table 1-54 Example -Replacing 2.2 GPM with 1.5 GPM Faucet Aerator

Faucet Aerator, New Orleans Weather Zone		
Water Usage Reduction (gal)	336	
T_{Supply}	74.8°F	
T_{Mixed}	106.8°F	
Water heater RE (excluding standby losses)	0.98 (Electric) / 2.2 (Heat Pump)	
Energy Savings	Electric: 26.8 kWh	Heat Pump: 11.94 kWh
Demand Savings	Electric: 0.0028 kW	Heat Pump: 0.0012 kW

1.2.4.6 In-Service Rates

Table 1-55 In-Service Rates

Delivery Channel	ISR
Direct Install	0.98

[68] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

Mailer Kit[69]	0.45

1.2.4.7 Future Studies

Metering studies for water use are exceedingly expensive. In past metering efforts, the TPE has found costs to exceed $750 per site. As such, we do not advise a metering study for this measure unless savings exceed 5% of residential program savings.

[69] Based on primary data collection from 4,572 PY5-9 program participants.

1.2.5 LOW-FLOW SHOWERHEADS

1.2.5.1 Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences. This measure applies to all residential applications.

1.2.5.2 Baseline and Efficiency Standards

The baseline average flow rate of the existing stock of showerheads is based on the current US DOE standard.

The incentive is for replacement of an existing showerhead with a new showerhead rated at 2.0, 1.75 or 1.5 gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

1.2.5.3 Installation Requirements for Trade Allies / Contractors

Existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Table 1-56 Low-Flow Showerhead – Baseline and Efficiency Standards

Measure	New Showerhead Flow Rate[70] (GPM)	Existing Showerhead Baseline Flow Rate (GPM)
2.0 GPM showerhead	2.00	2.50
1.75 GPM showerhead	1.75	2.50
1.5 GPM showerhead	1.50	2.50

The U.S. EPA WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM .

1.2.5.4 Estimated Useful Life

The EUL of this measure is 10 years according to DEER 2014.

1.2.5.5 Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperature is 74.8°F. The water main temperature data was approximated using the following formula .

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

[70] All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

Where:

R = 0.05

$T_{avg\ ambient}$ = the average annual ambient air dry-bulb temperature

ΔT_{amb} = 74.8 (New Orleans), the average of maximum and minimum ambient air dry-bulb temperature for the month (Tmax + Tmin)/2 where Tmax = maximum ambient dry bulb temperature for the month and Tmin = minimum ambient dry bulb temperature for the month

1.2.5.6 Estimated Hot Water Usage Reduction

Baseline and efficiency standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL . See Table 1-57 for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\frac{Gallons}{Showe} \times \frac{Showe \quad per\ Person}{Day} \times \frac{365\ Days}{Year} \times \frac{Occupants\ per\ Home}{Showerhead \quad per\ Home}$$

Applying the formula to the values from Table 1-57 returns the following baseline and post water consumption.

- Baseline (2.5 GPM): 20.7 x 0.69 x 365 x 2.37 / 1.62 = 7,627
- Post (2.0 GPM): 16.5 x 0.72 x 365 x 2.37 / 1.62 = 6,344
- Post (1.5 GPM): 12.4 x 0.72 x 365 x 2.37 / 1.62 = 4,767

Although the referenced studies do not provide data on 1.75 GPM showerheads, the consumption values for 2.5, 2.0, and 1.5 GPM roughly follow a linear pattern. Taking a simple average of the consumption for 2.0 and 1.5 GPM showerheads returns a value for a 1.75 GPM showerhead:

- Post (1.75 GPM): (6,344 + 4,767) / 2 = 5,556

Gallons of water saved per year can be found by subtracting the post consumption in gallons per year per showerhead from the baseline consumption. These values are also in Table 1-57.

- Gallons of water saved per year (2.0 GPM): (7,627 – 6,344) = 1,283
- Gallons of water saved per year (1.75 GPM): (7,627 – 5,556) = 2,071
- Gallons of water saved per year (1.5 GPM): (7,627 – 4,767) = 2,860

Table 1-57 Estimated Showerhead Hot Water Usage Reduction

Assumption Type	Seattle Study[71]	Tampa Study	East Bay Study[72]	Average	Value used for New Orleans
Gallons/shower @ 2.5 GPM (baseline)	19.8	20.0	22.3	20.7	20.7
Gallons/shower @ 2.0 GPM	15.8	16.0	17.8	16.5	16.5
Gallons/shower @ 1.5 GPM	11.9	12.0	13.4	12.4	12.4
Showers/person/day (baseline)	0.51	0.92	0.65	0.69	0.69
Showers/person/day (post)	0.59	0.82	0.74	0.72	0.72
Occupants per home	2.54	2.92	2.56	2.67	2.37[73]
Showerheads per home[74]	not listed	not listed	not listed	not listed	1.62
Water gal./yr./showerhead @ 2.0 GPM saved	not listed	not listed	not listed	not listed	1,283
Water gal./yr./showerhead @ 1.75 GPM saved	not listed	not listed	not listed	not listed	2,071
Water gal./yr./showerhead @ 1.5 GPM saved	not listed	not listed	not listed	not listed	2,860
Percent hot water	74.3%	not listed	66%	70.1%	70.1%

Based on the average percentage hot water shown in the table above, the average mixed water temperature across all weather zones was determined. The hot water temperature was found to be 122.24°F in a sample of 144 homes in New Orleans tested by the TPE. The mixed water temperature used in the energy savings calculation can be seen in the table below.

Table 1-58 Mixed Water Temperature Calculation

Weather Zone	Average Water Main Temperature (°F)	Average Setpoint Temperature (°F)	Percent Hot Water	Mixed Water Temperature (°F)
New Orleans	74.8	122.695	66.9%	106.8

[71] Seattle Study: Average of pre-retrofit percent shower hot water 73.1% on page 35, and post-retrofit percent shower hot water 75.5% on p. 53.

[72] East Bay Study: Average of pre-retrofit percent shower hot water 71.9% on page 31 and post-retrofit shower hot water percentage 60.0% on p. 54.

[73] 2010-2014, US Census Bureau. http://www.census.gov/quickfacts/table/PST045215/2255000

[74] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

1.2.5.7 Deemed Savings Values

1.2.5.7.1 Energy Savings

$$Annual\ Energy\ Savings\ = \frac{\rho \times C_P \times V \times (T_{Mixed} - T_{Supply}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor}$$

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 BTU/lb·°F

V = 2.0, 1.75, or 1.5 GPM showerhead water gallons saved per year from Table 1-57

T_{Mixed} = Mixed water temperature, 106.8°F, from Table 1-57

T_{Supply}= Average New Orleans area supply water temperature, 74.8°F

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters,

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

1.2.5.7.2 Demand Reductions

Demand reductions were calculated using the US DOE "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile which resulted in a ratio of 0.000104 Peak kW to Annual kWh . The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower, bath, and sink hot water use. An average was calculated using peak hours of 3pm to 6pm to generate an average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.

$$kW_{savings} = kWh_{\ savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

Table 1-59 Low Flow Showerhead Retrofit Deemed Energy Savings

2.0 GPM Showerhead		
Water gal. saved /year/showerhead @ 2.0 GPM	1,283	
T_{Supply}	74.8°F	
T_{Mixed}	106.8°F	
Water heater RE	0.98 (Electric Resistance) / 2.2 (Heat Pump)	
Energy Savings	Electric: 102 kWh	Heat Pump: 46 kWh
Demand Savings	Electric: 0.0106 kW	Heat Pump: 0.0047 kW
1.75 GPM Showerhead		
Water gal. saved /year/showerhead @ 1.5 GPM	2,071	
T_{Supply}	74.8°F	
T_{Mixed}	106.8°F	
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump)	

Energy Savings	Electric: 165 kWh	Heat Pump: 74 kWh
Demand Savings	Electric: 0.0172 kW	Heat Pump:0.0076 kW
1.50 GPM Showerhead		
Water gal. saved /year/showerhead @ 1.5 GPM	2,860	
T_{Supply}	74.8°F	
T_{Mixed}	106.8°F	
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump)	
Energy Savings	Electric: 228 kWh	Heat Pump: 102 kWh
Demand Savings	Electric: 0.0237 kW	Heat Pump: 0.0106 kW

1.2.5.8 In-Service Rates

Table 1-60 In-Service Rates

Delivery Channel	**ISR**
Direct Install	0.98
Mailer Kit[75]	0.62

1.2.5.9 Future Studies

The TPE has found costs to exceed $750 per site. As such, we do not advise a metering study for this measure unless savings exceed 5% of residential program savings.

[75] Based on primary data collection from 4,572 PY5-9 program participants.

1.2.6 SHOWERHEAD THERMOSTATIC RESTRICTOR VALVES

1.2.6.1 Measure Description

This measure consists of installing a thermostatic restrictor valve (TRV) between the existing shower arm and showerhead. The valve will reduce behavioral water waste by restricting water flow when the water reaches a set temperature (generally 95˚F). Restricting the flow when the water reaches the temperature set point, reduces the amount of water that goes down the drain prior to the user entering the shower.

1.2.6.2 Baseline and Efficiency Standards

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a thermostatic restrictor valve installed. The baseline average flow rate of the existing stock of showerheads is based on the current US DOE standard.

To qualify for thermostatic restrictor valve deemed savings, the installed equipment must be a thermostatic restrictor valve installed on a residential shower arm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to 1.2.5 *Low-Flow Showerheads* and claim additional savings as outlined in that measure.

For direct installation applications, the residence must have electric resistance water heating.

1.2.6.3 Estimated Useful Life

The EUL of this measure is 10 years according to DEER 2008 .

1.2.6.4 Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the New Orleans is 74.8°F. The water main temperature data was approximated using the following formula .

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

Where:

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature, 68.8°F in New Orleans

R = 0.05

ΔT_{amb} = the average of maximum and minimum ambient air-dry bulb temperature for the month (Tmax + Tmin)/2 where Tmax = maximum ambient dry bulb temperature for the month, and Tmin = minimum ambient dry bulb temperature for the month

1.2.6.4.1 Estimated Hot Water Usage Reduction

Water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.

Table 1-61 Estimated Showerhead Hot Water Usage Reduction

Assumption Type	Seattle Study	Tampa Study	East Bay Study	Average	Value used for New Orleans
Showers/person/day	0.51	0.92	0.65	0.69	0.69
Occupants per home	2.54	2.92	2.56	2.67	2.37[76]
Showerheads per home[77]	not listed	not listed	not listed	not listed	1.62
Percent hot water	76.1%	Not listed	57.6%	66.9%	66.9%

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used in conjunction with values from Table 1-61.

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR\ \times BW\ \times n_S\ \times\ 365_{days/year}\ \times \%_{HW} \times \frac{n_O}{n_{SH}}$$

Where:

$SHFR$ = Showerhead flow rate, gallons per minute (2.5, 2.0, 1.75 and 1.5 gpm)

BW = Behavioral waste, minutes per shower (0.783)

n_S = Number of showers per day (0.69)

n_O = Number of occupants per home (2.37)

n_{SH} = Number of showerheads per home (1.62)

$\%_{HW}$ = Percent hot water (.669)

Applying the formula to the values from Table 1-61 returns the following values for baseline behavioral waste in gallons per showerhead per year:

- 2.5 GPM (baseline): 2.5 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 483 gal
- 2.0 GPM: 2.0 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 386 gal
- 1.75 GPM: 1.75 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 338 gal
- 1.5 GPM: 1.5 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 290 gal

Table 1-62 Gallons of Hot Water Saved per Year

2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
483	386	338	290

[76] 2010-2014, US Census Bureau. http://www.census.gov/quickfacts/table/PST045215/2255000

[77] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

1.2.6.5 Deemed Savings Values

1.2.6.5.1 Energy Savings

$$Annual\ Energy\ Savings\ = \frac{\rho \times C_P \times V \times (T_{Setpoint} - T_{Supply}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor}$$

Where:

$\rho =$ Water density = 8.33 lb/gal

$C_P =$ Specific heat of water = 1 BTU/lb·°F

$V =$ Gallons of hot water saved per year (see Table 1-62)

$T_{Setpoint} =$ Water heater setpoint temperature (122.695°F)

$T_{Supply} =$ Average New Orleans area supply water temperature, 74.8°F

$RE =$ Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters[78].

$Conversion\ Factor =$ 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

1.2.6.5.2 Demand Reductions

Demand reductions for homes with electric water heating were calculated using the following formula:

$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$

The table below summarizes the deemed kWh and kW for TRVs installed on 2.5, 2.0, 1.75 and 1.5 gpm showerheads, using methods above.

Table 1-63 Deemed Savings for TRVs – Showerheads

Showerhead GPM	Water Heater Type	kWh	kW
2.5 gpm	Electric Resistance	58	0.006
	Heat Pump	26	0.003
2.0 gpm	Electric Resistance	46	0.005
	Heat Pump	21	0.002
1.75 gpm	Electric Resistance	40	0.004
	Heat Pump	18	0.002
1.50 gpm	Electric Resistance	35	0.004
	Heat Pump	15	0.002

[78] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

1.2.6.6 Incremental Cost

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $29.95 plus $15.47 labor if not available.

1.2.6.7 Future Studies

Metering studies for water use are exceedingly expensive. In past metering efforts, the TPE has found costs to exceed $750 per site. As such, we do not advise a metering study for this measure unless savings exceed 5% of residential program savings.

1.2.7 TUB SPOUT DIVERTERS AND THERMOSTATIC RESTRICTOR VALVES ON SHOWERHEADS

1.2.7.1 Measure Description

This measure consists of replacing existing tub spouts and shower heads with an automatically diverting tub spout and showerhead system with a thermostatic restrictor valve (TRV) between the existing shower arm and showerhead. When the water temperature reaches a set point (generally 95˚F), the thermostatic restrictor valve will engage the anti-leak diverter. The water will divert from the spout to a showerhead with a closed valve, which prevents the hot water from flowing down the drain prior to use.

1.2.7.2 Baseline and Efficiency Standards

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a thermostatic restrictor valve installed.

To qualify for deemed savings, the installed equipment must be a thermostatic restrictor valve installed on a residential shower arm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-Flow Showerheads measure (Section 1.2.5 Low-Flow Showerheads) and claim additional savings as outlined in that measure.

1.2.7.3 Estimated Useful Life

The EUL of this measure is 10 years according to DEER 2008[79].

1.2.7.4 Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the New Orleans area is 74.8°F. The water main temperature data was approximated using the following formula .

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

Where:

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature, 68.8°F in New Orleans

R = Decreased efficiency offset (0.05)[208]

ΔT_{amb} = the average of maximum and minimum ambient air-dry bulb temperature for the month (Tmax + Tmin)/2 where Tmax = maximum ambient dry bulb temperature for the month, and Tmin = minimum ambient dry bulb temperature for the month

[79] This value is consistent with the low flow showerhead EUL, DEER 2014.

1.2.7.5 Estimated Hot Water Usage Reduction

Water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL[80, 81, 82].

Table 1-64 Estimated Showerhead Hot Water Usage Reduction

Assumption Type	Seattle Study	Tampa Study	East Bay Study	Average	Value used for New Orleans
Showers/person/day	0.51	0.92	0.65	0.69	0.69
Occupants per home	2.54	2.92	2.56	2.67	2.37[83]
Showerheads per home[84]	not listed	not listed	not listed	not listed	1.62
Percent hot water	76.1%	Not listed	57.6%	66.9%	66.9%

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage. Total gallons of water saved are the sum of these two parts.

Part 1: To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used in conjunction with values from Table 1-64.

$$Annual\ Showerhead\ Behavioral\ Waste = \%WUE_{SH} \times SHFR \times BW \times n_S \times 365_{days/year} \times \%_{HW} \times \frac{n_O}{n_{SH}}$$

$$Annual\ Tub\ Spout\ Behavioral\ Waste = \%WUE_{TS} \times TSFR \times BW \times n_S \times 365_{days/year} \times \%_{HW} \times \frac{n_O}{n_{SH}}$$

[80] Seattle Home Water Conservation Study, 2000. “The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes.” December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle%20Home%20Water%20Conservation%20Study Average of pre-retrofit percent shower hot water 73.1% on page 35, and post-retrofit percent shower hot water 75.5% on p. 53.

[81] Residential Indoor Water Conservation Study, 2003 “Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area.” July. www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868 Average of pre-retrofit percent shower hot water 71.9% on page 31 and post-retrofit shower hot water percentage 60.0% on p. 54.

[82] Tampa Water Department Residential Water Conservation Study, 2004, “The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes.” January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

[83] 2010-2014, US Census Bureau. http://www.census.gov/quickfacts/table/PST045215/2255000

[84] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Where:

$\%WUE_{SH}$ = Showerhead percentage of warm-up events (0.6)

$\%WUE_{TS}$ = Showerhead percentage of warm-up events (0.4[8])

$SHFR$ = Showerhead flow rate, gallons per minute (2.5, 2.0, 1.75 and 1.5 gpm)

$TSFR$ = Tub Spout flow rate, gallons per minute (4 gpm)

BW = Behavioral waste, minutes per shower (0.783)

n_S = Number of showers per day (0.69)

n_O = Number of occupants per home (2.37)

n_{SH} = Number of showerheads per home (1.62)

$\%_{HW}$ = Percent hot water (.669)

Applying the formula to the values used for New Orleans from returns the following values for baseline behavioral waste in gallons per showerhead and tube spout per year:

Showerheads:

- 2.5 GPM (baseline): 0.6 x 2.5 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 290 gal
- 2.0 GPM: 0.6 x 2.0 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 232 gal
- 1.75 GPM: 0.6 x 1.75 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 203 gal
- 1.5 GPM: 0.6 x 1.5 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 174 gal

Tub Spout:

- 5.0 GPM: 0.4 x 5.0 x 0.783 x 0.69 x 365 x .669 x 2.37/1.62 = 386 gal

Table 1-65 Water Savings by Flow Rate (gallons)

2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm	Tub Spout
290	232	203	174	386

Part 2: To determine the baseline gallons of diverted leakage per year, the following formula was used:

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365_{days/year} \times \%_{HW} \times \frac{n_O}{n_{SH}}$$

Where:

DLR = Showerhead percentage of warm-up events

t_s = Shower time (mins/shower) (5.68)

n_S = Number of showers per day (0.69)

n_O = Number of occupants per home (2.37)

n_{SH} = Number of showerheads per home (1.62)

$\%_{HW}$ = Diverter water percentage (.669)

Applying the formula to the values used for New Orleans from Table 1-64 returns the following values:

Diverter (0.8 gpm): 0.8 x 5.68 x 0.69 x 365 x 2.37/1.62 x .737= 1,270 *gal*

Total water saved: To determine gallons of water saved per year can be found by adding the total waste from previous calculations:

$$Gallons\ Hot\ Water\ Saved = SHBW + TSBW + DW$$

Where:

$SHBW$ = Showerhead behavioral waste (see Table 1-65) (gal)

$TSBW$ = Tub spout behavioral waste (386 gal)

DW = Diverter waste (1,270 gal)

1.2.7.6 Deemed Savings Values

1.2.7.6.1 Energy Savings

$$Annual\ Energy\ Savings = \frac{\rho \times C_P \times V \times (T_{Setpoint} - T_{Supply}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor}$$

Where:

ρ = Water density = 8.33 lb/gal

C_P = Specific heat of water = 1 BTU/lb·°F

V = Total gallons of water saved per year (see steps 1 and 2)

$T_{Setpoint}$ = Water heater setpoint temperature (122.695°F)

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters[85].

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating

1.2.7.6.2 Demand Savings

Demand savings for homes with electric water heating were calculated using the following formula:

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kW}^{Peak\ kW}$$

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$

[85] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

The table below summarizes the deemed kWh and kW for TRVs installed on 2.5, 2.0, 1.75 and 1.5 gpm showerheads, using methods above.

Table 1-66 Deemed Savings for TRVs – Showerheads

Showerhead GPM Rating	Water Heater Type	kWh	kW
2.5 gpm	Electric Resistance	232	0.024
	Heat Pump	103	0.011
2.0 gpm	Electric Resistance	225	0.023
	Heat Pump	100	0.010
1.75 gpm	Electric Resistance	222	0.023
	Heat Pump	99	0.010
1.50 gpm	Electric Resistance	218	0.023
	Heat Pump	97	0.010

1.2.7.7 Incremental Cost

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $91.38 plus $20 labor if not available.

1.2.7.8 Future Studies

Metering studies for water use are exceedingly expensive. In past metering efforts, the TPE has found costs to exceed $750 per site. As such, we do not advise a metering study for this measure unless savings exceed 5% of residential program savings.

1.3 Heating, Ventilation & Air Conditioning

1.3.1 CENTRAL AIR CONDITIONER REPLACEMENT

1.3.1.1 Measure Description

This measure involves a residential retrofit with a new central air conditioning system or the installation of a new central air conditioning system in a residential new construction (packaged unit, or split system consisting of an indoor unit with a matching remote condensing unit). Maximum cooling capacity per unit is 65,000 Btu/hour. This measure applies to all residential applications.

1.3.1.2 Baseline and Efficiency Standards[86]

The Department of Energy (DOE) is changing the way HVAC systems are tested and modifying its rating system, replacing SEER, EER and HSPF ratings with SEER2, EER2 and HSPF2, respectively. All systems sold must meet new efficiency minimums using the new “M1” testing procedure which is designed to better reflect field conditions.

The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure, but the stipulated baseline is:

- $SEER2 = SEER \times 0.95$
- $EER2 = EER \times 0.95$

The new guidelines affect HVAC equipment manufactured prior to December 31, 2022 and installed in the Southwest region after January 1, 2023. EER ratings for the New Orleans region are subject to EER2 classification but required efficiency levels do not change.

For new construction (NC) and replace on burnout (ROB) projects, the cooling baseline is 14.3 SEER2 (15.0 SEER) for split systems and 13.4 SEER2 (14.0 SEER) for packaged systems, consistent with the current federal minimum standard .

For early retirement (ER) projects, the cooling baseline is reduced to 13.0 SEER (12.4 SEER2) for systems manufactured before January 1, 2015, and 14.0 (13.3 SEER2) for systems manufactured after. For ER HSPF baselines please see Table 1-67 below.

For Early Replacement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Air conditioning equipment shall be properly sized to the dwelling, based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed air conditioning equipment or the AHRI reference number must be provided to the utility. The installed central air conditioning equipment must be AHRI certified.

[86] https://www.federalregister.gov/documents/2022/03/30/2022-06450/energy-conservation-program-energy-conservation-standards-for-air-cooled-three-phase-small

Table 1-67 Central Air Conditioner – Baseline and Efficiency Levels

System Type	SEER	New SEER2	EER	New EER2
Split System AC (AC <45,000 Btu/h)	15.0	14.3	12.2 (< 15.2 SEER2)	11.7 (< 15.2 SEER2)
			10.2 (≥ 15.2 SEER2)	9.8 (≥ 15.2 SEER2)
Split System AC (AC ≥45,000 Btu/h)	14.5	13.8	12.2 (< 15.2 SEER2)	11.7 (< 15.2 SEER2)
			10.2 (≥ 15.2 SEER2)	9.8 (≥ 15.2 SEER2)
Single Packaged Units (ACs, Heat Pumps, Gas, Electric and Dual-Fuel HPs)	14.0	13.4	11.0	10.45

1.3.1.3 *Estimated Useful Life*

The EUL of this measure is 19 years according to the US DOE.[87]

1.3.1.4 *Deemed Savings Values*

Nameplate data should be used when collected. If not available, deemed savings values for NC and ROB are provided in Table 1-68 through Table 1-73 These values reflect the per-ton and per-dwelling averages from the PY5 through to-date PY9 program years. For systems where tonnage is unknown, deemed values have been provided based on 3.65 average capacity (TONs).

1.3.1.4.1 Split Systems

(i) Split Systems <45,000 Btu, or <3.75 TONs cooling

Table 1-68 Deemed kWh for Split Systems <45,000 Btu, or <3.75 TONs cooling

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
15 SEER2	64	234
16 SEER2	146	533
17 SEER2	218	796
18 SEER2	282	1,031
19 SEER2	340	1,240
20 SEER2	392	1,429

[87] U.S. DOE, 2011 Technical Support Document: “Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime.” June www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

Table 1-69 Deemed kW for Split Systems <45,000 Btu, or <3.75 TONs cooling

Efficiency	kW Saved per Ton	kW if Tonnage Unknown
12 EER2	0.020	0.07
13 EER2	0.079	0.29
14 EER2	0.130	0.47
15 EER2	0.174	0.63
16 EER2	0.212	0.77
17 EER2	0.246	0.90

(ii) Split Systems ≥45,000 Btu, or ≥3.75 TONs cooling

Table 1-70 Deemed kWh for Split Systems ≥45,000 Btu, or ≥3.75 TONs cooling

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
14 SEER2	20	74
15 SEER2	114	416
16 SEER2	196	714
17 SEER2	268	978
18 SEER2	332	1,212
19 SEER2	390	1,422
20 SEER2	441	1,611

Table 1-71 Deemed kW for Split Systems ≥45,000 Btu, or ≥3.75 TONs cooling

Efficiency	kW Saved per Ton	kW if Tonnage Unknown
10 EER2	0.019	0.07
11 EER2	0.103	0.38
12 EER2	0.173	0.63
13 EER2	0.232	0.85
14 EER2	0.283	1.03
15 EER2	0.327	1.19

(iii) Packaged Systems

Table 1-72 Deemed kWh for Packaged Systems

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
14 SEER2	63	229
15 SEER2	156	571
16 SEER2	238	870
17 SEER2	310	1,133
18 SEER2	375	1,367
19 SEER2	432	1,577
20 SEER2	484	1,766

Table 1-73 Deemed kW for Packaged Systems

Efficiency	kW Saved per Ton	kW if Tonnage Unknown
11 EER2	0.044	0.16
12 EER2	0.114	0.42
13 EER2	0.173	0.63
14 EER2	0.224	0.82
15 EER2	0.268	0.98
16 EER2	0.307	1.12
11 EER2	0.044	0.16

1.3.1.4.2 Deemed Savings Calculations

(i) Replace-on-Burnout

$$kWh_{Savings} = CAP_c \times \frac{1}{1{,}000} {}^{W}/_{kW} \times \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{Eff}}\right) \times EFLH_C$$

$$kW_{Savings} = CAP_c \times \frac{1}{1{,}000} {}^{W}/_{kW} \times \left(\frac{1}{EER2_{base}} - \frac{1}{EER2_{Eff}}\right) \times \%CF$$

Where,

CAP_c = Cooling capacity (in BTU)

$SEER2_{base}$ = Seasonal efficiency of baseline equipment (see Table 1-67)

$SEER2_{eff}$ = Seasonal efficiency of efficient equipment (see Table 1-67)

$EER2_{base}$ = Full-load efficiency of baseline equipment (see Table 1-67)

$EER2_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-67)

$EFLH_c$ = Equivalent Full-Load Cooling Hours

$\%CF$ = Peak Coincidence Factor

1.3.1.4.3 Equivalent Full-Load Hours

Equivalent Full-Load Cooling Hours (EFLHc) measures the total annual runtime of HVAC equipment. To support development of this value, the usage of 68 HVAC systems in New Orleans was metered. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans.

The resulting EFLHc is 1,637.

1.3.1.4.4 Peak Coincidence Factor

The Peak Coincidence Factor is defined as the percent time during the ENO peak period where the residential central air conditioner is operational. Peak hours were defined as:

- Weekdays
- Non-holidays
- 4:00-5:00 PM
- Average ambient temperature exceeding 90 degrees Fahrenheit.

The average central AC runtime during qualified hours was 77%. This peak coincidence factor is applied to calculate peak kW demand reductions from this measure.

1.3.1.4.5 Uncertainty Analysis

The uncertainties associated with the two key parameters collected in EM&V are as follows:

- EFLHc: ±7.81%
- % Coincidence: ±2.11%

1.3.1.5 Incremental Cost

The incremental cost of high central air conditioners is detailed in Table 1-74.

Table 1-74 High Efficiency Central AC Replacement Incremental Costs

Product Type	Incremental Cost Per Ton
16 SEER2	$119
17 SEER2	$238
18 SEER2	$358
19 SEER2	$477
20 SEER2	$596
21 SEER2	$670

1.3.2 WINDOW AIR CONDITIONER REPLACEMENT

1.3.2.1 Measure Description

This measure involves the replacement of a window air conditioner in a residential building.

1.3.2.2 Baseline and Efficiency Standards[88]

The baseline is a new air conditioning unit with a combined energy efficiency ratio (CEER) that meets federal standards established on June 1, 2014 .

Efficient units must meet ENERGY STAR standards, requiring 10% efficiency above federal minimum requirements.

Table 1-75 Window Air Conditioner – Baseline and Efficiency Levels

Reverse Cycle?	Louvered Sides?	Capacity	Baseline CEER	Efficient CEER	kWh	kW
No	Yes	< 8,000	11.0	12.1	46.4	0.0445
		≥ 8,000 and < 14,000	10.9	12.0	74.2	0.0453
		≥ 14,000 and < 20,000	10.7	11.8	118.8	0.0470
		≥ 20,000	9.4	10.3	171.5	0.0501
	No	< 8,000	10.0	11.0	51.0	0.0490
		≥ 8,000	9.6	10.6	78.8	0.0530
Yes	Yes	< 20,000	9.8	10.8	113.7	0.0509
		≥ 20,000	9.3	10.2	190.3	0.0511
	No	< 14,000	9.3	10.2	83.7	0.0511
		≥ 14,000	8.7	9.6	146.9	0.0581

1.3.2.3 Estimated Useful Life

According to the DOE's Technical Support Document, Chapter 8: Life Cycle Cost and Payback Period Analyses 2011, the EUL is 10.5 years.

1.3.2.4 Deemed Savings Values

1.3.2.4.1 Replace-on-Burnout

$$kWh_{Savings} = CAP_c \times \frac{1}{1{,}000} {}^{W}/_{kW} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{Eff}}\right) \times EFLH_C \times RAF$$

$$kW_{Savings} = CAP_c \times \frac{1}{1{,}000} {}^{W}/_{kW} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{Eff}}\right) \times \%CF$$

Where:

CAP_c = Cooling capacity (in BTU)

$CEER_{base}$ = Full-load efficiency of baseline equipment (see Table 1-75)

$CEER_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-75)

$CEER_{base}$ = Seasonal efficiency of baseline equipment (see Table 1-75)

$CEER_{eff}$ = Seasonal efficiency of efficient equipment (see Table 1-75)

EFLHc = Equivalent Full-Load Cooling Hours, 1,637

%CF = Peak Coincidence Factor, 77%

RAF = Room AC Adjustment Factor, .49

1.3.2.5 Equivalent Full-Load Hours

Equivalent Full-Load Cooling Hours (EFLHc) measures the total annual runtime of HVAC equipment. To support development of this value, the usage of 68 HVAC systems in New Orleans was metered. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans.

1.3.2.6 Peak Coincidence Factor

The Peak Coincidence Factor is defined as the percent time during the ENO peak period where the residential central air conditioner is operational. Peak hours were defined as:

- Weekdays
- Non-holidays
- 4:00-5:00 PM
- Average ambient temperature exceeding 90 degrees Fahrenheit.

The average central AC runtime during qualified hours was 77%. This peak coincidence factor is applied to calculate peak kW demand reductions from this measure.

1.3.2.7 Uncertainty Analysis

The uncertainties associated with the two key parameters collected in EM&V are as follows:

- EFLHc: ±7.81%
- % Coincidence: ±2.11%

1.3.2.8 Incremental Cost

The incremental cost of high central air conditioners is $50 .

1.3.2.9 Net-to-Gross Ratio

The NTGR for this measure is 62% .

1.3.3 ELECTRONICALLY COMMUTATED MOTORS ON FURNACE FANS

1.3.3.1 Measure Description

Electronically Commutated Motors (ECMs) are motors that provide the power to furnace blowers to circulate the heated air required for space conditioning. This measure focuses on ECMs installed on residential furnace fans and is not applicable for ECMs on separate air handling units. ECMs operate using a built-in inverter and magnetic rotor to vary the torque and/or air flow rate required by the HVAC system. These motors are able to maintain their high efficiency at a variety of operation points thus improving their desirability compared to baseline motors.

1.3.3.2 Baseline and Efficiency Standards

The baseline equipment for this measure is different depending on if the measure is retrofit or new construction. Two types of baseline equipment exist; Shaded-pole (SP) motors and permanent split capacitor (PSC) motors on residential furnaces.

1.3.3.2.1 Retrofit (Early Replacement)

The baseline equipment for retrofit is the existing motor type.

1.3.3.2.2 New Construction (Includes Major Remodel & ROB)

The baseline equipment for new construction is a PSC motor.

1.3.3.3 Deemed Savings Values

The algorithms below are to be used to calculate electric energy and demand reductions for this measure:

$$kWh_{savings} = \left(\frac{hp_{base}}{Eff_{base}} - \frac{hp_{ECM}}{Eff_{ECM}}\right) \times 0.746 \times EFLH_h \times y$$

$$kW_{savings} = \left(\frac{hp_{base}}{Eff_{base}} - \frac{hp_{ECM}}{Eff_{ECM}}\right) \times 0.746 \times CF$$

Where:

hp_{base} = Rated horsepower of baseline motor, hp

hp_{ECM} = Rated horsepower of installed ECM, hp

Eff_{pre} = Efficiency of baseline motor as found in Table 1-76Table 1-76 Furnace Fan Efficiency Valuesthe table below, %

Eff_{ECM} = Efficiency of ECM as found in Table 1-76 below, %

$EFLH_h$ = Equivalent full load hours of heating, 1,118

Y = Ratio of fan motor on to burner on as calculated below,

CF = Coincidence Factor, 0.71

The ratio of blower on time to furnace burner on time can be taken as 1.39 based on DOE estimated values or calculated based on the DOE furnace test procedure shown below[89] if the relevant parameters are known.

$$y = \frac{t^{+} - t^{-}}{t_{ON}}$$

[89] U.S. Department of Energy (2014, June). TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: RESIDENTIAL FURNACE FANS.

Where:

t^{+} = off-period between burner shutdown and blower shutdown (blower off delay), min

t^{-} = on-period between burner shutdown and blower shutdown (blower off delay), min

t_{ON} = average burner on-time, min

1.3.3.3.1 Calculation Variables

Typical motor efficiency values were obtained for HVAC applications from a DOE report and can be found below. The original report provided a range; however, the median value of the range was extracted for use in calculating savings.

Table 1-76 Furnace Fan Efficiency Values

Motor Type	Efficiency (%)
Shaded-Pole	30
Permanent Split Capacitor	60
Electronically Commutated	75

1.3.3.4 Estimated Useful Life

The EUL of this measure is 15 years[90].

1.3.3.5 Incremental Cost

Actual material and labor costs should be used when available. When not available, the incremental cost of this measure should be $475 .

1.3.3.6 Future Studies

There are no future studies planned for this measures at this time.

[90] DEER 2008

1.3.4 HEAT PUMP REPLACEMENT

1.3.4.1 Measure Description

This measure involves a residential retrofit with a new heat pump system or the installation of a new heat pump system in a residential new construction (packaged unit, or split system consisting of an indoor unit with a matching remote condensing unit). Maximum cooling capacity per unit is 65,000 BTU/hour. This measure applies to all residential applications.

1.3.4.2 Baseline and Efficiency Standards[91]

The DOE is changing the way HVAC systems are tested and modifying its rating system, replacing SEER, EER and HSPF ratings with SEER2, EER2 and HSPF2, respectively. All systems sold must meet new efficiency minimums using the new "M1" testing procedure which is designed to better reflect field conditions.

The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure, but the stipulated baseline is:

- $SEER2 = SEER \times 0.95$
- $HSPF2 = HSPF \times 0.85$

The new guidelines affect system heat pump (HP) equipment manufactured prior to December 31, 2022 and installed in the Southwest region after January 1, 2023. Further, SEER/SEER2 and HSPF/HSPF2 requirements have been increased. EER ratings for the New Orleans region are subject to EER2 classification but required efficiency levels do not change.

For new construction (NC) and replace on burnout (ROB) projects, the cooling baseline is 14.3 SEER2 (15.0 SEER) and 7.5 HSPF2 (8.8 HSPF) for split systems, and 13.4 SEER2 (14.0 SEER) and 6.7 HSPF2 (8.0 HSPF) for packaged systems, consistent with the current federal minimum standard .

For early retirement (ER) projects, the cooling baseline is reduced to 13.0 SEER (12.4 SEER2) for systems manufactured before January 1, 2015, and 14.0 (13.3 SEER2) for systems manufactured after. For ER HSPF baselines please see Table 1-77 below.

For Early Replacement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Heat Pump equipment shall be properly sized to the dwelling, based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed air conditioning equipment or the AHRI reference number must be provided to the utility. The installed central air conditioning equipment must be AHRI certified.

[91] https://www.federalregister.gov/documents/2022/03/30/2022-06450/energy-conservation-program-energy-conservation-standards-for-air-cooled-three-phase-small

Table 1-77 Heat Pump – Baseline and Efficiency Levels

Characterization	System Type	SEER	New SEER2	HSPF	New HSPF2
New Construction and Normal Replacement	Split	15.0	14.3	8.8	7.5
	Packaged	14.0	13.4	8.0	6.7
Early Retirement (< Jan 1, 2015)	Both	13.0	12.4	7.7	6.6
Early Retirement (≥ Jan 1, 2015)	Split	14.0	13.3	8.2	7.0
	Packaged[92]			8.0	6.8

The heating baseline for early retirement of an electric resistance furnace is 3.41 HSPF.

1.3.4.3 Estimated Useful Life

The EUL of this measure is 16 years, according to the US DOE.[93]

1.3.4.4 Deemed Savings Values

Nameplate data should be used when collected. If not available, deemed savings values for NC and ROB are provided in Table 1-78 through Table 1-83. These values reflect the per-ton and per-dwelling averages from the PY5 through to-date PY9 program years. For systems where tonnage is unknown, deemed values have been provided based on 3.01 average capacity (TONs). The baseline EER2 used is 10.45.

1.3.4.4.1 Deemed kWh and kW for Package Systems

Table 1-78 Deemed Cooling kWh Savings for Packaged Systems

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
14 SEER2	63	189
15 SEER2	156	470
16 SEER2	238	716
17 SEER2	310	933
18 SEER2	375	1,126
19 SEER2	432	1,299
20 SEER2	484	1,455

Table 1-79 Deemed Heating kWh Savings for Packaged Systems

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
7 HSPF2	46	138
8 HSPF2	175	525
9 HSPF2	275	826
10 HSPF2	355	1,066

[92] ACs, Heat Pumps, Gas, Electric and Duel-Fuel HPs

[93] US U.S. DOE, 2011. *Technical Support Document: "Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime*". June. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

11 HSPF2	420	1,263
12 HSPF2	475	1,427
13 HSPF2	521	1,566

1.3.4.4.2 Deemed kWh and kW for Split Systems

Table 1-80 Deemed Cooling kWh Savings for Split Systems

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
15 SEER2	64	193
16 SEER2	146	439
17 SEER2	218	656
18 SEER2	282	849
19 SEER2	340	1,022
20 SEER2	392	1,177
21 SEER2	438	1,318

Table 1-81 Deemed Heating kWh Savings for Split Systems

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
8 HSPF2	60	180
9 HSPF2	160	481
10 HSPF2	240	722
11 HSPF2	305	918
12 HSPF2	360	1,082
13 HSPF2	406	1,221
14 HSPF2	446	1,340

1.3.4.4.3 Deemed kWh for Electric Resistance to Heat Pump Conversion

Table 1-82 Deemed Cooling kWh Savings for Electric Resistance to Heat Pump Conversion[94]

Efficiency	kWh Saved per Ton	kWh if Tonnage Unknown
4 HSPF2	206	618
5 HSPF2	443	1,332
6 HSPF2	602	1,809
7 HSPF2	715	2,149
8 HSPF2	800	2,404
9 HSPF2	866	2,602
10 HSPF2	918	2,761
11 HSPF2	962	2,891
12 HSPF2	998	2,999
13 HSPF2	1,028	3,091
14 HSPF2	1,054	3,169

[94] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

1.3.4.4.4 Deemed kW Reductions

Table 1-83 Deemed kW Savings for Split Systems

Efficiency	kW Saved per Ton	kW if Tonnage Unknown
12 EER2	0.11	0.34
13 EER2	0.17	0.52
14 EER2	0.22	0.67
15 EER2	0.27	0.81
16 EER2	0.31	0.92
17 EER2	0.34	1.02
18 EER2	0.37	1.12

1.3.4.4.5 Replace-on-Burnout

(i) Cooling Savings

$$kWh_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{Eff}}\right) \times EFLH_C$$

$$kW_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER2_{base}} - \frac{1}{EER2_{Eff}}\right) \times \%CF$$

Where:

CAP_c = Cooling capacity (in BTU)

$EER2_{base}$ = Full-load efficiency of baseline equipment (see Table 1-77)

$EER2_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-77)

$SEER2_{base}$ = Seasonal efficiency of baseline equipment (see Table 1-77)

$SEER2_{eff}$ = Seasonal efficiency of efficient equipment (see Table 1-77)

EFLHc = Equivalent Full-Load Cooling Hours

%CF = Peak Coincidence Factor

(ii) Heating Energy Savings

Heating savings are calculated with the following formula:

$$kWh_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{HSPF2_{base}} - \frac{1}{HSPF2_{Eff}}\right) \times EFLH_h$$

Where:

CAP_c = Cooling capacity (in BTU)

$EER2_{base}$ = Full-load efficiency of baseline equipment (see Table 1-77)

$EER2_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-77)

$HSPF2_{base}$ = Heating Season Performance Factor of baseline equipment (see Table 1-77)

$HSPF2_{eff}$ = Heating Season Performance Factor of efficient equipment (see Table 1-77)

$EFLH_h$ = Equivalent Full-Load Heating Hours, 600

%CF = Peak Coincidence Factor

(iii) Derivation of Equivalent Full-Load Hours and Peak Coincidence Factor

(iv) Cooling Hours

Equivalent Full-Load Cooling Hours (EFLHc) measures the total annual runtime of HVAC equipment. To support development of this value, the usage of 68 HVAC systems in New Orleans was metered over the course of three years. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans.

The resulting EFLHc is 1,637.

(v) Peak Coincidence Factor

The Peak Coincidence Factor is defined as the percent time during the ENO peak period where the residential central air conditioner is operational. Peak hours were defined as:

- Weekdays
- Non-holidays
- 4:00-5:00 PM
- Average ambient temperature exceeding 90 degrees Fahrenheit.

The average central AC runtime during qualified hours was 77%. This peak coincidence factor is applied to calculate peak kW demand reductions from this measure.

(vi) Heating Hours

Equivalent Full-Load Heating Hours ($EFLH_h$) measures the total annual runtime of heating equipment. To support development of this value, the usage of 295 electric heating systems in New Orleans was estimated using a billing analysis. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans. In addition, the $EFLH_h$ was multiplied by a scaling factor of 1.51 to account for differences in usage for heat pump vs. electric resistance heating types.

The heat pump scaling factor was calculated using the following equation:

$$Scaling\ Factor_{HP} = ((\frac{\frac{kWh}{HDD}}{Ton}_{HP}) * COP_{HP})/((\frac{\frac{kWh}{HDD}}{Ton}_{ER}) * COP_{ER})$$

Where:

$kWh/HDD/Ton_{HP}$= Weighted average of predicted kWh/HDD/Ton for heat pump heating types for single and multi-family homes = 0.3282

$kWh/HDD/Ton_{ER}$= Weighted average of predicted kWh/HDD/Ton for electric resistance heating types for single and multi-family homes = 0.4348

COP_{HP} = Coefficient of performance for heat pumps = 2.0

COP_{HP} = Coefficient of performance for electric resistance = 1.0

The resulting $EFLH_H$ for Electric Resistance systems 396.

The resulting $EFLH_H$ for Heat Pumps is 600.

(vii) Uncertainty Analysis

The uncertainties associated with the four key parameters collected in EM&V are as follows:

- EFLHc: ±5.10%
- % Coincidence: ±2.11%
- EFLHh: Electric Resistance ±5.10%
- EFLHh: Heat Pumps ±37.10%

1.3.4.5 Incremental Cost

The incremental cost of high efficiency heat pump is detailed in Table 1-84 .

Table 1-84 Replacement Incremental Costs (HP Baseline)

Efficiency	Incremental Cost Per Ton
15 SEER2	$184
16 SEER2	$319
17 SEER2	$605
18 SEER2	$605

The incremental costs of retiring an electric resistance heating system early and replacing it with a high efficiency heat pump are detailed in the Table 1-85 table below.

Table 1-85 Replacement Incremental Costs (ER Baseline)

Efficiency	Incremental Cost Per Ton
15 SEER2	$1,605
16 SEER2	$1,740
17 SEER2	$2,026
18 SEER2	$2,026

1.3.4.6 Future Studies

There are no future studies planned for this measure at this time.

1.3.5 GROUND SOURCE HEAT PUMP REPLACEMENT

1.3.5.1 Measure Description

This measure involves the installation of water-to-air ground source heat pump as a replacement for an existing air-source heat pump. Maximum cooling capacity per unit is 65,000 BTU/hour. This measure applies to all residential applications.

1.3.5.2 Baseline and Efficiency Standards[95]

The Department of Energy (DOE) is changing the way HVAC systems are tested and modifying its rating system, replacing SEER, EER and HSPF ratings with SEER2, EER2 and HSPF2, respectively. All systems sold must meet new efficiency minimums using the new "M1" testing procedure[96] which is designed to better reflect field conditions.

The new guidelines affect system heat pump (HP) equipment manufactured prior to December 31, 2022 and installed in the Southwest region after January 1, 2023. Further, SEER/SEER2 and HSPF/HSPF2 requirements have been increased. EER ratings for the New Orleans region are subject to EER2 classification but required efficiency levels do not change.

For new construction (NC) and replace on burnout (ROB) projects, the cooling baseline is 14.3 SEER2 (15.0 SEER) and 7.5 HSPF2 (8.8 HSPF) for split systems, and 13.4 SEER2 (14.0 SEER) and 6.7 HSPF2 (8.0 HSPF) for packaged systems, consistent with the current federal minimum standard .

Due to the high cost of this equipment, all projects are assumed to be replacement on burnout or new construction.

Heat Pump equipment shall be properly sized to the dwelling, based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed air conditioning equipment or the AHRI reference number must be provided to the utility. The installed central air conditioning equipment must be AHRI certified.

Table 1-86 Heat Pump – Baseline and Efficiency Levels

	SEER2	EER2	HSPF2
New Construction and Normal Replacement	14.3	11.7 (< 15.2 SEER2) 9.8 (≥ 15.2 SEER2)	7.5 (split) 6.7 (packaged)
ENERGY STAR Criteria – Water-to-Air[97]		Closed Loop: 16.2	Closed Loop: 10.3
		Open Loop: 20.0	Open Loop: 11.8
ENERGY STAR Criteria – Water-to-Water		Closed Loop: 15.3	Closed Loop: 8.9
		Open Loop: 19.1	Open Loop: 10.0
		DGX: 15.2	DGX: 10.3

[96] https://www.energy.gov/sites/prod/files/2016/08/f33/Central%20Air%20Conditioners%20and%20Heat%20Pumps%20TP%20SNOPR_4.pdf

[97] EER and COP values given by the ENERGY STAR website have been converted into EER2 and HSPF2 vales for this table.

1.3.5.3 Estimated Useful Life

The EUL of this measure is 25 years, according to the US DOE.[98]

1.3.5.4 Calculation of Deemed Savings

1.3.5.4.1 Replace-on-Burnout

(i) Cooling Savings

$$kWh_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{Eff}}\right) \times EFLH_C$$

$$kW_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER2_{base}} - \frac{1}{EER2_{Eff}}\right) \times \%CF$$

Where:

CAP_c = Cooling capacity (in BTU)

$EER2_{base}$ = Full-load efficiency of baseline equipment (see Table 1-86)

$EER2_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-86)

$SEER2_{base}$ = Seasonal efficiency of baseline equipment (see Table 1-86)

$SEER2_{eff}$ = Seasonal efficiency of efficient equipment (see Table 1-86)

EFLHc = Equivalent Full-Load Cooling Hours

%CF = Peak Coincidence Factor

(ii) Heating Energy Savings

Heating savings are calculated with the following formula:

$$kWh_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{HSPF2_{base}} - \frac{1}{HSPF2_{Eff}}\right) \times EFLH_h$$

Where:

CAP_c = Cooling capacity (in BTU)

$EER2_{base}$ = Full-load efficiency of baseline equipment (see Table 1-86)

$EER2_{eff}$ = Full-load efficiency of baseline equipment (see Table 1-86)

$HSPF2_{base}$ = Heating Season Performance Factor of baseline equipment (see Table 1-86)

$HSPF2_{eff}$ = Heating Season Performance Factor of efficient equipment (see Table 1-86)

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[98] Source DOE Energy Savers website: www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640 .

$EFLH_h$ = Equivalent Full-Load Heating Hours, 600

%CF = Peak Coincidence Factor

1.3.5.5 Incremental Cost

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3838 per ton[99]), minus the assumed installation cost of the baseline equipment ($1,262 per ton for ASHP[100] or $2,011 for a new baseline 80% AFUE furnace or $3,424 for a new 82% AFUE boiler[101] and $833 per ton[102] for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,399 per ton for a new baseline Air Source Heat Pump, or $2,784 for a new baseline 90% AFUE furnace or $3,926 for a new 82% AFUE boiler and 928 per ton for new baseline Central AC replacement[103]. This future cost should be discounted to present value using the nominal societal discount rate.

1.3.5.6 Future Studies

There are not future studies planned for this measures at this time.

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[99] Based on data provided in 'Results of Home geothermal and air source heat pump rebate incentives documented by IL electric cooperatives.

[100] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

[101] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor.

[102] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.

[103] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

1.3.6 DUCTLESS HEAT PUMP

1.3.6.1 Measure Description

This measure involves the installation of ductless mini-split heat pumps (DMSHP). These systems have increased savings over efficient air source heat pumps as they use less fan energy to move heat and cooled air and don't incur distribution losses.

1.3.6.2 Baseline and Efficiency Standards

For new construction (NC) and ROB projects, the cooling baseline is 14 SEER and 8.0 HSPF, consistent with the current federal minimum standard . Due to the high cost of this equipment, all projects are assumed to be replacement on burnout or new construction.

A DMSHP must be a high-efficiency, variable-capacity system that exceeds program minimum efficiency requirements. Qualified systems will typically have an inverter-driven DC motor.

Heat Pump equipment shall be properly sized to the dwelling, based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed air conditioning equipment or the AHRI reference number must be provided to the utility. The installed central air conditioning equipment must be AHRI certified.

Table 1-87 Heat Pump – Baseline and Efficiency Levels

Replacement Type	SEER	New SEER2	HSPF	New HSPF2
New Construction and Replace on Burnout	15.0	14.3	8.8	7.5
Early Retirement	14.0	13.3	8.2	7.0

1.3.6.3 Estimated Useful Life

The EUL of this measure is 18 years.[104]

1.3.6.4 Deemed Savings Values

Savings are calculated in the same manner as for Heat Pump Replacement. See Section 1.3.4.4.4. According to the current AHRI database , the average efficiency of ENERGY STAR-rated ductless units that are currently in production is as follows:

- SEER: 21.17
- EER: 12.79
- HSPF: 10.43

The average capacity of these units is 2.28 tons.

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

The resulting average unit energy savings for a ductless mini-split are detailed in the Table 1-88 below. This is per-unit installed in a residence; a retrofit may constitute installation of multiple units, and if so, the calculation is performed separately for each and the savings added.

Table 1-88 Ductless Mini-Split Average Savings

	kWh Per Ton	kW per Ton	Average Tons	kWh per Unit	kW per Unit
New Construction and Normal Replacement	598	0.064	3.01	1,801	0.19

1.3.6.5 Incremental Cost

New Construction and Time of Sale: The actual installed cost of the DMSHP should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP[105] or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler[106] and $952 per ton[107] for new baseline Central AC replacement).

Default full cost of the DMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be applied .

Table 1-89 Ductless Mini-Split Full Installed Cost

Efficiency (HSPF2)	Full Install Cost ($/ton)
8-8.9	$1,443
9-9.9	$1,605
10-10.9	$1,715
12+	$2,041

The incremental cost of the DSMHP compared to a baseline minimum efficiency DSMHP is provided in the Table 1-90 below .

Table 1-90 Ductless Mini-Split Incremental Cost

Efficiency (HSPF2)	Incremental Cost ($/ton) over HSPF 8.0 DHP
8-8.9	$62
9-9.9	$224
10-10.9	$334
12+	$660

Early Replacement/retrofit (replacing existing equipment): The full installation cost of the DMSHP should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat

[105] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

[106] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.

[107] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator

Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and $1,047 per ton for new baseline Central AC replacement . If replacing electric resistance heat, there is no deferred replacement cost. This future cost should be discounted to present value using the nominal societal discount rate.

Where the DMSHP is a supplemental HVAC system, the full installation cost of the DMSHP should be used (default provided above) without a deferred replacement cost.

1.3.6.6 Future Studies

The baseline for ductless systems may vary widely. Program implementers and the TPE should coordinate to ensure collection of baseline data for these projects.

1.3.7 CENTRAL AC AND HEAT PUMP TUNE-UP

1.3.7.1 Measure Description

This measure applies to central air conditioners and heat pumps. An AC tune-up, in general terms, involves checking, adjusting, and resetting the equipment to factory conditions, such that it operates closer to the performance level of a new unit. This measure applies to all residential applications.

For this measure, the service technician must complete the following tasks according to industry best practices:

- Air Conditioner Inspection and Tune-Up Checklist[108]
- Inspect and clean condenser, evaporator coils, and blower.
- Inspect refrigerant level and adjust to manufacturer specifications.
- Measure the static pressure across the cooling coil to verify adequate system airflow and adjust to manufacturer specifications.
- Inspect, clean, or change air filters.
- Calibrate thermostat on/off set points based on building occupancy.
- Tighten all electrical connections, and measure voltage and current on motors.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the starting cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Provide documentation showing completion of the above checklist to the utility or the utility's representative.

1.3.7.2 Baseline and Efficiency Standards

The baseline is a system with demonstrated imbalances of refrigerant charge.

After the tune-up, the equipment must meet airflow and refrigerant charge requirements. To ensure the greatest savings when conducting tune-up services, the eligibility minimum requirement for airflow is the manufacturer specified design flow rate, or 350 CFM/ton, if unknown. Also, the refrigerant charge

[108] Based on ENERGY STAR HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance

must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or a capillary.

The efficiency standard, or efficiency after the tune-up, is assumed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump. The efficiency improvement resulting from the refrigerant charge adjustment depends on the pre-adjustment refrigerant charge.

1.3.7.3 Estimated Useful Life

The EUL for a full tune-up with refrigerant change is 10 years . If no refrigerant charge adjustment is made, the EUL is 3 years .

1.3.7.4 Deemed Savings Values

The methodologies in this chapter detail the approach program staff should take to capture data needed to calculate savings from AC tune-ups. However, this data may not always be readily available or measurable. The values in Table 1-91 and Table 1-92 reflect the per-ton and per-unit averages from the PY5 through to-date PY9 program years and should be used when test data cannot be collected. HSPF and EER gains used in deemed calculations were derived from the same data.

Table 1-91 AC Tune-Up Deemed Savings by Capacity

System Type	kWh/Ton	kW/Ton
Central AC	283.3	0.133
Central HP	603.2	0.133

Table 1-92 AC Tune-Up Deemed Savings by Dwelling

System Type	Average Single Family Capacity (Tons)	kWh/SF Dwelling	kW/SF Dwelling	Average Multifamily Capacity (Tons)	kWh/MF Dwelling	kW/MF Dwelling
Central AC	3.28	929.1	0.437	2.46	696.8	0.328
Central HP	3.28	1,978.4	0.437	2.46	1,483.8	0.328

1.3.7.4.1 Partial Deemed Savings Based on Tune Up Component

Partial savings may be claimed if the tune-up does not require all components. These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed.

Partial savings may be claimed if the tune-up does not require all components (e.g. a coil cleaning is required by a refrigerant charge is not). These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed. See Table 1-93 below for percentage savings that can be claimed. See Table 1-94 and Table 1-95 for per-residence deemed savings values by component, followed by an example.

Table 1-93 Savings by Component[109]

Tune-Up Component	% Savings
Condenser Cleaning	6.10%
Evaporator Cleaning	0.22%
Refrigerant Charge Off. ≤ 20%	0.68%
Refrigerant Charge Off. > 20%	8.44%
Combined (Refrigerant Off. ≤ 20%)	7.00%
Combined (Refrigerant Off.> 20%)	14.76%

Table 1-94 Deemed Savings by Component[110] for Single Family

Tune-Up Component	Central AC		Heat Pump	
	kWh/Dwelling	kW/Dwelling	kWh/Dwelling	kW/Dwelling
Condenser Cleaning	56.7	0.027	120.7	0.027
Evaporator Cleaning	2.0	0.001	4.4	0.001
Refrigerant Charge Off. ≤ 20%	6.3	0.003	13.5	0.003
Refrigerant Charge Off. > 20%	78.4	0.037	166.9	0.037
Combined (Refrigerant Off. ≤ 20%)	65.0	0.031	138.5	0.031
Combined (Refrigerant Off.> 20%)	137.1	0.065	292.0	0.065

Table 1-95 Deemed Savings by Component for Multifamily[111]

Tune-Up Component	Central AC		Heat Pump	
	kWh/Dwelling	kW/Dwelling	kWh/Dwelling	kW/Dwelling
Condenser Cleaning	42.5	0.020	90.5	0.020
Evaporator Cleaning	1.5	0.001	3.3	0.001
Refrigerant Charge Off. ≤ 20%	4.7	0.002	10.1	0.002
Refrigerant Charge Off. > 20%	58.8	0.028	125.2	0.028
Combined (Refrigerant Off. ≤ 20%)	48.8	0.023	103.9	0.023
Combined (Refrigerant Off.> 20%)	102.9	0.048	219.0	0.048

Example: A central AC at a single family dwelling only requires a condenser cleaning and evaporator cleaning as service. Using Table 1-94 above, we see these components provide 56.7 kWh and 2.0 kWh of savings, respectively. A total savings of 58.7 kWh and 0.028 kW can be claimed for this project.

[109] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

[110] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

[111] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

1.3.7.4.2 Deemed Savings Calculations

There are two ways in which deemed savings can be calculated for this measure:

- Test-in and test-out efficiency; or
- Application of a stipulated reduction in annual use.

(i) Test-in and Test-out Efficiency

$$kWh_{Savings\_Cooling} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times EFLH_C \; kWh_{Savings\_Heating} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times EFLH_H \; kW_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times \%CF$$

$$kWh_{Central\ AC} = kWh_{Savings\_Cooling} \; kWh_{Heat\ Pumps} = kWh_{Savings\_Cooling} + kWh_{Savings\_Heating}$$

Where:

CAP_c = Cooling capacity (in BTU)

EER_{pre} = Efficiency of the equipment prior to tune-up

EER_{post}= Nameplate efficiency of the existing equipment

EFLHc = Equivalent Full-Load Cooling Hours = 1,637

EFLHh = Equivalent Full-Load Heating Hours = 600

$HSPF_{pre}$ = Measured efficiency of the heating equipment before tune-up

$HSPF_{post}$ = Measured efficiency of the heating equipment after tune-up

%CF = Peak Coincidence Factor

(ii) Baseline Efficiency

Baseline efficiency is calculated as:

$$EER_{pre} = (1 - EL) \times EER_{post}$$

EL is the Efficiency Loss based on the current refrigerant charge level. The EL values are summarized in Table 1-96 and Table 1-97.

Table 1-96 Efficiency Loss by Refrigerant Charge Level (Fixed Orifice)

% Charged	EL
≤70	.37
75	.29
80	.20
85	.15

90	.10
95	.05
100	0
≥120	.03

Table 1-97 Efficiency Loss by Refrigerant Charge Level (TXV)

% Charged	EL
≤70	.12
75	.09
80	.07
85	.06
90	.05
95	.03
100	.00
≥120	.04

(iii) Equivalent Full-Load Hours

Equivalent Full-Load Cooling Hours (EFLHc) measures the total annual runtime of HVAC equipment. To support development of this value, the usage of 68 HVAC systems in New Orleans was metered. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans.

The resulting EFLHc is 1,637.

Equivalent Full-Load Heating Hours ($EFLH_h$) measures the total annual runtime of heating equipment. To support development of this value, the usage of 295 electric heating systems in New Orleans was estimated using a billing analysis. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans. In addition, the $EFLH_h$ was multiplied by a scaling factor of 1.51 to account for differences in usage for heat pump vs. electric resistance heating types.

The heat pump scaling factor was calculated using the following equation:

$$Scaling\ Factor_{HP} = ((\frac{\frac{kWh}{HDD}}{Ton}_{HP}) * COP_{HP})/((\frac{\frac{kWh}{HDD}}{Ton}_{ER}) * COP_{ER})$$

Where:

kWh/HDD/Ton$_{HP}$= Weighted average of predicted kWh/HDD/Ton for heat pump heating types for single and multi-family homes = 0.3282

kWh/HDD/Ton$_{ER}$= Weighted average of predicted kWh/HDD/Ton for electric resistance heating types for single and multi-family homes = 0.4348

COP_{HP} = Coefficient of performance for heat pumps = 2.0

COP_{HP} = Coefficient of performance for electric resistance = 1.0

(iv) Peak Coincidence Factor

The Peak Coincidence Factor is defined as the percent time during the ENO peak period where the residential central air conditioner is operational. Peak hours were defined as:

- Weekdays
- Non-holidays
- 4:00-5:00 PM
- Average ambient temperature exceeding 90 degrees Fahrenheit.

The average central AC runtime during qualified hours was 77%. This peak coincidence factor is applied to calculate peak kW demand reductions from this measure.

(v) % Off Annual Use

Alternatively, program administrators may elect to claim savings based off of a percent reduction in annual use.

$$kWh_{Savings} = CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER_{pre}}\right) \times EFLH_C \times \%Reduction\ kWh_{Savings} =$$

$$CAP_c \times 1kW/1{,}000W \times \left(\frac{1}{EER_{pre}}\right) \times EFLH_C \times \%Reduction\ kW_{Savings} = CAP_c \times 1kW/1{,}000W \times$$

$$\left(\frac{1}{EER_{pre}}\right) \times \%CF\%Reduction$$

In this, EERpre is assumed to be 10.164 . Percent reduction is 17.2%. This value is derived with PY7 through PY9 Residential Heating & Cooling Program data.

$$kWh_{Central\ AC} = kWh_{Savings\_Cooling}\ kWh_{Heat\ Pumps} = kWh_{Savings\_Cooling} +\ kWh_{Savings\_Heating}$$

Partial savings may also be claimed by applying values in Table 1-93.

(vi) Uncertainty Analysis

The uncertainties associated with the two key parameters collected in EM&V are as follows:

- EFLHc: ±7.81%
- EFLHh: Heat Pumps ±37.10%
- % Coincidence: ±2.11%

1.3.7.5 Incremental cost

The incremental cost of an AC Tune-Up is $175 .

1.3.7.6 Net-to-Gross

The NTG for this measure is 82% .

1.3.7.7 Future Studies

The incremental cost value is very sensitive to labor costs, and as such a New Orleans-specific cost study should be conducted to revise this value.

1.3.8 DUCT SEALING

1.3.8.1 Measure Description

This measure is comprised of performing duct sealing using mastic sealant or metal tape to the distribution system of homes with a central air conditioning system. Materials should be long-lasting materials such as UL 181A or UL 181 B-approved foil tape. Fabric-based duct tape is not allowed.

In calculating savings for this measure, program administrators are to use the leakage-to-unconditioned space metric, entailing a blower-door subtraction test method. this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website .

1.3.8.2 Baseline and Efficiency Standards

The baseline for this measure is unsealed ductwork, with a maximum pre-installation leakage rate of 40% of total fan flow . This cap is imposed because interior temperature in homes that exceed 40 percent total leakage would be above the thermally acceptable comfort levels published by ASHRAE in its 2009 Fundamentals publication. Historically, homeowners would remedy a situation in such a state of disrepair, and out of concern for the validity of baseline test measurements performed by duct sealing contractors and to ensure that the savings are program attributable, program administrators must cap baseline leakage at 40% of fan flow and report the extent to which contractors' baseline leakage measurements exceed this fan flow.

1.3.8.3 Estimated Useful Life

According to DEER 2014, the EUL for duct sealing is 18 years.

1.3.8.4 Deemed Savings Values

The methodologies in this chapter detail the approach program staff should take to capture data needed to calculate savings from duct sealing. However, this data may not always be readily available or measurable. The average leakage values in Table 1-98 and Table 1-99 reflect the average per-home leakage reductions from 5,163 residential single and multifamily duct sealing projects, spanning PY5 though PY9 with correction factors resulting from on-site testing applied . Additional deemed inputs which have been created from program data averages and used in savings calculations are detailed in Section 1.3.8.4.1, *Cooling Savings* below.

Table 1-98 Duct Sealing Deemed Savings Values – Single Family

System Type	Average Leakage Reduction[112]	kWh	kW
AC with Gas Heat	471	2,465	1.159
Heat Pump	471	2,879	1.159
AC with Electric Resistance Heat	471	4,106	1.159
Electric Resistance Heat, no AC	471	1,641	0.000

Table 1-99 Duct Sealing Deemed Savings Values – Multifamily

System Type	Average Leakage Reduction[113]	kWh	kW
AC with Gas Heat	443	2,317	1.090
Heat Pump	443	2,707	1.090
AC with Electric Resistance Heat	443	3,860	1.090
Electric Resistance Heat, no AC	443	1,543	0.000

The following formulas shall be used to calculate deemed savings for duct sealing.

1.3.8.4.1 Cooling Savings

$$kWh_{cooling} = \frac{\left(DL_{pre} - DL_{post}\right) \times EFLH_c \times (h_{out}\rho_{ou} \quad h_{in}\rho_{in}) \times 60}{1000 \times SEER}$$

Where:

DL_{pre} = Pre-measurement of leakage to unconditioned space

DL_{post} = Post-measurement of leakage to unconditioned space

[112] Based on average results from 4,939 SF participants over PY5-9.

[113] Based on average results from 325 MF participants over PY5-9.

$EFLH_c$ = Equivalent Full Load Cooling Hours, 1,637, based on the TPE's metering of New Orleans homes

H_{out} = Outdoor design enthalpy, 40 BTU/lb.

H_{in} = Indoor design enthalpy, 30 BTU/lb.

P_{out} = Density of outdoor air at 95 deg. F, .0740 lb./ft.^{3}

P_{in} = Density of outdoor air at 95 deg. F, .0756 lb./ft.^{3}

SEER = Seasonal Efficiency Rating of existing systems (BTU/W*hr.). Default of 13

1,000 = W/kW conversion factor

60 = Minutes/hour conversion factor

The default of 13 SEER is based on the inspection of 182 program participants in Home Performance with ENERGY STAR and Assisted Home Performance with ENRGY STAR. These 182 participants had 135 unique model numbers, with an average SEER of 12.98. The minimum code prior to 2015 was 13 SEER and given how close the mean value is to that code value, we recommend a default SEER of 13.

1.3.8.4.2 Heating Savings (Heat Pump)

Heating savings are calculated as:

$$kWh_{Heating,Heat\ Pump} = \frac{\left(DL_{pre} - DL_{post}\right)/((CAP/12{,}000) * 400) * EFLH_h * CAP * TRFheat}{\eta\text{Heat} \ / \ 3{,}412}$$

Where:

DL_{pre} = Pre-measurement of leakage to unconditioned space

DL_{post} = Post-measurement of leakage to unconditioned space

CAP = Heating output capacity (Btuh) of electric heat = Actual. Use 72,829 Btu/hr if CAP unavailable.

12,000 = Btu/ton conversion factor

400 = CFM/ton conversion factor

$EFLH_h$ = Equivalent full load heating hours of heat pumps = 600

TRFheat = Thermal Regain Factor for heating by space type = 1.0 for Unconditioned Spaces = 0.40 for Semi-Conditioned Spaces

ηHeat = Efficiency in COP of Heating equipment = Actual. If unavailable, use 2.40.

3,412 = Conversion of BTU/kWh.

The default CAP of 72,829 is based on average capacity found for 2,022 residential customers who participated in a residential program PY5-PY9.

1.3.8.4.3 Heating Savings (Electric Resistance)

Heating savings are calculated as:

$$kWh_{Heating,Electric\ Resistance} = \frac{(DL_{pre} - DL_{post})/((CAP/12{,}000) * 400) * EFLH_h * CAP * TRFheat}{\eta\text{Heat / 3,412}}$$

Where:

DL_{pre} = Pre-measurement of leakage to unconditioned space

DL_{post} = Post-measurement of leakage to unconditioned space

CAP = Heating output capacity (Btu/hr) of electric heat = Actual. Use 72,829 Btu/hr if CAP unavailable.

12,000 = Btu/ton conversion factor

400 = CFM/ton conversion factor

$EFLH_h$ = Equivalent full load heating hours = 396

TRFheat = Thermal Regain Factor for heating by space type = 1.0 for Unconditioned Spaces = 0.40 for Semi-Conditioned Spaces

ηHeat = Efficiency in COP of Heating equipment = Actual. If unavailable, use 1.0.

3,412 = Conversion of BTU/kWh.

1.3.8.4.4 Demand Savings (Cooling)

Demand savings are calculated by applying peak coincidence to the Cooling kWh savings. If the residence does not have central air conditioning (i.e., the ductwork is used only for heating distribution) then demand savings are 0.

$$kW = \frac{kWh_{cooling}}{EFLH_c} \times Coincidence\%$$

Where:

$kWh_{cooling}$ = Calculated kWh cooling savings

$EFLH_c$ = Equivalent Full Load Cooling Hours, 1,637, based on the TPE metering of New Orleans homes

Coincidence% = 77%, calculated based on the TPE metering of New Orleans homes.

1.3.8.4.5 Derivation of Equivalent Full-Load Hours and Peak Coincidence Factor

(i) Cooling Hours

Equivalent Full-Load Cooling Hours (EFLHc) measures the total annual runtime of HVAC equipment. To support development of this value, the usage of 68 HVAC systems in New Orleans was metered over. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans.

The resulting EFLHc is 1,637.

1. Peak Coincidence Factor

The Peak Coincidence Factor is defined as the percent time during the ENO peak period where the residential central air conditioner is operational. Peak hours were defined as:

- Weekdays
- Non-holidays
- 4:00-5:00 PM
- Average ambient temperature exceeding 90 degrees Fahrenheit.

The average central AC runtime during qualified hours was 77%. This peak coincidence factor is applied to calculate peak kW demand reductions from this measure.

(ii) Heating Hours

Equivalent Full-Load Heating Hours ($EFLH_h$) measures the total annual runtime of heating equipment. To support development of this value, the usage of 295 electric heating systems in New Orleans was estimated using a billing analysis. This runtime was then normalized to correspond to Typical Meteorological Year ("TMY") weather data for New Orleans. In addition, the $EFLH_h$ was multiplied by a scaling factor of 1.51 to account for differences in usage for heat pump vs. electric resistance heating types.

The heat pump scaling factor was calculated using the following equation:

$$Scaling\ Factor_{HP} = ((\frac{\frac{kWh}{HDD}}{Ton}_{HP}) * COP_{HP})/((\frac{\frac{kW}{HDD}}{Ton}_{ER}) * COP_{ER})$$

Where:

$kWh/HDD/Ton_{HP}$= Weighted average of predicted kWh/HDD/Ton for heat pump heating types for single and multi-family homes = 0.3282

$kWh/HDD/Ton_{ER}$= Weighted average of predicted kWh/HDD/Ton for electric resistance heating types for single and multi-family homes = 0.4348

COP_{HP} = Coefficient of performance for heat pumps = 2.0

COP_{HP} = Coefficient of performance for electric resistance = 1.0

The resulting $EFLH_H$ for Electric Resistance systems 396.

The resulting $EFLH_H$ for Heat Pumps is 600.

1.3.8.5 Uncertainty Analysis

The uncertainties associated with the four key parameters collected in EM&V are as follows:

- EFLHc: ±5.10%
- % Coincidence: ±2.11%
- EFLHh: Electric Resistance ±5.10%
- EFLHh: Heat Pumps ±37.10%

1.3.8.6 Incremental cost

The incremental cost of this measure is the full installed cost. If this is not available than the PY6 average cost of $368 may be used instead.

1.3.8.7 Net-to-Gross

The NTG for this measure is 95%.

1.3.8.8 Future Studies

This is a high impact measure, regularly constituting a large percent of Energy Smart program savings. The TPE recommends that savings estimates for Duct Sealing be validated with a billing analysis of the past three years of

1.3.9 SMART THERMOSTATS

1.3.9.1 Measure Description

The Smart Thermostats measure involves the replacement of a manually operated or programmable thermostat with a smart programmable thermostat. This measure applies to all residential applications.

Recent research indicates that today's programmable thermostat is evolving into a more usable, capable, and connected device. Smart thermostats are the next generation of programmable thermostats, which provide an array of features including automatic occupancy sensing and set-point adjustment. An energy management system that includes a communicating climate control will provide energy users with vastly improved and potentially real-time information on heating, ventilation, and air conditioning (HVAC) consumption and cost. Armed with these capabilities, consumers are able to take immediate action to reduce energy use and see the results in real-time.

The location of the smart thermostat can affect its performance and efficiency. To operate properly, a thermostat must be installed on an interior wall away from direct sunlight, drafts, doorways, skylights, and windows. Additionally, thermostats should be installed in a location with the house that is regularly occupied while residents are home.

For homes with a heat pump, smart thermostats must be professionally installed and commissioned. Smart thermostats on heat pumps must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.

Smart thermostats have capabilities beyond those found in a traditional programmable thermostat. To qualify as a smart thermostat, the units installed, at a minimum, should have the following capabilities and installation parameters:

- Successful connection to existing WIFI
- Remote adjustment via smart phone or online
- Automatic scheduling
- Energy history
- Occupancy sensing (set "on" as a default)

Other optional features include:

- Early on function to allow desired set points to be met at onset of occupancy
- Filter reminders
- On screen indication when temperature is set to an energy saving value
- For heat pumps, smart thermostat must be able to control heat pump to optimize energy use and minimize the use of backup electric resistance heat

1.3.9.2 Baseline and Efficiency Standards

The baseline condition is a manually operated or properly programmed thermostat.

1.3.9.3 Estimated Useful Life

According to DEER 2014, the EUL for thermostats is 11 years.[114]

1.3.9.4 Deemed Savings Values

The deemed savings values for this measure is 343 kWh per household.

Savings are based on the results of the Smart Thermostat Direct Install Pilot Program, comprised of 894 multifamily dwellings, with 749 used in the estimation of final savings.

Billing data was used from program participants and supplemented with a matched control group. The evaluation used a pre-post fixed effects model with a vector of control variables for each month to capture seasonal effects. This is called a model specification allows the model to capture much of the baseline differences across customers while obtaining reliable estimates of the impact of the thermostat installation. The reductions are calculated in terms of kWh per day.

The model is shown below in Equation 1:

Equation 1 P Pre-Post Fixed Effects Model

$$kWh\ Usage_{it} = \alpha_0 + \beta_1 * Post_i + \beta_2 * Post_i * Treatment_i$$

$$+ \beta_3 * Month_t + \beta_4 * Post_i * Month_t + \beta_5 * Post_i * Treatment_i * Month_t$$

$$+\beta_6 * Customer_i + \varepsilon_{it}$$

Where:

> *i* = *i*th customer
>
> *t* = the first, second, third, etc. month of the post-treatment period
>
> $kWh\ Usage_{it}$ = the average daily use during month *t* for household *i* in the post-treatment period
>
> $Post_i$ = a dummy indicator for whether an observation for household *i* occurs pre- or post-installation of the thermostat
>
> $Treatment_i$ = a dummy indicator for whether the household was a participant household with a Nest thermostat installed
>
> $Month_t$ = the month of the billing period t
>
> $Post_i * Treatment_i$ = an interaction term between the Post and Treatment variables
>
> $Post_i * Month_t$ = an interaction term between the Post and Month variables
>
> $Post_i * Treatment_i * Month_t$ = an interaction term between the Post, Treatment and Month variables

---

[114] Database for Energy Efficient Resources (2014). www.deeresources.com/.

$Customer_i$ = a customer-specific dummy variable which account for exogenous heterogeneity that cannot be explicitly controlled for (for a Fixed Effects Model)

α_0 = an intercept term

ε_{it} = an error term

In this specification, the predicted participant savings in the post-period are calculated as in the equation below.

$$Participant\ Annual\ Savings = \sum_{t=1}^{12\ month} \left\{\beta_{2t} * \frac{Days}{Month_t} + \beta_{5t} * \frac{Days}{Month_t}\right\}$$

Where:

β_2 = the coefficient for Post*Treatment parameter

β_5 = the coefficient for the Post*Treatment*Month parameter, which captures the seasonal factors following the installation of the thermostat

$\frac{Days}{Mont\ \ t}$ = the total number of days during billing period t

Below, Table 1-100 shows the model results and average annual savings per household.

Table 1-100 Model Results and Annual Savings

	Average Annual Usage (kWh)	Average Annual kWh Savings	kWh Savings (%)	Average kWh Savings Variance	Error	90% Confidence Interval	R^2
Average	12,821.58	343.13	2.68%	3,300.19	94.50	(248.63, 437.63)	0.6797

1.3.9.5 Incremental Cost

For HPwES and other programs for which installation services are provided, the actual material, labor, and other costs should be used. If this is not available, use $394.17 for retrofit, $199.12 for new construction.

1.3.9.6 Future Studies

This sample from the program pilot was sufficient to provide statistically valid savings on a per-dwelling basis, but not sufficient to provide robust savings based on annual household energy use. These results, and savings estimates, will be updated with PY12 M&V results.

1.4 Envelope Measures

1.4.1 ATTIC KNEE WALL INSULATION

1.4.1.1 Measure Description

This measure involves adding attic knee wall insulation to un-insulated knee wall areas in residential dwellings of existing construction. A wall with an insulation value of R-0 has no insulation but does have a nominal wall R-value made up of interior and exterior wall materials, air film and wood studs. This measure applies to all residential applications.

1.4.1.2 Baseline and Efficiency Standards

This measure applies to existing construction only.

Table 1-101 Attic Knee Wall Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Uninsulated knee wall	Minimum R-19 or R-30

1.4.1.3 Estimated Useful Life

The EUL of this measure is 20 years based on NEAT V.8.6.

1.4.1.4 Deemed Savings Values

This measure has not been included in Energy Smart programs to-date. To provide an estimate of per-project savings, we use PY6 average project size for attic insulation. The average project in PY6 Home Performance with Energy Star was 1,633 square feet. For this estimation, we assume a square attic (40.41 feet per wall side). The assumed knee-wall height is three feet. The resulting surface area to be insulated is:

$$\text{Knee} - \text{Wall Area} = 40.41_{\text{Wall length}} \times 4_{\#\text{walls}} \times 3_{\text{Wall height}} = 496.92 \text{ ft.}^2$$

Table 1-102 Knee Wall Insulation – Deemed Savings Values Per Residence

Ceiling Insulation Base R-Value	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)
R-19	1,789	487	3,328	1,155
R-30	2,225	302	3,747	1,297

Table 1-103 Knee Wall Insulation – Deemed Savings Values Per Square Foot

Ceiling Insulation Base R-Value	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)
R-19	3.600	6.698	2.324	0.000
R-30	4.477	7.540	2.610	0.000

The deemed savings are dependent on the R-value of the attic knee wall, pre- and post-retrofit.

BEoptTM was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since attic knee wall insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions was used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3, *Appendices*.

1.4.1.5 Incremental Cost

The incremental cost for this measure is the total cost. The cost is $0.035 per sq. ft. per "R" unit of insulation . For the average project size of 496.92 square feet, the resulting cost is:

- R-19: $330
- R-49: $522

1.4.1.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values based on simulation results. If this measure is added to Energy Smart programs and exceeds 1% of residential savings, then the simulation model should be updated to align with the billed use of customers that install the measure.

1.4.2 CEILING INSULATION

1.4.2.1 Measure Description

This measure requires adding ceiling insulation above a conditioned area in a residential dwelling of existing construction to a minimum ceiling insulation value of R-38, as well as additional insulation above R-38 in new construction applications. In both scenarios, Savings are estimated for a final insulation level of R-38 for retrofit applications and R-49 for both. This measure pertains to residential ceiling insulation only (attic floor).

1.4.2.2 Baseline and Efficiency Standards

In existing construction, ceiling insulation levels vary greatly, depending on the age of the home, type of insulation, and attic space utilization (such as using the attic for storage and HVAC equipment). The average pre-retrofit insulation level of the treated area will be determined and documented by the insulation contractor according to the ranges in Table 1-104. Degradation due to age and condition of the existing insulation will need to be considered by the insulation contractor.

IECC 2021 specifies an R-value of R-38 for ceiling insulation. Therefore, the eligibility standard for retrofit applications of this measure (minimum final R-value) is R-38. For new construction applications, R-38 is the baseline value.

Table 1-104 Ceiling Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
R-0 to R-1	R-38 or R-49
R-2 to R-4	
R-5 to R-8	
R-9 to R-14	
R-15 to R-22	

1.4.2.3 Estimated Useful Life

The EUL of this measure is 20 years according to DEER 2014.

1.4.2.4 Deemed Savings Values

Deemed savings values have been calculated for four major HVAC configurations: AC with electric resistance heating, AC with gas heating, heat pumps and spaces heated with electric resistance heating, but not cooled. The deemed savings are based on the R-value of the ceiling insulation pre-retrofit and a combined post-retrofit R-value (R-values of the existing insulation and the insulation being added) of at least R-38.

Note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space that is being insulated.

For deemed savings for installation between the range of R-38 to R-49, linear interpolation can be used to determine the value that can be claimed as savings.

When providing per-residence estimates, we have included the following parameters from ceiling insulation projects from the PY9 through PY12 Energy Smart residential programs which offer ceiling insulation.

- Average project size: 1,539 ft^2 for single family, 953 ft^2 for multifamily
- Average baseline R-value: R-3.84[115] for single family, R-0 for multifamily

The tables below provide savings multipliers per dwelling ceiling insulation installed. Values are differentiated by dwelling type and HVAC configuration.

Table 1-105 Deemed Savings for R-38 – Per-Residence

Dwelling Type	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
Single Family	1,202	3,139	1,580	1,937	3.920
Multifamily	744	1,944	979	1,200	2.428

Table 1-106 Deemed Savings for R-49 – Per-Residence

Dwelling Type	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
Single Family	1,256	3,281	1,651	2,026	1,256
Multifamily	778	2,032	1,023	1,255	778

The tables below provide savings multipliers per square foot of ceiling insulation installed. These values are applicable to both single family and multifamily dwellings.

Table 1-107 Deemed Savings for R-38 – Per $ft.^2$

Beginning R-Value	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
0 to 4	0.7808	2.0397	1.0267	1.2589	0.0025
5 to 8	0.5389	1.4174	0.7149	0.8785	0.0020
9 to 14	0.3164	0.8189	0.4096	0.5025	0.0011
15 to 22	0.1496	0.4017	0.2039	0.2521	0.0010

Table 1-108 Deemed Savings for R-49 – Per $ft.^2$

Beginning R-Value	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
0 to 4	0.8159	2.1323	1.0730	1.3163	0.0027
5 to 8	0.5740	1.5100	0.7612	0.9360	0.0021
9 to 14	0.3515	0.9115	0.4559	0.5600	0.0013
15 to 22	0.1847	0.4942	0.2502	0.3095	0.0011

[115] This value is the average starting R-value for 632 projects between PY9 through PY12.

Below, Table 1-109 and Table 1-110 provide savings multipliers per dwelling ceiling insulation installed. Values are differentiated by dwelling type and HVAC configuration.

Table 1-109: New Construction Deemed Savings for R-49 – Per-Residence

Dwelling Type	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
Single Family	54	142	71	88	0.211
Multifamily	33	88	44	55	0.131

Table 1-110: New Construction Deemed Savings for R-49 – Per $ft.^2$

Beginning R-Value	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	Electric Resistance w/o AC	kW
38	0.0351	0.0925	0.0463	0.0575	0.0001

The algorithms below may be used for the calculation of deemed savings in retrofit applications only. For New Construction, use provided per-ft^2 or per-dwelling figures

BEoptTM was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine; available TMY3 weather data specific to the New Orleans area was used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3, *Appendices*.

1.4.2.4.1 Energy Savings

$$\begin{aligned}\mathrm{Savings_{kWh}} = {} & \mathrm{Installed\ Square\ Footage} \\ & \times \left[(\mathrm{I_1} \times \mathrm{R_{Final}}) - (\mathrm{C_1} \times \mathrm{R_{initial}}) + \left(\mathrm{C_2} \times \mathrm{R_{initial}}^2\right) - \left(\mathrm{C_3} \times \mathrm{R_{initial}}^3\right) \right. \\ & \left. + \left(\mathrm{C_4} \times \mathrm{R_{initial}}^4\right) + \mathrm{I_2}\right]\end{aligned}$$

Where:

Installed Square Footage = Total installed square footage of insulation

R_{final} = Ending R-value of insulation

$R_{initial}$ = Starting R-value of insulation

I_1, I_2, C_1, C_2, C_3, C_4 = Coefficients as found in Table 1-111 below

Table 1-111 Coefficients for kWh Savings Calculations

Coefficient	AC/Gas Heat	AC/Electric Resistance	Heat Pump	No AC/Electric Resistance
I1	0.0031887755	0.0084122935	0.0042112083	0.0052235180
C1	0.2388320100	0.5693145100	0.2753752100	0.3304825000
C2	0.0204054900	0.0451657500	0.0210182200	0.0247602600

C3	0.0008743000	0.0018119600	0.0008110100	0.0009376600
C4	0.0000143100	0.0000281000	0.0000121400	0.0000137900
I2	1.3226049300	3.3375076800	1.6578403600	2.0149027600

Rounding is not permitted.

1.4.2.4.2 Demand Reductions

$$\begin{aligned}\text{Savings}_{\text{kW}} = {} & \text{Installed Square Footage} \\ & \times \left[(\text{I}_1 \times \text{R}_{\text{Final}}) - (\text{C}_1 \times \text{R}_{\text{initial}}) + \left(\text{C}_2 \times \text{R}_{\text{initial}}{}^2\right) - \left(\text{C}_3 \times \text{R}_{\text{initial}}{}^3\right) \right. \\ & \left. + \left(\text{C}_4 \times \text{R}_{\text{initial}}{}^4\right) - \left(\text{C}_5 \times \text{R}_{\text{initial}}{}^5\right) + \left(\text{C}_6 \times \text{R}_{\text{initial}}{}^6\right) + \text{I}_2\right]\end{aligned}$$

Where:

Installed Square Footage = Total installed square footage of insulation

R_{final} = Ending R-value of insulation

$R_{initial}$ = Starting R-value of insulation

I_1, I_2, C_1, C_2, C_3, C_4, C_5, C_6 = Coefficients as found in Table 1-112 below

Table 1-112 Coefficients for kW Savings Calculations

Coefficient	AC/Gas Heat	AC/Electric Resistance	Heat Pump	No AC/Electric Resistance
I1	0.00001246	0.00001246	0.00001157	0.00000564
C1	0.00413666	0.00413666	0.00414756	0.00239700
C2	0.00100819	0.00100819	0.00100863	0.00053761
C3	0.00012807	0.00012807	0.00012790	0.00006509
C4	0.00000857	0.00000857	0.00000855	0.00000423
C5	0.00000029	0.00000029	0.00000029	0.00000014
C6	0.00000000	0.00000000	0.00000000	0.00000000
I2	0.00870883	0.00870883	0.00878639	0.00565800

Rounding is not permitted.

1.4.2.5 Incremental Cost

The incremental cost for this measure is the total cost. The average cost is \$0.040/ft^2 per "R" unit of insulation for SF applications and \$0.025/ft^2 per "R" unit of insulation for MF applications . For the average single family project size of 1,539 ft^2, and multifamily project of 953 ft^2, the resulting costs are in the table below.

Table 1-113 Incremental Cost

Dwelling Type	Final R-Value	
	R-38	**R-49**
SF	$2,321	$2,993
MF	$889	$1,146

1.4.2.6 Future Studies

This measure should have its simulation model recalibrated to the billed use of the past three years of program participants.

1.4.3 WALL INSULATION

1.4.3.1 Measure Description

This measure consists of adding wall insulation in the wall cavity in residential dwellings of existing construction. This measure applies to all residential applications.

1.4.3.2 Baseline and Efficiency Standards

In order to qualify for this measure, there must be no existing wall cavity insulation. Post-retrofit condition will be a wall cavity filled with either fiberglass or cellulose insulation (R-13 nominal value), open cell insulation (R-13 nominal value), or closed cell foam insulation (R-23 nominal value). Each type of insulation's nominal R-value depends on a full thickness application within the cavity of a wall with 2x4 inch studs.

Table 1-114 Wall Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard (Nominal R-Values)	
Uninsulated wall cavity	Fiberglass/Cellulose	R-13
	Open Cell Foam	R-13
	Closed Cell Foam	R-23

1.4.3.3 Estimated Useful Life

The EUL of this measure is 20 years according to DEER 2014.

1.4.3.4 Deemed Savings Values

The savings per square foot is a factor to be multiplied by the square footage of the net wall area insulated. Wall area must be part of the thermal envelope of the home and shall not include window or door area.

Deemed savings for R-13 can be achieved with either fiberglass, cellulose, or open cell foam insulation. Deemed savings for R-23 is only applicable to closed cell insulation. The R-value represents the nominal value of the cavity insulation and not the R-value of the wall assembly.

For deemed savings for installation between the range of R-13 to R-23, linear interpolation can be used to determine the value that can be claimed as savings.

To calculate savings per-residence, the following assumptions are used:

Average square feet of insulation: 1,501[116]

Table 1-115 Wall Insulation – Deemed Savings Values Per-Residence

Ceiling Insulation Base R-Value	kWh Savings / SQFT		kW Peak Savings / SQFT	
	R-13	R-23	R-13	R-23
Electric Cooling w Gas Heat	0.78286	0.82574	0.00033	0.00060

[116] ENERGY STAR guidance. https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Savings_and_Cost_Estimate_Summary.pdf

Electric Cooling W Electric Resistance Heat	3.33772	3.74885	0.00033	0.00060
Electric Cooling w Electric Heat Pump	1.05252	1.13064	0.00033	0.00051

Table 1-116 Wall Insulation – Deemed Savings Values Per-Ft.[2]

Ceiling Insulation Base R-Value	**kWh Savings / SQFT**		**kW Peak Savings / SQFT**	
	R-13	**R-23**	**R-13**	**R-23**
Electric Cooling with Gas Heat	0.78286	0.82574	0.00033	0.00060
Electric Cooling with Electric Resistance Heat	3.33772	3.74885	0.00033	0.00060
Electric Cooling with Electric Heat Pump	1.05252	1.13064	0.00033	0.00051

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent on the R-value of the wall pre- and post-retrofit. BEoptTM was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since wall insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3, *Appendices*.

1.4.3.5 Incremental Cost

The incremental cost of this measure is equal to the full installed cost. If this is not available, use $.92 per square foot[117]. For the average project size of 1,501 square feet, this results in an incremental cost of $1,381.

1.4.3.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values based on simulation results. If this measure is added to Energy Smart programs and exceeds 1% of residential savings, then the simulation model should be updated to align with the billed use of customers that install the measure.

If there is adequate participation, the assumed default square foot value should be revised.

[117] Midpoint value for floor insulation specified on Home Advisor. http://www.homeadvisor.com/cost/insulation/

1.4.4 FLOOR INSULATION

1.4.4.1 Measure Description

This measure presents two eligible scenarios for retrofitting a crawl space underneath an uninsulated floor[118]:

- Insulating the underside of the floor (above the vented crawl space), where the floor previously had no insulation
- “Encapsulating” the crawl space – sealing and insulating the vented perimeter skirt or stem wall between the ground (finished grade) and the first floor of the house, leaving the underside of the first floor structure uninsulated

This measure applies to all residential applications.

1.4.4.2 Baseline and Efficiency Standards

The baseline is considered to be a house with pier and beam construction, no insulation under the floor of the conditioned space, and a vented crawl space. In order to qualify for deemed savings, either the floor can be insulated to a minimum of R-19 or the crawl space can be encapsulated as described below. Deemed savings are provided for each option.

- Option 1 – Insulating the underside of the floor to a minimum of R-19.
- Option 2 – Encapsulating the crawl space: The crawl space perimeter skirt or stem walls are sealed in a sound and durable manner and the ground (floor of the crawl space) is sealed with a heavy plastic vapor barrier. The skirt or stem wall interior surfaces are insulated to R-13 (minimum) with closed cell foam[119]. The underside of the floor above the crawlspace is left uninsulated. A small flow of conditioned air to the crawl space is recommended to moderate humidity levels[120].

OSHA standards and applicable versions of the IECC and IRC codes will be pertinent to the installation. Note that this will include ensuring that any oil or gas-fueled furnaces or water heaters located in the crawlspace be provided with dedicated combustion air supply or be sealed-combustion units equipped with a powered combustion system.[121]

Table 1-117 Floor Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
No insulation under floor	R-19 installed under floor; or encapsulated crawl space with air-sealed perimeter having R-13 insulation on the interior side, no floor insulation under the floor above, and moisture-sealed grade under the crawl space

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[118] U.S. DOE publication “Building America Best Practices Series, Vol 17, “Insulation” found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15) has extensive building science and code conformance information regarding insulating floors as well as sealing and insulating crawl spaces.

[119] IECC 2012, Table R402.1

[120] U.S. DOE publication “Building America Best Practices Series, Vol 17, “Insulation” found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15), p. 58, 1 cfm per every 50 sq. ft. of floor area.

[121] *Ibid* (p. 59).

1.4.4.3 Estimated Useful Life

The average lifetime of this measure is 20 years according to DEER 2014.

1.4.4.4 Deemed Savings Values

The deemed savings values listed below are per square foot of first level floor area above the crawl space.

For the per-residence savings, we assume the same square feet as attic insulation (1,633 ft.2), due to a lack of participation in this measure. This is to be updated when there is adequate participation to support an estimate.

Table 1-118 R-19 Floor Insulation – Deemed Savings Values Per-Residence

Equipment Type	kWh Savings / residence	kW Peak Savings / residence
Electric Cooling with Gas Heat	-393.226	Negligible
Electric Cooling with Electric Resistance Heat	108.5945	n/a
Electric Cooling with Electric Heat Pump	807.5185	Negligible

Table 1-119 R-19 Floor Insulation – Deemed Savings Values Per-Ft.2

Equipment Type	kWh Savings / sq. ft.	kW Peak Savings / sq. ft.
Electric Cooling with Gas Heat	-0.2408	Negligible
Electric Cooling with Electric Resistance Heat	0.4945	Negligible
Electric Cooling with Electric Heat Pump	0.0952	Negligible

Deemed savings values have been calculated for each of the four weather zones. BEoptTM was used to estimate energy savings for both options using the same base case model (uninsulated floor) and the DOE EnergyPlus simulation engine. Savings are sensitive to weather; therefore, available TMY3 weather data specific to New Orleans used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3 *Appendices*.

1.4.4.5 Incremental Cost

The incremental cost of this measure is equal to the full installed cost.

1.4.4.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values based on simulation results. If this measure is added to Energy Smart programs and exceeds 1% of residential savings, then the simulation model should be updated to align with the billed use of customers that install the measure. If there is adequate participation, the assumed default square foot value should be revised.

1.4.5 ENERGY STAR WINDOWS, DOORS & SKYLIGHTS

1.4.5.1 Measure Description

This measure involves the replacement of windows with an ENERGY STAR window(s), door(s) or skylight(s) in an existing home. This measure applies to all residential applications and are calculated on per square foot of window basis, inclusive of frame and sash. All windows must be in a metal frame. Converted residences are not eligible.

ENEGRY STAR U-factor and Solar Heat Gain Coefficient (SHGC) qualification criteria vary based on climate zone. Figure 1-3 displays the fours zones, with New Orleans appearing in the 'Southern' zone. Relevant required efficiency levels are shown in Table 1-120.

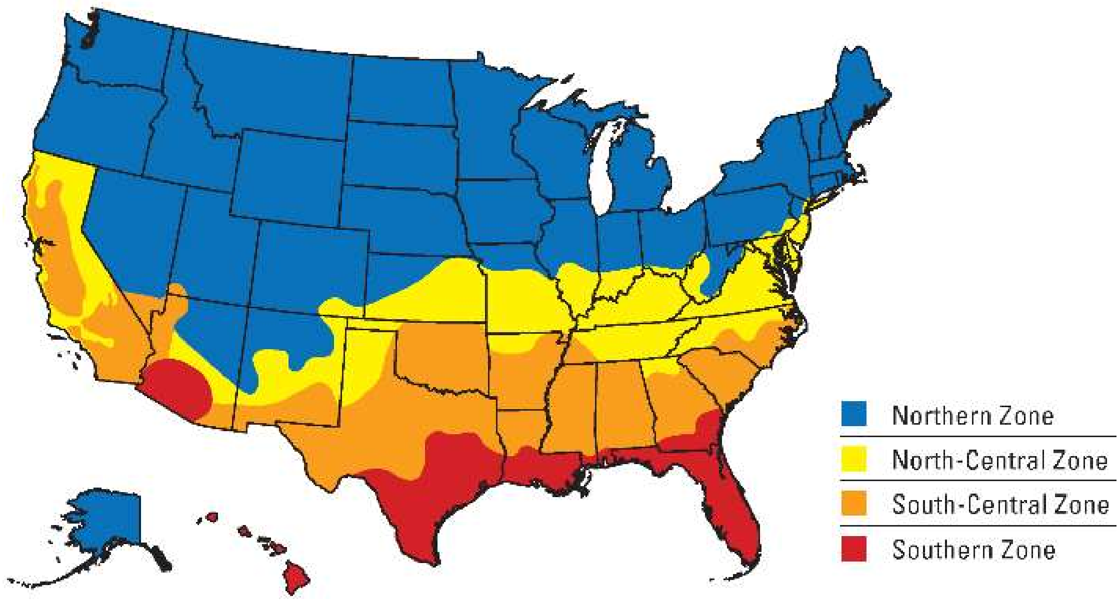

Figure 1-3 ENERGY STAR Window Program Climate Map

Table 1-120 ENERGY STAR Efficiency Requirements for New Orleans[122, 123, 124]

New Orleans - Southern	U-Factor	SHGC
Windows	≤ 0.40	≤ 0.25
Doors (Opaque)	≤ 0.17	No Rating
Doors (≤ ½ Glass)	≤ 0.25	≤ 0.25
Doors (> ½ Glass)	≤ 0.30	≤ 0.25
Skylights	≤ 0.60	≤ 0.28

[122] Effective as of January 1, 2016: https://www.energystar.gov/sites/default/files/asset/document/Windows_Doors_and_Skylights_Program_Requirements%20v6.pdf

[123] Btu/(h*ft2 *°F)

[124] Solar Heat Gain Coefficient

1.4.5.2 Baseline and Efficiency Standards

For this measure, there are two separate baseline assumptions and two sets of deemed savings values for both single and double pane windows. Prototypical U-Values and SHGCs for baseline windows are presented in Table 1-121.

Table 1-121 Baseline Windows

Number of Panes	U-Factor BTU/ (h*FT^2 *°F)	Solar Heat Gain Coefficient (SHGC)
1	1.12	0.79
2	0.81	0.64

1.4.5.3 Estimated Useful Life

The EUL of an ENERGY STAR window is 20 years[125].

1.4.5.4 Deemed Savings Values

1.4.5.4.1 Windows

Table 1-122 and Table 1-123 provide per-square foot deemed savings values for single pane and double pane windows.

Table 1-122 ENERGY STAR Replacement for Single-Pane Window[126]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	5.847	0.0024
Elec. AC with Resistance Heat	6.149	0.0024
Heat Pump	5.975	0.0024

Table 1-123 ENERGY STAR Replacement for Double-Pane Window[127]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	3.931	0.0017
Elec. AC with Resistance Heat	3.990	0.0017
Heat Pump	4.035	0.0017

Table 1-124 and Table 1-125 show savings for a typical window, 11.06ft^2 (approximately 35.6” x 44.5”).[128]

[125] DEER 2008, 2014.

[126] Modeled at 202 ft^2 area

[127] Modeled at 202 ft^2 area

[128] Based on an inventory of the 100 highest-selling windows in local stores.

Table 1-124 Average Savings for Single-Pane Windows

Equipment Type	kWh Savings	kW Savings
Electric AC with Gas Heat	64	0.027
Elec. AC with Resistance Heat	68	0.027
Heat Pump	66	0.027

Table 1-125 Average Savings for Double-Pane Windows

Equipment Type	kWh Savings	kW Savings
Electric AC with Gas Heat	43	0.019
Elec. AC with Resistance Heat	44	0.019
Heat Pump	44	0.019

1.4.5.4.2 Doors

Table 1-126 through Table 1-128 provide per-square foot deemed savings values for doors.

Table 1-126 ENERGY STAR Replacement for Doors (Opaque)[129]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	0.725	0.0171
Elec. AC with Resistance Heat	3.725	0.0171
Heat Pump	1.750	0.0171

Table 1-127 ENERGY STAR Replacement for Doors (≤ ½-Lite)[130]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	1.400	0.0262
Elec. AC with Resistance Heat	4.100	0.0262
Heat Pump	2.275	0.0262

Table 1-128 ENERGY STAR Replacement for Doors (> ½-Lite)[131]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	3.000	0.0523
Elec. AC with Resistance Heat	6.225	0.0523
Heat Pump	4.175	0.0523

1.4.5.4.3 Skylights

Table 1-129 provides per-square foot deemed savings values for skylights.

Table 1-129 ENERGY STAR Replacement for Skylights[132]

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.
Electric AC with Gas Heat	0.842	0.0322
Elec. AC with Resistance Heat	0.842	0.0322
Heat Pump	0.901	0.0322

[129] 40 ft^2 area, no glass

[130] 40 ft^2 area, 25% glass

[131] 40 ft^2 area, 75% glass

[132] 101 ft^2 area

BEoptTM was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since ENERGY STAR window, skylight and door savings are sensitive to weather, available TMY3 weather data specific to New Orleans was used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3, *Appendices*.

1.4.5.5 Incremental Costs

- Windows: ENERGY STAR[133] estimates window incremental costs for the New Orleans climate zone to be \$0.61/ft2, or \$6.74 for a typical 11.06ft^2 window.
- Doors: ENERGY STAR[134] estimates incremental costs for doors to be \$13 for ≤ 1/2 lite doors and \$30 for >1/2 lite doors. The average cost increase over best-selling opaque doors is \$0, thus the incremental cost for opaque doors is \$0.
- Skylights: ENERGY STAR[134] estimates incremental costs for skylights to be \$20-\$40 for a typical skylight.

1.4.5.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure has not yet been implemented in Energy Smart programs. As a result, savings are calculated using Texas values which have been weather-normalized for New Orleans. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents.

If participation reached 1% of residential Energy Smart program savings, the TPE recommends a simulation models be calibrated with utility metering data and deemed savings estimates be updated at that time.

[133] https://www.energystar.gov/sites/default/files/asset/document/Savings_and_Cost_Estimate_Summary.pdf

[134] https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/windows_doors/Draft6_V1_Criteria_Analysis_Report.pdf

1.4.6 ENERGY STAR LOW EMISSIVITY STORM WINDOWS

1.4.6.1 Measure Description

This measure involves the installation of interior or exterior ENERGY STAR low emissivity (low-e) storm windows over existing windows. Savings is achieved through lowering structure emissivity, solar gain and air leakage. This measure applies residential applications including low-rise multifamily buildings. ENEGRY STAR U-factor and Solar Heat Gain Coefficient (SHGC) qualification criteria vary based on climate zone. Figure 1-3 displays the fours zones, with New Orleans appearing in the 'Southern' zone. Relevant required efficiency levels are shown in Table 1-130.

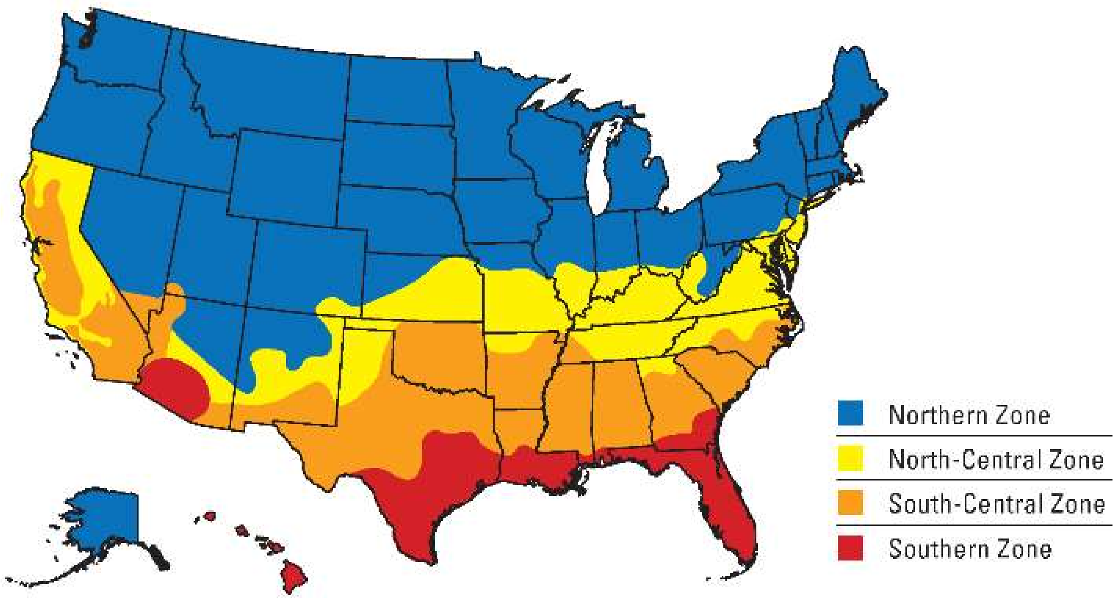

Figure 1-4 ENERGY STAR Window Program Climate Map

Table 1-130 ENERGY STAR Requirements for Storm Windows (Southern Region)

Emissivity	Solar Transmission	Air Leakage
≤ 0.22	≤ 0.55	≤ 1.5 (exterior) ≤ 0.5 (interior)

1.4.6.2 Baseline and Efficiency Standards

The baseline for this measure is an existing single or double pane glass window with no existing storm window.

1.4.6.3 Estimated Useful Life

The lifetime of an ENERGY STAR window is 20 years[135].

[135] DEER 2008, 2014.

1.4.6.4 Deemed Savings Values

The table below provide deemed savings values for interior and exterior ENERGY STAR storm windows.

Table 1-131 ENERGY STAR Interior Storm Window Deemed Savings

Equipment Type	kWh Savings/ ft.^{2}	kW Savings/ ft.^{2}
Gas & AC	1.51	0.0007
AC & Elec Resistance	2.98	0.0007
Heat Pump	1.96	0.0007

Table 1-132 ENERGY STAR Exterior Storm Window Deemed Savings

Equipment Type	kWh Savings/ ft.^{2}	kW Savings/ ft.^{2}
Gas & AC	1.38	0.0006
AC & Elec Resistance	2.10	0.0006
Heat Pump	1.62	0.0006

BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since ENERGY STAR storm window savings are sensitive to weather, available TMY3 weather data specific to New Orleans was used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in the NO TRM V6.1 Volume 3 Appendices.

1.4.6.5 Incremental Costs

The incremental cost of this measure is equal to the full installed cost. If this is not available, the incremental costs for low-E storm windows are assumed to be $1/SQFT[136].

1.4.6.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure has not yet been implemented in Energy Smart programs. As a result, savings are calculated using national values which have been weather-normalized for New Orleans. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units purchased by New Orleans residents. If participation reached 1% of residential Energy Smart program savings, the TPE recommends running simulation models be calibrated with utility metering data and deemed savings estimates be updated at that time.

[136] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24826.pdf

1.4.7 AIR INFILTRATION

1.4.7.1 Measure Description

This measure reduces air infiltration into the residence, using pre- and post-treatment blower door air pressure readings to quantify the air leakage reduction. There is no post-retrofit minimum infiltration requirement, however, installations must comply with the prevailing Arkansas mechanical code. This measure applies to all residential applications.

1.4.7.2 Baseline and Efficiency Standards

1.4.7.2.1 Existing Buildings

The baseline for this measure is the existing leakage rate of the residence to be treated. The existing leakage rate should be capped to account for the fact that the deemed savings values per CFM50 leakage reduction are only applicable up to a point where the existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.

Baseline assumptions used in the development of these deemed savings are based on the 2013 ASHRAE Handbook of Fundamentals, Chapter 16, which provides typical infiltration rates for residential structures. In a study of low income homes reported in ASHRAE, approximately 95 percent of the home infiltration rates were below 3.0 ACHNat.[137] Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or improperly conducted blower door tests, these savings should only be applied starting at a baseline ACHNat of 3.0 or lower.

To calculate the maximum allowable CFM50, pre-value for a particular house, use the following equation:

$$CFM_{50,pre}/ft^2 = \frac{ACH_{Nat,pre} \times h \times N}{60}$$

Where:

$CFM_{50,pre}/ft^2$ = Per square foot pre-installation infiltration rate ($CFM50/ft^2$)

$ACH_{Nat,pre}$ = Maximum pre-installation air change rate (ACH_{Nat}) = 3.0

60 = Constant to convert from minutes to hours

h = Ceiling height (ft.) = 8.5 (default)[138]

N = N factor (Table 1-133)

[137] 2013 ASHRAE Handbook of Fundamentals, Chapter 16, pp. 16.18, Figure 12.

[138] Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

Table 1-133 Air Infiltration – N Factor[139]

Wind Shielding	Number of Stories		
	Single Story	Two Story	Three + Story
Well Shielded	25.8	20.6	18.1
Normal	21.5	17.2	15.1
Exposed	19.4	15.5	13.5

- Well Shielded is defined as urban areas with high buildings or sheltered areas, and buildings surrounded by trees, bermed earth, or higher terrain.
- Normal is defined as buildings in a residential neighborhood or subdivision, with yard space between buildings. Approximately 80-90 percent of houses fall in this category.
- Exposed is defined as buildings in an open setting with few buildings or trees around and buildings on top of a hill or ocean front, exposed to winds.

Maximum CFM50 per square foot values are available in Table 1-134. Pre-retrofit leakage rates are limited to fa maximum per ft.^{2} value specified in the table, as this generally indicates severe structural damage not repairable by typical infiltration reduction techniques.

Table 1-134 Pre-Retrofit Infiltration Cap (CFM50/ft^2)

Wind Shielding	Number of Stories		
	Single Story	Two Story	Three + Story
Well Shielded	11.0	8.8	7.7
Normal	9.1	7.3	6.4
Exposed	8.2	6.6	5.7

1.4.7.2.2 New Construction

The maximum ACH50 allowable under IECC2021 is 5.0. The maximum CFM50 is partially determined by the total volume of the sealed space. To calculate the maximum allowable CFM50, pre-value for a particular house, use the following equation:

$$ACH_{50} = \frac{CFM_{50} \times Volume}{60}$$

Using a maximum ACH50 of 5.0 and rearranging the equation, the maximum allowable air leakage, and thus the baseline for NC is:

$$CFM_{50} = \frac{Volume}{12}$$

[139] Krigger, J. & Dorsi, C. 2005, Residential Energy: Cost Savings and Comfort for Existing Buildings, 4th Edition. Version RE. Volume 3, *Appendices*-11: Zone 3 Building Tightness Limits, p. 284., December 20. www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf

Where:

ACH_{50}= Air Exchanges per Hour (maximum 5.0)

CFM_{50}= Air Flow (ft^3 at 50 pascals)

Volume = Volume of sealed space

1.4.7.3 Estimated Useful Life

According to DEER 2014 the Estimated Useful Life for air infiltration is 11 years.

1.4.7.4 Deemed Savings Values

Programs should calculate savings based on pre- and post-retrofit leakage testing. If this data is not available, default estimates may be applied. The following assumptions based on PY6 evaluation results of the Home Performance with ENERGY STAR program are used in providing per-residence savings estimates:

- Leakage reduction: 2,045 CFM

Table 1-135 Air Infiltration Reduction – Retrofit Deemed Savings Values Per-Residence

Equipment Type	kWh Savings/ CFM50 (ESF)	kW Savings/ CFM50 (DSF)
Electric AC with Gas Heat	840	0.6769
Elec. AC with Resistance Heat	2,082	0.6789
Heat Pump	1,474	0.6789

The following formulas shall be used to calculate deemed savings for infiltration efficiency improvements. The formulas apply to all building heights and shielding factors.

$$kWh_{savings} = CFM_{50} \times ESF$$

$$kW_{savings} = CFM_{50} \times DSF$$

Where:

CFM_{50} = Air infiltration reduction in Cubic Feet per Minute at 50 pascals, as measured by the difference between pre- and post-installation blower door air leakage tests

ESF = corresponding energy savings factor (Table 1-136)

DSF = corresponding demand savings factor (Table 1-136)

Table 1-136 Air Infiltration Reduction – Deemed Savings Values Per-Ft.2

Equipment Type	kWh Savings/ CFM50 (ESF)	kW Savings/ CFM50 (DSF)
Electric AC with Gas Heat	0.4108	0.000331
Elec. AC with Resistance Heat	1.018	0.000332
Heat Pump	0.721	0.000332

BEoptTM was used to estimate energy savings for a series of models using the US DOE EnergyPlus simulation engine. Since infiltration savings are sensitive to weather, available TMY3 weather data specific to New Orleans was used for the analysis. The prototype home characteristics used in the BEoptTM building model are outlined in Volume 3, *Appendices*.

The deemed savings are dependent on the pre- and post-CFM50 leakage rates of the home and are presented as annual savings / CFM50 reduction. A series of model runs was completed in order to establish the relationship between various CFM50 leakage rates and heating and cooling energy consumption. The resulting analysis of model outputs was used to create the deemed savings tables of kWh and kW per CFM50 of air infiltration reduction.

1.4.7.5 Incremental Cost

The incremental cost of this measure is equal to the full installed cost. If this is not available, a default value of $0.25 per square foot of conditioned floor area may be applied[140]. This should use a default of 1,762 square feet, based on PY6 program tracking for the Home Performance with ENERGY STAR program.

The resulting per-project incremental cost is $441.

1.4.7.6 Net-to-Gross

The NTG for this measure is 95%[141].

1.4.7.7 Future Studies

This measure should have its simulation model recalibrated to the billed use of the past three years of program participants.

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[140] ENERGY STAR guidance. https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Savings_and_Cost_Estimate_Summary.pdf

[141] Based on primary data collection from 78 PY6-9 program participants.

1.4.8 WINDOW FILM

1.4.8.1 Measure Description

This measure consists of adding solar film to east, west and south-facing windows. This measure applies to all residential applications.

1.4.8.2 Baseline and Efficiency Standards

This measure is applicable to existing homes only. Low E windows and tinted windows are not applicable for this measure. To qualify for deemed savings, solar film should be applied to east, west and south-facing facing glass.

Table 1-137 Window Film – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Single- or double-pane window with no existing solar films, solar screens, or low-e coating	Solar Film with SHGC <0.50

1.4.8.3 Estimated Useful Life

The average lifetime of this measure is 10 years according to DEER 2014.

1.4.8.4 Deemed Savings Values

The savings per square foot is a factor to be multiplied by the square footage of the window area to which the films are being added. For the per-residence values, we assume 330 total window SQFT.

Table 1-138 Window Film – Deemed Savings Values Per-Residence

Existing Windowpane Type	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)
Single Pane	1,391	-218	531	0.33
Double Pane	813	-75	273	0.33

Table 1-139 Window Film – Deemed Savings Values Per-SqFt.[2]

Existing Windowpane Type	AC/Gas Heat kWh	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)
Single Pane	4.216	-0.661	1.610	0.001
Double Pane	2.465	-0.226	0.826	0.001

The deemed savings are dependent on the SHGC of pre- and post-retrofit glazing. BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since window film savings are sensitive to weather, available TMY3 weather data specific to New Orleans was used for the analysis. The prototype home characteristics used in the BEopt building model are outlined in Volume 3 Appendices.

1.4.8.5 Incremental Cost

The incremental cost of this measure is equal to the full installed cost. If this is not available, the default cost is:

- $2.00 per square foot[142]
- $660 per residence

1.4.8.6 Future Studies

At the time of authorship of the TRM, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values based on simulation results. If this measure is added to Energy Smart programs and exceeds 1% of residential savings, then the simulation model should be updated to align with the billed use of customers that install the measure.

If there is adequate participation, the assumed default square foot value should be revised.

[142] Energize Connecticut cost documentation. http://www.uinet.com/wps/wcm/connect/193bba80476e1bc19d6c9d02c80795ac/FINAL-C0118-2017-UI-CI-Incentive-Matrix-Gas-Caps-Rev.+02.17.pdf?MOD=AJPERES&CACHEID=193bba80476e1bc19d6c9d02c80795ac

1.4.9 RADIANT BARRIERS

1.4.9.1 Measure Description

Radiant barriers are designed to block radiant heat transfer between a building roof and the attic space insulation. They typically consist of a metallic foil material (usually aluminum) and are generally installed on the roof decking or beneath roof sheathing. Radiant barriers are most effective at reducing cooling consumption by reflecting heat away from a home.

1.4.9.2 Baseline and Efficiency Standards

This measure applies to existing construction that does not have a radiant barrier installed on the roof decking.

The efficiency requirements for radiant barriers must meet the standards set by the Reflective Insulation Manufacturers Association International (RIMA) to include proper attic ventilation. The following table displays the requirements for radiant barriers.

Table 1-140: Required Substantiation

Required Substantiation		
Physical Property	Test Method or Standard	Requirement
Surface Emittance	ASTM C 1371	0.1 or less
Water Vapor Transmission	ASTM E 96: Procedure A Desiccant Method	0.02 for Vapor Retarder 0.5 or greater for perforated products
Surface Burning		
Flame Spread	ASTM E 84	25 or less
Smoke Density	ASTM E 84	450 or less
Corrosivity	ASTM D 3310	Corrosion on less than 2% of the affected surface
Tear Resistance	ASTM D 2261	
Adhesive Performance		
Bleeding	Section 10.1 of ASTM C 1313	Bleeding or delamination of less than 2% of the surface area
Pliability	Section 10.2 of ASTM C 1313	No cracking or delamination
Mold and Mildew	ASTM C 1338	No growth when visually examined under 5X magnification

Interior radiation control coatings are not applicable for the deemed savings derived. A study performed by RIMA found that none of the coating-type products currently on the market had an emittance of 0.10 or lower as required by the standards set by the American Society for Testing and Materials (ASTM) for a product to be considered a radiant barrier.[143] Therefore, all coating materials and spray application materials are ineligible for application of these savings values.

All radiant barriers should be installed according to the RIMA Handbook, Section 7.4.[144] However, horizontal installation is not eligible, due to the likelihood of dust buildup and wear-and-tear damage to the radiant barrier.

A radiant barrier cannot be in contact with any other materials on its underside or else it becomes defective. Therefore, once a radiant barrier is installed on the roof decking, no roof deck insulation can be installed.

1.4.9.3 Estimated Useful Life

The average lifetime of this measure is estimated to be about 25 years for downward facing radiant barriers, based on the DOE's Radiant Barrier Fact Sheet.[145]

1.4.9.4 Deemed Savings Values

Deemed savings values have been calculated for New Orleans. The calculations for deemed savings values are based on the addition of a radiant barrier to the roof decking where a radiant barrier did not previously exist. Please note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space to which the radiant barrier is applied. Gas Heat (no AC) kWh applies to forced air furnace systems only.

Table 1-141 Deemed Savings Values

Addition of Radiant Barrier with existing attic insulation level	AC/Gas Heat kWh	Gas Heat (no AC) kWh	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic insulation ≤R-19	0.2142	0.006	0.3238	0.1794	0.0001
Attic insulation >R19	0.1361	0.0039	0.1853	0.0993	0.0001

1.4.9.5 Incremental Cost

The incremental cost is $0.15 to $0.45 per square feet.[146]

1.4.9.6 Future Studies

There are no future studies planned for this measures at this time.

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143 Study by RIMA that found no radiant coating on the market having a low enough emittance to be considered a radiant barrier: http://www.rimainternational.org/technical/ircc.html

144 RIMA Handbook available online: http://www.rimainternational.org/technical/handbook.html

145 http://web.ornl.gov/sci/ees/etsd/btric/RadiantBarrier/RBFactSheet2010.pdf

146 Oak Ridge National Laboratory. https://web.ornl.gov/sci/buildings/tools/radiant/rb2/rb-tables/index.shtml#table1

1.5 Lighting

1.5.1 ENERGY STAR LIGHTING

1.5.1.1 Measure Description

This chapter provides energy and demand savings calculations for the replacement of residential lighting equipment with energy efficient lamps or fixtures. The operating hours and demand factors are based on primary research in the New Orleans market. This chapter now incorporates the 2007 Energy Independence & Security Act (EISA) Phase II standards (also known as the "EISA Backstop").

This chapter applies to omnidirectional, directional and specialty lamps. Using ANSI C79.1-2002 nomenclature this includes omnidirectional lamps with A, BT, P, PS, S, and T[147] shapes. Reflector and specialty lamps covered are PAR, R, BR, MR, and similar lamp shapes, as well as other specialty lamps such as 3-way lamps, globes and candelabra base lamps which now fall under the expanded General Service Lamp (GSL) definition. It is applicable only to manually controlled (switches and dimmers) residential lighting, and not LED fixtures or connected, 'smart' or otherwise automatically controlled lighting.

1.5.1.2 Baseline and Efficiency Standards

The baseline equipment was originally assumed to be an incandescent or halogen lamp with adjusted baseline wattages compliant with EISA 2007 Regulations. The first of two advances of lighting standards from EISA 2007 Regulations were phased in from January 2012 to January 2014 and dictated higher efficiency for General Service Lamps (GSLs).

Phase II takes effect on July 25, 2022, stipulating that all GSLs sold in the United States (US) must achieve a minimum efficacy of 45 lumens/watt[148]. The ruling also significantly expands the definition of GSLs, extending the covered lumen range, base types, and shapes, while reducing the types of bulbs exempted[149].

"General Service Lamp means a lamp that it:

- Has an [American National Standards Institute] (ANSI) base;
- Is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or at 277 volts for integrated lamps, or is able to operate at any voltage for non-integrated lamps;
- Has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens;
- Is not a light fixture;

[147] According to ENERGY STAR, omni-directional LED products "…shall have an even distribution of luminous intensity (candelas) within the 0° to 135° zone (vertically axially symmetrical). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux (lumens) must be emitted in the 135°-180° zone. Distribution shall be vertically symmetrical as measured in three vertical planes at 0°, 45°, and 90°."

http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf.

[148] Federal Registrar document, page 27440: https://www.govinfo.gov/content/pkg/FR-2022-05-09/pdf/2022-09477.pdf

[149] Ibid.

- Is not an LED downlight retrofit kit; and
- Is used in general lighting applications."

Previously exempt lamps that are now subject to regulations under the expanded GSL definition include:

- Reflectors: The following three reflector lamp types (which represent most reflectors) are no longer exempt from GSL standards:
    - (A) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps;
    - (B) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or
    - (C) R20 incandescent reflector lamps rated 45 watts or less;
- Lumen maximums: The lumen maximum subject to the EISA GSL definition has been increased from 2,600 to 3,300 lumens;
- Base types: All standard bulb bases are included (small screw base and candelabra); and
- Others lamp types: 3-way, decorative (including globes <5", flame shapes and candelabra shapes), T-lamps (≤40w OR ≥ 10"), vibration service, rough service, and shatter resistant bulb exemptions are also discontinued.

The 45 lumen/watt efficacy requirement inherently disallows incandescent and halogen lamps, but the EISA backstop does not directly specify a technological standard to satisfy the efficacy requirement. LEDs are well beyond 45 lumens/W (very often operating at greater than 60 lumens/watt), and alternative technologies all fall below the new EISA backstop, effectively meaning that general service lamps which operate at 45 lumens/watts for common lighting categories are not available for purchase[150].

This precludes savings from being claimed in most circumstances such as time of sale, new construction, and kits distribution channels. Savings can still be realized through early replacement direct install program channels, where existing incandescent, halogen, CFL and other inefficient technologies can be directly identified. To claim savings, implementation staff must record as-found lamp types and wattages and use the tables below to determine the baseline.

Table 1-142 Baseline Wattage by Lumen Output for Omni-Directional Lamps[151]

Minimum Lumens	Maximum Lumens	EISA Phase I W_{base}	EISA Phase II W_{base}
310	749	29	12
750	1,049	43	20
1,050	1,489	53	28
1,490	2,600	72	45

[150] Notable exceptions include some compact fluorescent bulbs (CFL).

[151] Wattages developed using the 45 LPW standard.

Table 1-143 Baseline Wattage by Lumen Output for Directional/Reflector Lamps[152]

Lamp Type	Incandescent Equivalent (Pre-EISA)	EISA Phase I W_{base}	EISA Phase II W_{base}
PAR20	50	35	23
PAR30	50	35	23
R20	50	45	29
PAR38	60	55	35
BR30	65	EXEMPT	38
BR40	65	EXEMPT	38
ER40	65	EXEMPT	38
BR40	75	65	42
BR30	75	65	42
PAR30	75	55	35
PAR38	75	55	35
R30	75	65	42
R40	75	65	42
PAR38	90	70	45
PAR38	120	70	45
R20	≤ 45	EXEMPT	23
BR30	≤ 50	EXEMPT	EXEMPT
BR40	≤ 50	EXEMPT	EXEMPT
ER30	≤ 50	EXEMPT	EXEMPT
ER40	≤ 50	EXEMPT	EXEMPT

Table 1-144 Baseline Wattage by Lumen Output for Exempt Lamps[153]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent (W_{base})
310	749	40
750	1,049	60
1,050	1,489	75
1,490	2,600	100

1.5.1.3 Allowable Distribution Channels

Table 1-145 below shows the application of the backstop by delivery channel.

[152] Based on manufacturer available reflector lighting products as available in August 2013; using 45 lumens/watt.

[153] Lumen bins and incandescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.0 http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Lamps%20V1.0%20Final%20Draft%20Specification.pdf EISA Standards from: United States Department of Energy. Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.

Table 1-145 Application of Backstop by Delivery Channel

Delivery Channel	Description	Application of EISA Backstop
Retail Markdown	Incentives to retailers that reduce the cost of LEDs at point of sale.	Savings for purchases made after June 30, 2023, will be disallowed. Program administrators may process incentives for purchases made prior to the effective date until September 30, 2023.
Online Marketplace	Online store run by Entergy or the TPA that sells LEDs at a discounted price.	Savings for purchases made after June 30, 2023, will be disallowed. Program administrators may process incentives for purchases made prior to the effective date until September 30, 2023.
School Kits	Program-provided school kits which incorporate self-install energy efficiency measures and educational materials for fifth-grade students. These kits have traditionally included LEDs, low flow showerheads, and faucet aerators.	The TPE acknowledges that school kits may warrant greater interest as a matter of education. However, EISA impacts need to be accounted. To retain any savings from school kits after June 30, 2023, the TPA must include survey questions in the student questionnaire developed by the TPE that address what the replaced bulb. The questionnaire must be submitted to the TPE before use in the program. The TPE will incorporate survey responses from the student questionnaire, creating a weighted baseline for savings. Responses that indicate having replaced a CFL or LED will have savings reduced accordingly. This differs from past evaluations in that minimum code was applied to all school kit LEDs irrespective of preexisting lamp type.
Direct Install	TPA staff or their trade allies directly remove old lamps and install LEDs in customer homes.	Direct install activities may continue after June 30, 2023. However, all projects that occur after June 30, 2023, will require that the TPA “bag and tag” the old lamps, to be stored until a quarterly verification inspection is conducted by TPE staff. Direct install may be used to replace incandescent, halogen, or CFL lamps, with savings adjusted accordingly.
Mailer Kit	TPA staff ship kits that include LEDs to residential customers. This may manifest as “push” (kits sent to customers unprompted) or “pull” (kits requested by customers).	Savings for shipments made after June 30, 2023, will be disallowed (determined by postmark date). Program administrators may process incentives for distributions made prior to the effective date until September 30, 2023.

1.5.1.4 *Efficiency Standard*

Lamps must be a standard ENERGY STAR qualified lighting.

Exceptions to the ENERGY STAR label are allowed for unlisted lamps, fixtures or other lighting-related devices that have been submitted to ENERGY STAR for approval. If the lamp or fixture does not achieve ENERGY STAR approval within the New Orleans program year, however, then the lamp or fixture would have to be immediately withdrawn from the program.

1.5.1.5 Effective Useful Life

The EUL for LED replacement under the auspices of EISA Phase II is based on the remaining useful life of the baseline lamp. The EUL for incandescent and halogen lamps is two years. With a final sale date of June 30, 2023, this puts the “savings ending date” for savings with an incandescent or halogen baseline on June 30, 2025.

If a CFL baseline is used, the EUL will assume a CFL with an 8,000-hour rated life, which results in an EUL of five years[154]. With a final sale date of June 30, 2023, this puts the “savings ending date” for savings with an incandescent or halogen baseline on June 30, 2028.

To simplify implementation, single values based on implementation year may be used. This is summarized in Table 1-146.

Table 1-146 EUL by Implementation Year and Baseline Type

Implementation Year	Incandescent / Halogen Baseline	CFL Baseline
2023	2.5	5.5
2024	1.5	4.5
2025	0.5	3.5

1.5.1.6 Lighting Hours of Use (HOU) Metering

Hours of use (HOU) were estimated through direct monitoring of lighting in the on-site sample homes. Each logger was extrapolated to full annual usage by using a linear model with day length as the predictor, where day length varies inversely with the number of HOU. Latitude and longitude coordinates for New Orleans, Louisiana were used in the computation of day length (29.9511, -90.0715). The regression used to extrapolate the meter data to a full year is shown in the equation below.

$$H_d = \alpha + \beta * \text{Day Length} + \varepsilon_d$$

Where:

H_d = hours of use on day d

Day Length = number of daylight hours on day d

α and β are coefficients determined by the regression

ε_d = residual error

A similar model was run which added room type as an explanatory variable to estimate hours of use for each room type.

[154] EUL based on 8,000 hours and 2.38 hours per day, with a .526 “switching degradation factor” for CFL.

1.5.1.6.1 Hours of Use (HOU) Results

Results of the regressed logger data provided the TPE with overall efficient lighting hours of use, as well as breakdowns of hours of use by room type as shown in. In total 355 lighting loggers were used, and all results were found to meet precision requirements. Overall daily HOU are 2.38, which corresponds to 871 annual HOU. The coefficients from the overall model and the model which adds room type are also shown below.

Table 1-147 Hours of Use by Area

Area/Room	HOU Annual	HOU Daily	# Loggers	Precision
Kitchen	855	2.34	83	0.04
Living Room	841	2.3	81	0.04
Bedroom	796	2.18	49	0.06
Bath	1,121	3.07	62	0.04
Dining Room	769	2.11	80	0.05
Overall	871	2.38	355	0.02

Table 1-148 Lighting Model Coefficients

Coefficient	Estimate	SE	T-Stat	P-value
Intercept	4.263	0.561	7.594	3.26E-14
Day Length	-0.154	0.043	-3.567	0.000362

Figure 1-5 below is a scatterplot showing average HOU for all the loggers in the M&V sample and the corresponding day length (based on New Orleans, LA). The fitted line shows a slightly negative relationship between average daily hours and day length, which an expedited pattern ex-ante. The day length coefficients for both models also confirm this relationship, as they are both negative, although neither is statistically significant.

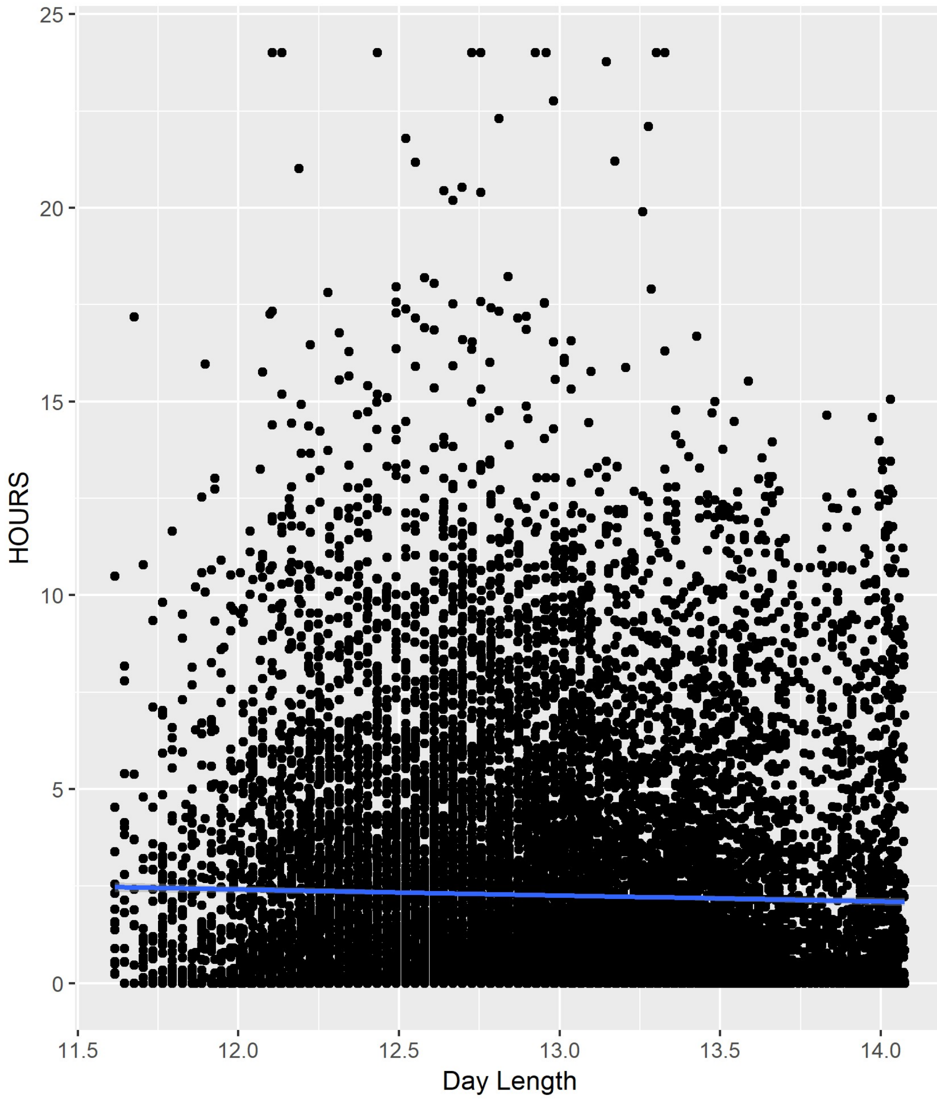

Figure 1-5 Scatterplot Showing Average Hours of Use

1.5.1.6.2 Coincident Factor

The TPE calculated the coincident factor (CF) based on actual lighting logger data in July through September between the hours of 4 and 5 pm as 11.12%.

1.5.1.6.3 Exterior Lighting

Annual hours of operation for exterior lighting, which operates during non-daylight hours, was calculated using dusk-to-dawn data taken from the National Oceanic and Atmospheric Administration website. Savings for lamps installed in exterior areas of residences should be calculated using 4,319 hours annually, and 0% CF.

1.5.1.7 Deemed Savings Values

$$kWh_{savings} = \left((W_{base} - W_{post})/1000\right) \times Hours \times ISR \times IEF_E$$

Where:

W_{base} = Based on wattage equivalent of the lumen output of the lamp (see Table 1-142,

Table 1-143, and Table 1-144)

W_{post} = Actual wattage of lamp installed

Hours = Average hours of use per year (see Table 1-149)

IEF_E = Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces (Table 1-151)

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed (see Table 1-150)

When the EISA 2007 standard goes into effect for lighting, the reduced wattage savings should be claimed for the rest of the EUL.

Table 1-149 Average Hours of Use Per Year

Installation Location	Hours
Indoor[155]	870.5
Outdoor[156]	4,319

Table 1-150 In-Service Rate (ISR)

Delivery Channel	ISR
Retail (TOS) and Direct Install[157]	0.98

Table 1-151 IEF_E for Cooling/Heating Savings

Heating Type	Interactive Effects Factor (IEF_E)[158]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[159]	0.91

[155] Indoor Hours based off aggregated lighting study performed by TPE with lighting logger data from 80 homes.

[156] Calculated using dusk-to-dawn data taken from the National Oceanic and Atmospheric Administration website.

[157] Dimetrosky, S. et al, 205, “Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.” January. ISR for upstream programs, including storage lamps installed within four years of purchase.

[158] Refer to Appendix I, Arkansas TRM V8.2 Volume 3.

[159] Unknown factors are based on ENERGY STAR Interactive effects, weighted by primary data collected on New Orleans typical HVAC arrangements.

$$kW_{savings} = \left((W_{base} - W_{post})/1000\right) \times CF \times ISR \times IEF_D$$

Where:

CF = Coincidence Factor (see Table 1-152)

IEF_D = Interactive Effects Factor to account for cooling demand savings; this factor also applies to outdoor and unconditioned spaces (see Table 1-153).

Table 1-152 Summer Peak Coincidence Factor

Lamp Location	**CF**
Indoor[160]	11.12%
Outdoor	0.00%

Table 1-153 IEF for Cooling Demand Savings

Heating Type	**Interactive Effects Factor (IEF_D)[161]**
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[162]	1.21

1.5.1.7.1 Annual kWh, Annual kW, and Lifetime kWh Savings Calculation Examples

1.5.1.7.2 Early Replacement of an Incandescent Lamp

A 9W 850lm LED is installed by an implementer in program year (PY) 2023 and directly replaces a 43W incandescent lamp (i.e., an EISA Phase I-compliant incandescent lamp). Per Table 1-142, this is eligible as early replacement and can use the 43W baseline. Other necessary inputs for calculating the kWh savings include the EUL (2.5 years), IEFD (1.25 for unknown heating/cooling type), IEFE (0.97 for unknown cooling/heating type), ISR (0.98), summer coincidence factor (0.1112), and HOU per Year (870.50 hours). All kWh values are rounded to the second decimal place.

First Year Savings:

$$kWh\ Savings = \left(\frac{[43-9]}{1000}\right) \times 870.50 \times 0.97 \times 0.98 = 28.13\ kWh\ kW\ Savings = \left(\frac{[43-\ ]}{1000}\right) \times 0.1112 \times$$

$$1.21 \times 0.98 = 0.004\ kW$$

Lifetime Savings: This LED has a rated life of 15,000 hours but is capped at 2.5 years because the incandescent lamp it is replacing will burn out within two years of the final sale date of June 30, 2023.

[160] Based off TPE light metering study, detailed in this chapter.

[161] Refer to Appendix I, Arkansas TRM V8.2 Volume 3.

[162] Unknown factors are based on ENERGY STAR Interactive effects, weighted by primary data collected on New Orleans typical HVAC arrangements.

$$Claimable\ Lifetime\ kWh\ Savings\ = 28.13\ kWh \times 2.5\ EUL\ = 70.34\ kWh$$

1.5.1.7.3 Early Replacement of a CFL Lamp

A 9W 850lm LED is installed by an implementer in program year (PY) 2023 and directly replaces a 14W CFL lamp. The CFL meets EISA Phase II efficacy requirements, but there are still marginal savings achieved via installation of an LED. The EUL is 5.5 years. The other inputs are the same as specified in the incandescent example presented above.

First Year Savings:

$$kWh\ Savings = \left(\frac{[14-9]}{1000}\right) \times 870.50 \times 0.97 \times 0.98 = 4.14\ kWh$$

$$kW\ Savings = \left(\frac{[14-9]}{1000}\right) \times 0.1112 \times 1.21 \times 0.98 = 0.0005\ kW$$

Lifetime Savings: This LED has a rated life of 15,000 hours but is capped at 5.5 years because the incandescent lamp it is replacing will burn out within five years of the final sale date of June 30, 2023.

$$Claimable\ Lifetime\ kWh\ Savings\ = 4.14\ kWh \times 2.5\ EUL\ = 22.76\ kWh$$

1.5.1.8 Incremental Cost

Prices for LEDs decrease each year. Given this, actual lighting costs should be compared to a stipulated baseline cost where feasible. If that information is not available, use $1.45

1.5.1.9 Net-to-Gross

The NTG for this measure is 62% for direct install applications.

1.5.1.10 Future Studies

At the time of authorship of this chapter, the TPE could not identify lighting options that are broadly available that are set to meet 45 lumens/watt. Available options tend to vastly exceed this (with LEDs typically exceeding 60 lumens/watt). The TPE will conduct an annual market review to address whether low-cost options designed to meet and not exceed EISA Phase II efficacy requirements become available and will reassess baselines in response to relevant market developments in this area.

1.5.2 ENERGY STAR OMNI-DIRECTIONAL LEDS (RETIRED)

This measure has been retired based upon Tier II EISA legislation. Remaining relevant information has been transferred to the ‘ENERGY STAR Lighting’ chapter.

1.5.3 ENERGY STAR DIRECTIONAL AND SPECIALTY LEDS (RETIRED)

This measure has been retired based upon Tier II EISA legislation. Remaining relevant information has been transferred to the ‘ENERGY STAR Lighting’ chapter.

1.5.4 ENERGY STAR OMNI-DIRECTIONAL COMPACT FLUORESCENT LAMPS (CFLS) (RETIRED)

This measure has been retired based upon Tier II EISA legislation. Remaining relevant information has been transferred to the 'ENERGY STAR Lighting' chapter.

1.5.5 ENERGY STAR SPECIALTY COMPACT FLUORESCENT LAMPS (CFLS) (RETIRED)

This measure has been retired based upon Tier II EISA legislation. Remaining relevant information has been transferred to the 'ENERGY STAR Lighting' chapter.

2. NON-RESIDENTIAL MEASURES

This chapter presents commercial and industrial (C&I), or non-residential measures.

2.1 Motors

2.1.1 Electronically Commutated Motors for Refrigeration and HVAC Applications

2.1.1.1 Measure Description

An electronically commutated motor (ECM) is a fractional horsepower direct current (DC) motor used most often in commercial refrigeration applications such as display cases, walk-in coolers/freezers, refrigerated vending machines, and bottle coolers. ECMs can also be used in HVAC applications, primarily as small fan motors for packaged terminal units or in terminal air boxes. ECMs generally replace shaded pole (SP) or permanent split-capacitor (PSC) motors and offer energy savings of at least 50 percent.

2.1.1.2 Baseline and Efficiency Standards

The standard motor type for this application is a shaded pole or permanent split-capacitor motor.

Any ECM up to 1 HP in size will meet the minimum requirements for both retrofit and new construction installations.

2.1.1.3 Estimated Useful Life

In accordance with DEER 2014 the EUL is 15 years.

2.1.1.4 Deemed Savings Values

The table below summarizes deemed kWh and kW by facility type for this measure. The following assumptions are used: baseline watts are 102; this is the average of SP motors (132W) and PSC motors (72W).

Hours:

- HVAC: 4,386
- Refrigeration: 8,760
- Unknown: 6,573

COP:

- HVAC: 3.45 (assumes 11.8 EER)
- Refrigeration: 1.90 (average of refrigerator and freezer)
- Unknown: 2.67

Duty Cycle:

- HVAC, medium-temp refrigeration: 1.00
- Freezer: .94
- Unknown: .985

Table 2-1 Deemed Savings by Facility Type

End-Use	HVAC		Refrigeration (Med. temps)		Refrigeration (Freezers)		Unknown	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Assembly	351	0.066	829	0.095	779	0.089	552	0.07
College	351	0.066	829	0.095	779	0.089	552	0.069
Fast Food	351	0.067	829	0.095	779	0.089	552	0.071
Full Menu	351	0.062	829	0.095	779	0.089	552	0.066
Grocery	351	0.068	829	0.095	779	0.089	552	0.071
Health Clinic	351	0.072	829	0.095	779	0.089	552	0.076
Large Office	351	0.068	829	0.095	779	0.089	552	0.071
Lodging	351	0.067	829	0.095	779	0.089	552	0.071
Religious Worship	351	0.062	829	0.095	779	0.089	552	0.065
Retail	351	0.066	829	0.095	779	0.089	552	0.069
Unknown	351	0.07	829	0.095	779	0.089	552	0.074

2.1.1.4.1 Energy Savings

$$kWh_{savings} = (W_{base} - W_{ECM}) \times Hrs \times DC \times (1 + \frac{1}{COP})/1000\, {}^{W}/_{kW}$$

Where:

kW_{base} = Power of the motor being replaced; use known wattage of motor, or if unknown, use 132W (SP motors)[163] or 72W (PSC motors)[164]

kW_{ECM} = Power of the replacement EC motor; use known wattage of motor, or if unknown, use 40W[165]

The motor's power for either Base or ECM can be calculated using the following equation if power is not known. The values for rated wattage and phase can be found on motor's nameplate:

$$kW_{motor} = \frac{Volts\ \times Amperage}{1000} \times \sqrt{Phase} \times Power\ Factor$$

Hrs = Hours of yearly operation, use 8,760 hours for refrigeration and 4,386 for HVAC

DC = Duty cycle, only use a value of 0.94 if the application of the motor being replaced is for a freezer system. This is because the freezer will complete four 20-min defrost cycles per day where the evaporator fan will not be used. Use a value of 1 if the application is for a cooler refrigeration or HVAC.

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[163] http://www.fishnick.com/publications/appliancereports/refrigeration/GE_ECM_revised.pdf

[164] The Massachusetts TRM specifies a load factor of 54% for SP motors and a load factor of 29% for PSC motors, as specified by National Resource Management (NRM). Multiplying the 132 W default value for SP motors by the ratio of PSC load factor to SP load factor results in a default PSC motor wattage of 72 watts.

[165] http://www.fishnick.com/publications/appliancereports/refrigeration/GE_ECM_revised.pdf

$PowerFactor$ = Power factor of the motor, if not known an average value of 0.55 can be used for ECM in refrigeration, 0.7 for ECM in HVAC, and 0.85 for base motor in both applications.[166]

COP = Coefficient of Performance for the motor's operation based on application. COP value depends on the end temperature of the refrigeration process. The COP values to use for refrigeration analysis are 1.3 for freezers and 2.5 for coolers[167]. For HVAC, use the EER value from install spec sheet and the conversion COP = EER/3.412.

2.1.1.4.2 Demand Reductions

$$kW_{HVAC\ reduction} = (kW_{base} - kW_{ECM}) \times CF \ \times (1 + \frac{1}{COP})$$

$$kW_{Refrigeration\ reduction} = (kW_{base} - kW_{ECM}) \times DC \ \times CF \ \times (1 + \frac{1}{COP})$$

Where:

CF = Coincidence Factor, use values from Table 2-2 for HVAC applications; default value of 1.0 for refrigeration applications[168]

DC = Duty cycle, only use a value of 0.94 if the application of the motor being replaced is for a freezer refrigeration. This is because the freezer will complete four 20-min defrost cycles per day where the evaporator fan will not be used. Use a value of 1 if the application is for a cooler refrigeration of HVAC.

Table 2-2 Commercial Coincidence Factors by Building Type[169]

Building Type	Coincidence Factor
Assembly	0.82
College	0.84
Fast Food	0.78
Full Menu	0.85
Grocery	0.90
Health Clinic	0.85
Large Office	0.84
Lodging	0.77
Religious Worship	0.82
Retail	0.88
School	0.71
Small Office	0.84

[166] http://www.ecw.org/sites/default/files/230-1.pdf

[167] PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, pp. 4-103 -4-106.

[168] CF set to 1.0 for refrigeration applications based on annual run-time assumption of 8,760 hours

[169] Values for Assembly and Religious Worship building types developed using an adjustment factor derived through a comparison of average CFs for College/University and Assembly/Religious Worship building types from the Texas state Technical Reference Manual. College/University was selected as a reference building type due to average alignment with Assembly/Religious worship building types in other TRMs, inclusion of a summer session, and increased evening usage.

2.1.1.5 Incremental Cost

Incremental cost by end-use type is $177.[170]

2.1.1.6 Future Studies

There are no future studies planned for this measure at this time.

[170] Difference in the fully installed cost ($468) for ECM motor and controller, listed in Work Paper PGE3PREF126, "ECM for Walk-In Evaporator with Fan Controller," June 20,2012, and the measure cost specified in 4.6.6 ($291)

2.1.2 PREMIUM EFFICIENCY MOTORS

2.1.2.1 Measure Description

Currently a wide variety of NEMA premium efficiency motors from 1-500 HP are available. Deemed values for demand and energy savings associated with this measure must be for motors with an equivalent operating period (hours x Load Factor) over 1,000 hours.

2.1.2.2 Baseline and Efficiency Standards

2.1.2.2.1 Replace on Burnout

The EISA 2007 Sec 313 adopted the new federal standard and required that electric motors that are manufactured and sold in the United States meet the new standard by December 19, 2010. The standards can also be found in sections 431.25(c)-(f) of the Code of Federal Regulations (10 CFR Part 431).

With these changes, any 1-500 HP motor bearing the “NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) has already adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

In addition to the new standards for 200-500 HP motors, additional motors in the 1-200 HP range are now included in the NEMA Premium standard. These new motors are referred to as “General Purpose Electric Motors (Subtype II)”. These additional types of motors include:

- U-Frame Motors
- Design C Motors
- Close-coupled pump motors
- Footless motors
- Vertical solid shaft normal thrust (tested in a horizontal configuration)
- 8-pole motors
- All poly-phase motors with voltages up to 600 volts other than 230/460 volts (230/460-volt motors are covered by EPAct-92)

2.1.2.2.2 Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct), as listed in

NEMA Premium Efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for both replace on burnout and early retirement projects exceeds that listed in Table 2-3.

The maximum age of an eligible for early retirement is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Table 2-3 Premium Efficiency Motors – Replace on Burnout Baseline[171]

hp	$\eta_{baseline, Open Motors}$			$\eta_{baseline, Closed Motors}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	87.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	94.1
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	94.5	95.4	94.5	95.0	95.0	95.4
300	94.5	95.4	95.0	95.0	95.4	95.4
350	94.5	95.4	95.0	95.0	95.4	95.4
400	n/a	95.4	95.4	n/a	95.4	95.4
450	n/a	95.8	95.8	n/a	95.4	95.4
500	n/a	95.8	95.8	n/a	95.8	95.4

Table 2-4 Premium Efficiency Motors – Early Retirement Baseline[172]

hp	$\eta_{baseline, Open Motors}$			$\eta_{baseline, Closed Motors}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
50	93.0	93.0	92.4	93.0	93.0	92.4

[171] Federal Standards for Electric Motors, Table 1: Full Load Efficiencies for Standard Electric Motors, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50. Accessed June 2013.

[172] Federal Standards for Electric Motor Efficiency from the Federal Energy Policy Act of 1992 (EPACT). http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/e-pact92.pdf . Accessed June 2013.

60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0
250	94.5	95.4	94.5	95.0	95.0	95.4
300	94.5	95.4	95.0	95.0	95.4	95.4
350	94.5	95.4	95.0	95.0	95.4	95.4
400	n/a	95.4	95.4	n/a	95.4	95.4
450	n/a	95.8	95.8	n/a	95.4	95.4
500	n/a	95.8	95.8	n/a	95.8	95.4

2.1.2.3 *Estimated Useful Life*

According to DEER 2014 the EUL is 15 years.

2.1.2.4 *Deemed Savings Values*

Actual motor operating hours are expected to be used to calculate savings. Every effort should be made to capture the estimated operating hours. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 2-5 or Table 2-6.

Table 2-5 Premium Efficiency Motors – Operating Hours, Load Factor (HVAC)

Building Type	Load Factor[173]	HVAC Fan Hours[174]
College/ University	0.75	4,581
Fast Food Restaurant		6,702
Full Menu Restaurant		5,246
Grocery Store		6,389
Health Clinic		7,243
Lodging		4,067
Large Office (>30k SqFt)		4,414
Small Office (≤30k SqFt)		3,998
Retail		5,538
School		4,165

[173] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. Accessed May 2013.http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf .

[174] Fan schedule operating hours taken as the average of operating hours from the Connecticut, Maine, and Pennsylvania Technical Reference Manuals: CL&P and UI Program Savings Documentation for 2008 Program Year, Connecticut Lighting & Power Company; Efficiency Maine Technical Reference User Manual No. 2007-1; Pennsylvania Utility Commission Technical Reference Manual June 2012.

Table 2-6 Premium Efficiency Motors – Operating Hours, Load Factor (Non-HVAC)

Industrial Processing	Load Factor[175]	Hours[176]					
		Chem	Paper	Metals	Petroleum Refinery	Food Production	Other
1-5 hp	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20 hp	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50 hp	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100 hp	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200 hp	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500 hp	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000 hp		7,495	7,255	7,750	5,934	5,260	8,157
>1,000 hp		7,693	8,294	7,198	6,859	6,240	2,601

2.1.2.4.1 Measure/Technology Review

Premium efficiency motors are a mature technology, and a wealth of information exists on the measure. A summary of the key resources is included in Table 2-7.

Table 2-7 Premium Efficiency Motors- Review of Motor Measure Information

Resource	Notes
PG&E 2006[177]	Savings for common motor retrofits
Xcel Energy 2006[178]	Program level savings estimates for high-efficiency motors
DEER 2014[179]	Savings and cost for common motor retrofit
KEMA 2010[180]	Motor savings included in comprehensive potential study
CEE[181]	Industrial motor efficiency initiative
RTF[182]	Savings for common motor retrofit
ITP[183]	Savings for common motor retrofit
NPCC 2010[184]	Market information and overview of savings potential
NEMA 2009[185]	Minimum efficiency level for premium efficiency motors

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175 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. Accessed May 2013. www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mTRMkt.pdf

176 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. Accessed May 2013. www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mTRMkt.pdf

177 Pacific Gas & Electric (PG&E). 2006. *2006 Motors Unit Savings Workpapers.V14.*

178 Xcel Energy. 2006. 2007/2008/2009 *Triennial Plan Minnesota Natural Gas and Electric Conversation Improvement Program.*

179 Consortium of Energy Efficiency. Commercial Lighting Program. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists

180 KEMA. 2010. *Measurement Manual*. Prepared for Tennessee Valley Authority.

181 Consortium for Energy Efficiency. 2010. Industrial Motors & Motor Systems. http://library.cee1.org/content/cee-2012-summary-member-programs-motors-motor-systems

182 Regional Technical Forum (RTF). http://rtf.nwcouncil.org/measures/

183 Industrial Technologies Program http://www1.eere.energy.gov/industry/

184 Northwest Power and Conservation Council (NPCC). 2010. *The Sixth Northwest Electric Power and Conservation Plan.*

185 National Electrical Manufacturers Association (NEMA). 2009. *Motors and Generators. NEMA* MG 1-2009.

MotorMaster+[186]	Comprehensive resource of motor efficiencies and tools to calculate savings
PacifiCorp 2009[187]	Motor savings included in comprehensive potential study

Deemed electric motor demand and energy savings should be calculated by the following formulas.

2.1.2.4.2 Replace on Burnout (ROB)

$$kWh_{savings} = Rated\ Horsepower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times hours$$

$$kW_{reduction} = Rated\ Horsepower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times CF$$

Where:

$Rated\ HorsePower$ = Nameplate horsepower data of the motor

$Conversion\ Factor$ = 0.746 kW/hp

LF = Estimated load factor for the motor; if load factor is not available, deemed load factors in Table 2-5 or Table 2-6 can be used.

$\eta_{baseline}$= Efficiencies listed in Table 2-3 should be used (in the case of rewound motors, in situ efficiency may be reduced by a percentage as found in Table 2-9)

η_{post}= Efficiency of the newly installed motor

Hours= Estimated annual operating hours for the motor; if unavailable, annual operating hours in Table 2-5 or Table 2-6 be used.

CF = Coincidence Factor = 0.74[188]

2.1.2.4.3 Early Retirement (ER)

Annual kWh and kW savings must be calculated separately for two time periods:

- The estimated remaining life (RUL, see Table 2-8) of the equipment that is being removed, designated the first N years, and
- Years EUL - N through EUL, where EUL is 15 years.

[186] MotorMaster+. 2010. https://www1.eere.energy.gov/manufacturing/tech_assistance/software_motormaster.html

[187] PacifiCorp. 2009. *FinAnswer Express Market Characterization and Program Enhancements Utah Service Territory.*

[188] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf Accessed May 2013.

Table 2-8 Premium Efficiency Motors – Remaining Useful Life (RUL) of Replaced Systems[189,190]

Age of Replaced System (Years)	RUL (Years)
5	10.0
6	9.1
7	8.2
8	7.3
9	6.5
10	5.7
11	5.0
12	4.4
13	3.8
14	3.3
15	2.8
16	2.5
17	2.2
18	1.9
19	0.0

For the first N years:

$$kWh_{savings} = Rated\ Horsepower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times hours$$

$$kW_{reduction} = Rated\ Horsepower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times CF$$

Where:

$Rated\ HorsePower$ = Nameplate horsepower data of the motor

$Conversion\ Factor$ = 0.746 kW/hp

LF = Estimated load factor for the motor; if load factor is not available, deemed load factors in Table 2-5 or Table 2-6 can be used

$\boldsymbol{\eta_{baseline}}$= In situ efficiency of the baseline motor; if unavailable, efficiencies listed in Table 2-3 can be used (in the case of rewound motors, in situ efficiency may be reduced by a percentage as found in Table 2-9).

η_{post}=Efficiency of the newly installed motor

Hours= Estimated annual operating hours for the motor; if unavailable, annual operational hours in Table 2-5 or Table 2-6 can be used

[189] Because the motor EUL is 15 years, it is consistent for use with the RUL determined using the Weibull distribution offered in the DOE's Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls".
http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

[190] Use of the early retirement baseline is capped at 18 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 18 years should use the ROB baseline.

CF = Coincidence Factor = 0.74[191]

Table 2-9 Rewound Motor Efficiency Reduction Factors[192]

Motor Horsepower	Efficiency Reduction Factor
<40	0.01
≥40	0.005

For Years EUL - N through EUL: Savings should be calculated exactly as they are for replace on burnout projects, referred to as $kWh_{SavingsROB}$.

Total lifetime savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations.

$$Lifetime\ kWh\ savings\ for\ Early\ Retirement\ Projects$$
$$= (kWh_{savingsRUL} \times RUL) + [kWh_{savingsROB} \times (EUL - RUL)]$$

Where:

RUL= The Remaining Useful Life of the equipment, in years, see Table 2-8.

EUL = The Estimated Useful Life of the equipment, deemed at 15 years

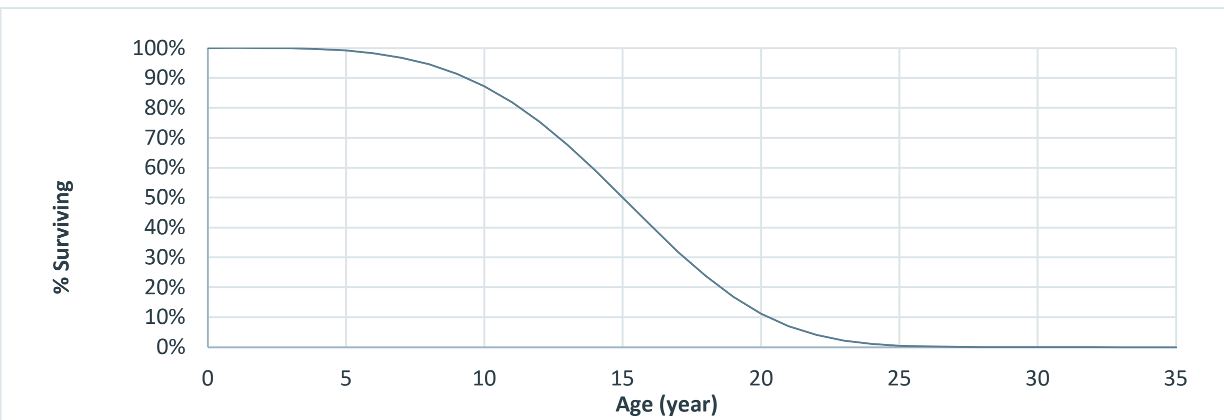

Figure 2-1 Survival Function for Premium Efficiency Motors[193]

The method used for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 2-1. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The

[191] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf. Accessed May 2013.

[192] U.S. DOE, Preliminary Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 2.7.2 Impact of Repair on Efficiency." July 23, 2012. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50. Download TSD at: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/em_preanalysis_tsdallchapters.pdf .

[193] Source: Weibull distribution based on the Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls".

http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

2.1.2.5 Incremental Cost

Table 2-10 Motor Incremental Cost by Size[194]

Motor Horsepower	Incremental Cost
5	$918
7.5	$918
10	$918
15	$918
20	$933
25	$1,012
30	$1,091
40	$1,300
50	$1,497
60	$1,796
75	$1,943
100	$2,389
125	$3,087
150	$3,784
200	$4,555
250	$4,655
300	$4,755
350	$4,855
400	$4,955
450	$5,055
500	$5,155

2.1.2.6 Future Studies

In Energy Smart and other utility portfolios, this is typically a low-volume measure. High-saving motor applications are more commonly found in custom applications. As a result, the TPE does not advise funding future measure research, and recommend that the measure receive updated only when applicable codes or standards warrant it.

[194] Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL, March 28, 2011,TetraTech

2.2 Water Heating

2.2.1 WATER HEATER REPLACEMENT

2.2.1.1 Measure Description

This measure includes:

- The replacement of electric water heaters in commercial buildings by high efficiency electric resistance water heaters
- The replacement of electric water heaters in commercial buildings by heat pump water heaters
- The replacement of small (< 12 kW) electric water heaters in commercial buildings by electric tankless water heaters

Commercial water heater savings are measured per location and are calculated for new construction or replace-on-burnout. Storage tank models and tankless models, utilizing electricity are eligible.

2.2.1.2 Baseline and Efficiency Standards

The baseline standards for IECC 2009 are detailed in Table 2-11.

Table 2-11 Water Heaters – Water Heater Performance Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[195],[196]	Test Procedure
Water heaters, electric	≤ 12 kW	Resistance	IECC 2009: 0.97 - 0.00132V, EF	DOE 10 CFR Part 430
	> 12 kW		1.73V + 155, SL (Btu/hr)	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat Pump	0.93 - 0.00132V, EF	DOE 10 CFR Part 430

For smaller water heaters where energy factor (EF) is used, EF considers the overall efficiency, including combustion efficiency and standby loss (SL). Regulated by DOE as “residential water heaters”, these smaller water heaters manufactured on or after April 16, 2015, must comply with the amended standards found in the Code of Federal Regulations, 10 CFR 430.32(d), detailed in Table 2-12.

[195] Energy factor (EF) and thermal efficiency (Et) are minimum requirements. In the EF equation, V is the rated volume in gallons.

[196] Standby loss (SL) is the maximum Btu/hr based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, Q is the nameplate input rate in Btu/hr. In the SL equation for electric and gas water heaters and boilers, V is the rated volume in gallons.

Table 2-12 Small Commercial Water Heaters – Standards and their Compliance Dates[197]

Product Class	Energy Factor as of April 16, 2015
Electric Water Heater	For Vs < 55 gallons: 0.960 – (0.0003V) For Vs > 55 gallons: 2.057 – (0.00113V)

For larger water heaters, thermal efficiency (Et) is used and does not factor into SL; however, a limitation on SL is noted.

The savings calculations consider the minimum water heater efficiency requirements listed in Table 2-11 to be the baseline.

2.2.1.3 Estimated Useful Life

The EUL of this measure is dependent on the type of water heating. According to DEER 2014, the following measure lifetimes should be applied.[198]

- 10 years for Heat Pump Water Heater (HPWH)
- 15 years for High Efficiency Commercial Storage Water Heater
- 20 years for Commercial Tankless Water Heater

2.2.1.4 Deemed Savings Values

Program staff should endeavor to collect unit-specific information to support energy savings calculations. However, if such data is not available the tables below may be used. The assumptions are as follows:

- Electric Resistant Water Heating:
    - Assume full facility load met by a series of 50-gallon units
    - Resulting baseline EF is .945
    - Efficient EF is .98
- Heat Pump Water Heating:
    - Assume full facility load met by a series of 200-gallon units
    - Resulting baseline EF is 2.00
    - Efficient EF is 2.20

[197] Where V is the rated storage volume, which equals the water storage capacity of a water heater (in gallons), as certified by the manufacturer.

[198] http://www.deeresources.com/files/deer2008exante/downloads/EUL_Summary_10-1-08.xls

Table 2-13 Deemed Savings: Electric Resistant Water Heaters

Building Type	Annual Hot Water/1,000 ft.^{2}	Average ft.^{2}	kWh Savings	kW Savings
Convenience Store	4,255	2,800	50	0.0057
Education	6,746	45,000	1,267	0.1446
Grocery	646	21,300	57	0.0065
Health	22,734	72,000	6,829	0.7796
Large Office	1,686	95,000	668	0.0763
Large Retail	1,254	80,000	419	0.0478
Lodging	27,399	76,500	8,745	0.9983
Nursing	28,279	72,000	8,495	0.9697
Restaurant	41,224	3,850	662	0.0756
Small Office	1,428	6,000	36	0.0041
Small Retail	5,660	6,400	151	0.0172
Warehouse	1,148	14,000	67	0.0076
Other Commercial	3,652	4,000	61	0.0070

Table 2-14 Deemed Savings: Heat Pump Water Heaters

Building Type	Annual Hot Water/1,000 ft.^{2}	Average ft.^{2}	kWh Savings	kW Savings
Convenience Store	4,255	2,800	60	0.0068
Education	6,746	45,000	1,523	0.1739
Grocery	646	21,300	69	0.0079
Health	22,734	72,000	8,214	0.9376
Large Office	1,686	95,000	804	0.0917
Large Retail	1,254	80,000	503	0.0575
Lodging	27,399	76,500	10,518	1.2007
Nursing	28,279	72,000	10,217	1.1663
Restaurant	41,224	3,850	796	0.0909
Small Office	1,428	6,000	43	0.0049
Small Retail	5,660	6,400	182	0.0207
Warehouse	1,148	14,000	81	0.0092
Other Commercial	3,652	4,000	73	0.0084

Typically, two types of ratings exist for water heaters: energy factor (EF) for smaller units, and thermal efficiency (Et) for larger water heaters. Large heat pump water heaters may also be rated by a third method, coefficient of performance (COP), which is the ratio of heat energy output to electrical energy input and is analogous to thermal efficiency. EF includes standby losses, while Et and COP only consider the amount of energy required to heat the water. Therefore, in the formulas below, the baseline and energy efficiency measure may be compared for each type of water heater.

The electricity savings for this measure are highly dependent on the estimated hot water consumption, which varies significantly by building type. The following tables list estimated hot water consumption for various building types by number of units, occupants, or building size.

Table 2-15 Hot Water Requirements by Building Type and System Capacity[199]

Building Type	Annual Hot Water Consumption Per Gallon of Rated Capacity
Convenience Store	489
Education	526
Grocery	489
Health	730
Large Office	474
Large Retail	489
Lodging	663
Nursing	623
Restaurant	577
Small Office	474
Small Retail	489
Warehouse	316
Other Commercial	316

Table 2-16 converts the values from Table 2-15 into per-1,000 square feet value based on the same CBECS 2012 data.

Table 2-16 Hot Water Requirements by Building Size[200]

Building Type	Annual Hot Water Consumption Per 1,000 SQFT
Convenience Store	4,255
Education	6,746
Grocery	646
Health	22,734
Large Office	1,686
Large Retail	1,254
Lodging	27,399
Nursing	28,279
Restaurant	41,224
Small Office	1,428
Small Retail	5,660
Warehouse	1,148
Other Commercial	3,652

2.2.1.4.1 Small Electric Storage Water Heaters

As small (≤ 12 kW) electric water heaters are typically rated by EF, this section of this measure includes both higher-efficiency resistance water heaters and small (≤ 24 amps and ≤ 250 volts) heat pump water heaters. Deemed annual energy savings for small electric water heater replacements are calculated by the following formula.

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199 Methodology based on TPE analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West South Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80.

200 This is a conversion of the capacity values to a per-square foot value based on average building size in the CBECS.

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times (EF_{pre} - EF_{post})}{3{,}412\ Btu/kWh}$$

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb.·°F

V = Average annual hot water use (gallons). See for Table 2-15 and Table 2-16

estimates of water consumption.

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F[201]

EF_{pre} = Calculated energy factor of existing water heater, based on the water heater tank volume; Table 2-11.

EF_{post} = Energy Factor of replacement water heater (taken from nameplate); the replacement water heater may be either a high efficiency electric storage water heater or a heat pump water heater

$Conversion\ Factor$ = 3,412 Btu/kWh

Deemed demand reduction for small electric water heater replacements are calculated by formula as follows:

$$kW_{reduction} = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times (EF_{pre} - EF_{post})}{3{,}412\ Btu/kWh} \times 1/24 \times 1/365$$

Where all variables are the same as in the energy equation and the average hourly ratio is a best estimate of peak coincidence for commercial hot water heater replacements.[202]

2.2.1.4.2 Large Electric Storage Water Heaters

Large (> 12 kW) electric resistance water heaters can be replaced with heat pump water heaters.

For replacement of large electric resistance water heaters with a heat pump water heater, deemed annual energy savings are calculated by the following formula.

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[201] Calculated using area groundwater data. See Volume 3, *Appendices.*

[202] For replacement with high-efficiency electric storage water heaters and tankless water heaters, the 1/24 peak coincidence factor accurately reflects that improvements in the efficiency of electric resistance storage water heaters are driven almost entirely by reductions in storage losses (conversion efficiency, RE, is close to 1), which are distributed evenly throughout the day.

$$kWh_{Savings} = \frac{\rho \times C_p \times GPD \times (T_{SetPoint} - T_{Supply}) \times \left(\frac{1}{E_{t,base}} - \frac{1}{COP_{post}}\right) \times Days/Year}{3{,}412\ Btu/kWh}$$

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Average daily hot water use (gallons). See Table 2-15 and Table 2-16 for estimates of water consumption

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average New Orleans area supply water temperature, 74.8°F

$E_{t,base}$ = .98

COP_{post} = Coefficient of performance of new heat pump water heater

2.2.1.4.3 Demand Savings

Deemed demand reduction for replacement of large electric resistance water heaters with a heat pump water heater are calculated by the following formula.

$$kW_{reduction} = \frac{\rho \times C_p \times GPD \times (T_{SetPoint} - T_{Supply}) \times (EF_{pre} - EF_{post})}{3{,}412\ Btu/kWh} \times 1/24$$

Where all variables are the same as in the energy equation and the 1/24 ratio is a best estimate of peak coincidence for commercial hot water heater replacements.

2.2.1.5 Incremental Cost

The incremental cost for heat pump water heaters are as follows[203]:

- 50 Gallon: $1,050
- 80 Gallon: $1,050
- 100 Gallon: $1,950

2.2.1.6 Future Studies

Current DHW load estimates are based off of CBECS data for the West South region. If there is significant participation, we recommend updating with actual participant loads. Further, a study of commercial DHW setpoints would be warranted.

[203] Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I.xls" for more information.

2.2.2 FAUCET AERATORS

2.2.2.1 Measure Description

This measure consists of installing low-flow faucet aerators in commercial facilities which reduce water usage and save energy associated with heating the water.

2.2.2.2 Baseline and Efficiency Standards

The baseline faucet aerators are assumed to have a flow rate of 2.2 gallons per minute.[204] To qualify for this measure, the flow rate of installed low-flow faucet aerators must be ≤1.5 gallon per minute.[205]

2.2.2.3 Estimated Useful Life

The EUL of this measure is 10 years according to DEER 2014.

2.2.2.4 Deemed Savings Values

Table 2-17 presents the savings for 1.5, 1.0, and 0.5 GPM aerators. The “unknown” category being an average of the listed facility types.

Table 2-17 Faucet Aerator Deemed Savings

Building Type	Days per Year	Minutes per Day	kWh Savings			kW Savings		
			1.5 GPM	1.0 GPM	0.5 GPM	1.5 GPM	1.0 GPM	0.5 GPM
Hospital, nursing home	365	3	86	148	210	0.0071	0.0122	0.0172
Dormitory	274	30	648	1,111	1,574	0.0946	0.1622	0.2298
Multifamily	365	3	86	148	210	0.0071	0.0122	0.0172
Lodging	365	3	86	148	210	0.0047	0.0081	0.0115
Commercial	250	30	591	1,014	1,436	0.1892	0.3244	0.4596
School	200	30	473	811	1,149	0.1183	0.2028	0.2873
Unknown	303	17	329	563	798	0.0702	0.1203	0.1704

Annual kWh electric and peak kW savings can be calculated using the following equations:

$$kWh\ Savings = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times Days/Year}{3{,}412\ Btu/kWh}$$

$$kW_{reduction} = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times P}{3{,}412\,\frac{Btu}{kWh}}$$

[204] Maximum flow rate for lavatories and aerators set in Federal Energy Policy Act of 1992 and codified at 2.2 GPM at 60 psi in 10CFR430.32.

[205] “High-Efficiency Lavatory Faucet Specification.” WaterSense. EPA. October 1, 2007. http://www.epa.gov/watersense/partners/faucets_final.html

Table 2-18 Commercial Aerator Savings Parameters

Parameter	Description	Value
F_B	Average baseline flow rate of aerator (GPM)	2.2
F_P	Average post measure flow rate of aerator (GPM)	≤1.5
Days/Year	Annual Building type operating days for the applications:	
	1.Hospital, Nursing home	365
	2. Dormitory	274[206]
	3. Multifamily	365
	4. Lodging	365
	5. Commercial	250
	6. School	200
T_{supply}	Average supply (cold) water temperature (°F)	74.8
T_H	Average mixed water (after aerator) temperature (°F)	120[207]
U	Baseline water usage duration, following applications	
	1. Hospital, Nursing home	3 min/day/unit
	2. Dormitory	30 min/day/unit
	3. Multifamily	3 min/day/unit
	4. Lodging	3 min/day/unit
	5. Commercial	30 min/day/unit
	6. School	30 min/day/unit
ρ	Unit conversion: 8.33 pounds/gallon	8.33
C_p	Heat capacity of water - 1 Btu/lb. °F	1
E_t	Thermal Efficiency of water heater	Default Values: 0.98 for ER, 2.2 (COP) for HP
	Hourly water consumption during peak period as a fraction of average daily consumption for applications:	
	1. Hospital, Nursing home	0.03
	2. Dormitory	0.04
	3. Multifamily	0.03
	4. Lodging	0.02
	5. Commercial	0.08
	6. School	0.05

Example: The following is an electric example calculation for a 1.0 GPM aerator replacement for a school using the previous equations and information. Example electric savings are based on heating water with a conventional electric resistance storage tank water heater.

[206] Dormitories with few occupants in the summer: 365 x (9/12) = 274.

[207] Calculated based on area groundwater temps.

$\Delta kWh = [8.33\ x\ 30 minday\ x\ (2.2{-}1.0)\ GPM\ x\ (120{-}74.8°\text{F})\ x\ (1/.98) * 200 dayyear]/3412$

$Btu/kWh = 811\ kWh$

$\Delta kW = [8.33\ x\ 30 minday\ x\ (2.2{-}1.0)\ GPM\ x\ (120{-}74.8°\text{F})\ \text{x}\ (1/.98)\ x\ .05]/3412\ Btu/kWh$

$= 0.202\ kW$

2.2.2.5 Incremental Cost

Program-actual costs should be used where available. If not available, the incremental cost of a faucet aerator is $8.00[208].

2.2.2.6 Future Studies

If there is significant participation, we recommend updating with actual participant loads. Further, a study of commercial DHW setpoints would be warranted.

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

2.2.3 LOW-FLOW SHOWERHEADS

2.2.3.1 *Measure Description*

This measure consists of removing existing showerheads and installing low-flow showerheads at the following commercial building types: hospitals and nursing homes, lodging facilities, commercial facilities (offices or other commercial buildings in which showers are provided for employees), fitness centers, and schools.[209]

2.2.3.2 *Baseline and Efficiency Standards*

The savings values for low-flow showerheads are for the retrofit of existing operational showerheads with a flow rate of 2.5 gallons per minute (GPM) or higher.[210] Facilities must have electric water heating to qualify for this measure.

The baseline showerhead has an average flow rate of 2.5 GPM based on the current DOE standard. To qualify for the deemed savings, replacement showerheads must have a flow rate of 2.0 GPM or less.[211]

Existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. Low flow shower heads that are easily tampered with should not be used. Removed showerheads shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Table 2-19 Low-Flow Showerhead – Baseline and Efficiency Standards

Measure	New Showerhead Flow Rate[212] (GPM)	Existing Showerhead Baseline Flow Rate (GPM)
2.0 GPM showerhead	2.0	2.5
1.75 GPM showerhead	1.75	2.5
1.5 GPM showerhead	1.5	2.5

The U.S. EPA WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM[213].

2.2.3.3 *Estimated Useful Life*

The EUL of this measure is 10 years according to DEER 2014.

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[209] This measure draws from multiple sources, including the residential low flow showerhead measure and commercial faucet aerator measure. Information specific to hot water use in commercial market sectors was drawn from CLEAResult, Inc. draft white paper: *Work Papers for Low Flow Shower Heads with Gas or Electric Water Heaters: Savings Calculation Methodology for Application in Arkansas Energy Efficiency Programs*, February 2014.

[210] 10 CFR Part 430, Energy Conservation Program for Consumer Products: Test Procedures and Certification and Enforcement Requirements for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances; Final Rule, March 1998. Online. Available: http://www.regulations.gov/#!documentDetail;D=EERE-2006-TP-0086-0003.

[211] The U.S. Environmental Protection Agency (EPA) WaterSense Program has a thorough specification for showerheads that meet a maximum flow rate of 2.0 gpm. The specification is available on the EPA website at: www.epa.gov/WaterSense/partners/showerhead_spec.html

[212] All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

[213] http://www1.eere.energy.gov/femp/program/waterefficiency_bmp7.html.

2.2.3.4 Deemed Savings Values

Table 2-20 through Table 2-22 present the default savings for 1.5, 1.0, and 0.5 GPM aerators, respectively. The results are presented by facility type, with the "unknown" category being an average of the listed facility types. For the "unknown" facility type, the values are the average of all other facilities excluding Fitness Center; this facility is a high outlier in savings and the TPE has opted to exclude it from the "unknown" category due to the risk of this facility skewing results.

Table 2-20 Showerhead Deemed Savings – 2.0 GPM

Building Type	Hot Water Reduction	kWh Savings	kW Savings
Hospital / Nursing Home	232	26.11	0.7844
Hospitality	326	36.67	0.7345
Commercial Employee Shower	253	28.46	2.2798
Fitness Center	5203	584.96	46.8656
Schools	344	38.72	1.9390
Unknown	288.75	32.49	1.4642

Table 2-21 Showerhead Deemed Savings – 1.75 GPM

Building Type	Hot Water Reduction	kWh Savings	kW Savings
Hospital / Nursing Home	348	39.16	1.1766
Hospitality	489	55.01	1.1017
Commercial Employee Shower	380	42.68	3.4197
Fitness Center	7,804	877.44	70.2984
Schools	517	58.09	2.9085
Unknown	433.5	48.73	2.1963

Table 2-22 Showerhead Deemed Savings – 1.5 GPM

Building Type	Hot Water Reduction	kWh Savings	kW Savings
Hospital / Nursing Home	464	52.22	1.5688
Hospitality	652	73.34	1.4690
Commercial Employee Shower	506	56.91	4.5596
Fitness Center	10,405	1169.93	93.7312
Schools	689	77.45	3.8780
Unknown	577.75	64.98	2.9284

Energy and demand reduction are estimated as functions of the reduction in daily water use (ΔV) attributable to installation of low flow showerheads in a given commercial building type. Reduction in water use and deemed savings calculations make use of the data provided by building type in Table 2-23 and the New Orleans average water main temperature, 74.8.

Table 2-23 Showers per Day (per Showerhead) and Days of Operation by Building Type

Building Type	Showers/Day	Days/Year
Hospital/Nursing Home	0.89	365
Hospitality	1.25	365
Commercial	0.97	250
Fitness Center	19.94	365
School	1.32	200

2.2.3.4.1 Estimated Hot Water Usage Reduction

Reduction in annual hot water usage is estimated based on the typical duration of a shower and the expected number of showers per year for an installed showerhead in a given facility.

Reduction in daily hot water consumption is estimated on a per-showerhead basis using the following formula.

$$\Delta V = U \times N \times (Q_B - Q_P) \times F_{HW}$$

Where:

ΔV = Reduction in daily hot water use in gallons per day (GPD)

U = Typical shower duration of 7.8 (minutes/shower)

N = Number of showers per day (per showerhead); (N) is a function of the commercial building type, values for N are provided in Table 2-25.

Q_B = Baseline showerhead flow rate, 2.5 GPM

Q_P = Flow rate of installed showerhead (in GPM)

F_{HW} = Hot Water Fraction (share of water flowing through showerhead from the water heater, %)

The fraction of hot water is a function of the inlet water temperature (T_{supply}) the temperature of water from the hot water heater (T_{HW} = 120 ^oF), and the desired temperature at the showerhead (T_{mixed} = 105 ^oF).

Reduction in daily hot water usage is provided for reference in Table 2-24.

Table 2-24 Reduction in Daily Hot Water Usage, ΔV (GPD)

Flow Rate of Installed Showerhead	Building Type				
	Hospital / Nursing home	Hospitality	Commercial - Employee Shower	Fitness Center	Schools
2.0 GPM	232	326	253	5,203	344
1.75 GPM	348	489	380	7,804	517
1.5 GPM	464	652	506	10,405	689

2.2.3.4.2 Energy Savings

The deemed energy savings are calculated as follows:

$$kWh_{savings} = \frac{\rho \times C_P \times \Delta V \times (T_{HW} - T_{Supply}) \times \left(\frac{1}{E_t}\right)}{Conversion\ Factor}$$

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb·°F

ΔV = gallons of hot water saved per day (GPD, calculated above identified in Table 2-24)

T_{HW} = Temperature to which water is heated in the water heater, 120°F

T_{Supply}= Average inlet water temperature (water mains temperature), 74.8.

E_t = Thermal efficiency of water heater (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters[214]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/therm for gas water heating

2.2.3.4.3 Demand Savings

The deemed demand reduction is calculated as follows.

$$kW_{reduction} = \frac{\rho \times C_P \times \Delta V \times (T_{HW} - T_{Supply}) \times \left(\frac{1}{E_t}\right)}{Conversion\ Factor}\ x\ P$$

[214] Default values based on median recovery efficiency of commercial water heaters by fuel type in the AHRI database as cited in previous iterations of the AR TRM. Online: available at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Where:

All inputs are the same as described in the Energy Savings Equation; and

P = electric peak coincidence factors, as provided for each building type in Table 2-25. [215]

Parameters for savings calculations can be found in the table below.

Table 2-25 Parameters for Annual Energy and Peak Demand Savings Calculations

Parameter	Description	Value
U	Baseline shower duration[216] (min/shower)	7.8
N	Number of showers per day per showerhead[217] Hospital, Nursing Home Lodging Commercial 24-Hour Fitness Center Schools	 0.89 1.25 0.97 19.94 1.32
Q_B	Average baseline flow rate of showerhead (GPM)	2.5
Q_P	Flow rate of installed showerhead (GPM)	≤ 2.0
F_{HW}	Share of water flowing through showerhead coming from the water heater (%)	66.9
ρ	Density of water (lb./gal)	8.33
Cp	Heat capacity of water (Btu/lb.-ºF)	1
T_{HW}	Temperature to which water is heated by the water heater (ºF)[218]	120
T_{supply}	Average supply (cold) water temperature (ºF)	74.8
E_t	Thermal Efficiency of hot water heater: Conventional Electric Storage Water Heater Heat Pump Water Heater (COP) Gas Storage Water Heater	 0.98 2.2 0.80

[215] For all building types except 24-Hour Fitness Centers, derived from *ASHRAE Handbook 2011. HVAC Applications.* American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The peak factor is the ratio of the gallons of hot water used during the peak times of 3pm to 6pm, to the total amount of hot water used during the day. 24-Hour Fitness Center is assigned the same value as Commercial.

[216] Hendron, R., & Engebrech, C. 2010, "*Building America Research Benchmark Definition, Updated December 2009, Technical Report NREL/TP-550-47246,* January. National Renewable Energy Laboratory The average shower duration taken from Table 12, p. 20.

[217] Primary source is Northwest Power and Conservation Council ProCost V2.3. The number of showers per day per showerhead is back-calculated for hospitals and nursing homes, lodging and commercial building types, coefficients from annual minutes per showerhead estimates. N = (Minutes/year) x (year/days) x (Shower/minutes) = Showers/day. For 24-hour fitness centers, minutes per year were taken from informal telephone survey of Fitness Centers in the Northwest, conducted by Northwest Power and Conservation Council Regional Technical Forum staff in June, 2013. The estimate for schools is derived from Water consumption from Planning and Management Consultants, Ltd., Aquacraft, Inc. and John Olaf Nelson, Water Resources Management. "*Commercial and Institutional End Uses of Water,*" American Water Works Association Research Foundation, 2000.

[218] ASHRAE Handbook 2011. HVAC Applications. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE), Inc., Atlanta, GA.

Parameter	Description	Value
$Days/year$	Annual building type operating days for the applications:[219] Hospital, Nursing Home Lodging Commercial 24-Hour Fitness Center School	 365 365 250 365 200
P	Peak Factor:[220] Hospital, Nursing Home Lodging Commercial 24-Hour Fitness Center School	 0.03 0.02 0.08 0.08 0.05

2.2.3.5 Incremental Cost

Program-actual costs should be used where available. If not available, the incremental cost of a low flow showerhead is $12[221].

2.2.3.6 Future Studies

If there is significant participation, we recommend updating with actual participant loads. Further, a study of commercial DHW setpoints would be warranted.

[219] All values except 24-Hour Fitness Center from Osman , S. & Koomey, J. Lawrence Berkeley National Laboratory 1995. *Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting.* December 1995. Value for 24-Hour Fitness Center based on observation.

[220] Derived from *ASHRAE Handbook 2011. HVAC Applications.* American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The peak factor is the ratio of the gallons of hot water used during the peak times of 3 pm to 6pm, to the total amount of hot water used during the day.

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

2.2.4 WATER HEATER PIPE INSULATION

2.2.4.1 Measure Description

This measure consists of installing water heater pipe insulation exceeding the IECC mandated standard (0.5-inch of insulation that delivers an R-value of at least 3.7 per inch) over at least the first 8 feet of exposed pipe in small commercial settings. Water heaters plumbed with heat traps or automatic-circulating systems are not eligible to receive incentives for this measure.[222]

2.2.4.2 Baseline and Efficiency Standards

Baseline insulation is R = 1.85 sq. ft. h °F/Btu, the mandated standard since IECC 2000.

2.2.4.3 Estimated Useful Life

The EUL of this measure is the remaining service life of the water heater. If unknown, use one-third of the life of an electric resistant water heater, rounded down. This is a measure life of 4 years.[223]

2.2.4.4 Deemed Savings Values

The TPE assume three feet of R-3 insulation in providing an estimate of per-project savings. Program administrators are encouraged to incorporate facility-specific inputs when possible. Deemed savings are:

- 112 kWh; and
- 0.0128 kW

2.2.4.4.1 Energy Savings

$$kWh_{savings} = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient}\right) \times \left(\frac{1}{E_t}\right) \times \frac{Hours_{Total}}{Conversion\ Factor}$$

Where:

U_{pre}= 1/(2.03[224]) = 0.49 BTU/h sq. ft. degree F

$U_{post} = 1/(2.03 + R_{Insulation})$

$R_{Insulation}$= R-value of installed insulation

$A =$ Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

$T_{Pipe}(°\text{F}) =$ Average temperature of the pipe. Default value $= 90$ °F (average temperature of pipe between water heater and the wall)

$T_{ambient}(°\text{F}) = 68.78$°F (New Orleans TMY3 average hourly temperature)

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[222] A survey of several large online home-improvement retailers shows three general classes of commercially available pipe insulation: one around R-2.3 (typically 5/8" thick foam), another around R-3 (typically 1/2" thick rubber) and lastly high-end insulation in the R-6 to R-7 range (1" thick rubber).

[223] To see water heater EUL, go to Section 2.2.1.3.

[224] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe and between the surface and air. *Mark's Standard Handbook for Mechanical Engineers, 8th edition*.

Et = Thermal efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric water heaters, 2.2 for a heat pump water heater.[225]

$Hours_{Total}$ = 8,760 hr per year[226,227]

$Conversion\ Factor$ = 3,412 Btu/kWh

For example, deemed savings for water heater pipe insulation with an R-value of 3 installed on an electric water heater in New Orleans would be as follows.

$$kWh_{savings} = (0.49 - 0.20) \times 2.1 \times (90 - 74.8) \times \left(\frac{1}{0.98}\right) \times \frac{8{,}760}{3{,}412} = 24.3\ kWh/yr$$

2.2.4.4.2 Demand Savings

Peak demand reduction for hot water heaters installed in conditioned space can be calculated using the following formula for electric demand reduction.

$$kW_{reduction} = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambientMAX}\right) \times \left(\frac{1}{E_t}\right) \times \frac{1}{3{,}412\ Btu/kWh}$$

Where:

U_{pre} = 1/(2.03) =0.49 BTU/h SQFT °F

$U_{post} = 1/(2.03 + R_{Insulation})$

$R_{Insulation}$ = R-value of installed insulation

$A =$ Surface area in SQFT (πDL) with L (length) and D pipe diameter in feet

$T_{Pipe}(°\mathrm{F}) =$ Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambientMAX}(°\mathrm{F})$ = Installed in unconditioned basements use 68.8°F; Inside thermal envelope uses 78 °F

Et = Thermal efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric water heaters, 2.2 for a heat pump water heater.

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[225] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

[226] Ontario Energy's Measures and Assumptions for Demand Side Management (DSM) Planning www.ontarioenergyboard.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[227] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Residential, Multi-Family, and Commercial/Industrial Measures http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf

2.2.4.5 Incremental Cost

The incremental cost of a Water Heater Pipe Insulation is equal to the full installed cost. If the cost is unknown, use $4.45 for ¾" pipe and $4.15 for ½" pipe per linear foot of insulation[228].

2.2.4.6 Future Studies

This measure is not anticipated to contribute significant savings. Future updates for this measure will be limited to applicable code revisions.

[228] Illinois TRM

2.2.5 WATER COOLER TIMERS

2.2.5.1 Measure Description

This measure involves installing a timer on an existing water cooler to shut down operation during unoccupied hours. It is applicable to both ENERGY STAR and non-ENERGY STAR-certified models to the following system types:

- Cold Only
- Cook and Cold
- Hot and Cold
- Hot, Cook and Cold

2.2.5.2 Baseline and Efficiency Standards

The baseline is an existing water cooler without a timer, integral or otherwise. The efficient condition is the cooler with a properly programmed timer installed.

2.2.5.3 Estimated Useful Life

According to DEER 2014, this measure has an EUL of 5 years[229].

2.2.5.4 Deemed Savings Values

Deemed savings are provided by cooler type and program delivery channel.

Table 2-26 Deemed Savings for Water Cooler Timers

Cooler Type	Efficiency level	kWh Savings	kW Savings
Cold only	Non-ENERGY STAR	46	0.00
	ENERGY STAR	28	0.00
Hot/Cold	Non-ENERGY STAR	251	0.00
	ENERGY STAR	159	0.00

2.2.5.5 Incremental Cost

The incremental cost for a digital weekly timer controller, inclusive of install cost, is $24.46 for mail-by-request and $22.13 for direct install[230].

2.2.5.6 Future Studies

There are currently no future studies planned for this measure at this time.

[229] "EUL_Summary_10-1-08.xlsx" (available at http://www.deeresources.com/)

[230] https://nwcouncil.box.com/v/ComWaterCoolerTimerv2-0

2.3 Heating, Ventilation & Air Conditioning

2.3.1 PACKAGED TERMINAL AC/HP EQUIPMENT

2.3.1.1 Measure Description

This measure requires the installation of a PTAC or PTHP. AHRI Test Standard 310/380-2004 defines a PTAC or PTHP as "a wall sleeve and a separate non-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvers, forced ventilation, and heating availability by purchaser's choice of, at least, hot water, steam, or electrical resistance heat." These definitions are consistent with federal code (10 CFR Part 431.92).

PTAC/PTHP equipment is available in standard and non-standard sizes. Standard size refers to PTAC/PTHP equipment with wall sleeve dimensions having an external opening greater than or equal to 16 inches high or greater than or equal to 42 inches wide, and a cross-sectional area greater than or equal to 672 square inches. Non-standard size refers to PTAC/PTHP equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide, and a cross-sectional area less than 672 square inches.

2.3.1.2 Baseline and Efficiency Standards

The baseline for units that are used in new construction or are replaced on burnout is energy code IECC 2021, which goes into effect in Louisiana on July 1, 2023. The baseline for early replacement is the previous Louisiana energy code, IECC 2009.

IECC 2021 leverages new DOE testing methods and associated metrics. The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure, but the stipulated baseline is:[231]

$$SEER2 = SEER \times Conversion\ Factor$$

$$EER2 = EER \times Conversion\ Factor$$

$$HSPF2 = HSPF \times Conversion\ Factor$$

Where:

Table 2-27: Efficiency Rating Conversion Factors (Ducted and Ductless)

System Type	SEER2	EER2	HSPF2
Ducted	0.95	0.95	0.91
Ductless	1.00	1.00	0.95
Packaged	0.95	0.95	0.84

[231] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

Table 2-28 displays relevant NC and ROB baselines.

Table 2-28 PTAC/PTHP Equipment – Baseline Efficiency Levels

Equipment Type	Operation Mode	Size	Capacity	Minimum Efficiency
PTAC	Cooling Mode	Standard Size	< 7,000	EER = 11.9
			7,000 – 15,000	EER = 14.0 – (0.300 x CAP/1,000)
			> 15,000	EER = 9.5
		Nonstandard Size	< 7,000	EER = 9.4
			7,000 – 15,000	EER = 10.9 – (0.213 x CAP/1,000)
			> 15,000	EER = 7.7
PTHP	Cooling Mode	Standard Size	< 7,000	EER = 11.9
			7,000 – 15,000	EER = 14.0 – (0.300 x CAP/1,000)
			> 15,000	EER = 9.5
		Nonstandard Size	< 7,000	EER = 9.3
			7,000 – 15,000	EER = 10.8 – (0.213 x CAP/1,000)
			> 15,000	EER = 7.6
PTHP	Heating Mode	Standard Size	< 7,000	COP = 3.3
			7,000 – 15,000	COP = 3.7 – (0.052 x CAP/1,000)
			> 15,000	COP = 2.90
		Nonstandard Size	< 7,000	COP = 2.7
			7,000 – 15,000	COP = 2.9 – (0.026 x CAP/1,000)
			> 15,000	COP = 2.5

2.3.1.3 Estimated Useful Life

The EUL of the measure is 10 years in accordance with the DOE Packaged Terminal Air Conditioners and Heat Pumps Energy Conservation Standard Technical Support Document.[232]

2.3.1.4 Deemed Savings Values

For the deemed savings values, the TPE assume a Standard size category, and a capacity of 11,000 BTU (midpoint of the central size category) and a 13 EER/3.4 COP system.

[232] U.S. DOE, Technical Support Document: "*Packaged Terminal Air Conditioners and Heat Pumps, 3.2.7 Equipment Lifetime*". http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45.

Table 2-29 Deemed Savings by Building Type - PTAC

Building Type	kWh	kW
Fast Food	432	0.142
Grocery	278	0.164
Health Clinic	362	0.155
Large Office	270	0.153
Lodging	381	0.140
Full Menu Restaurant	363	0.155
Retail	580	0.160
School	424	0.129
Small Office	375	0.153
University	275	0.153
Unknown	432	0.142

Table 2-30 Deemed Savings by Building Type - PTHP

Building Type	kWh	kW
Fast Food	507	0.142
Grocery	320	0.164
Health Clinic	394	0.155
Large Office	378	0.153
Lodging	494	0.140
Full Menu Restaurant	409	0.155
Retail	722	0.160
School	462	0.129
Small Office	445	0.153
University	442	0.153
Unknown	507	0.142

Deemed peak demand and annual energy savings for PTAC/PTHP equipment should be calculated using the following formulas.

$$kWh_{Savings,PTAC} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right)$$

$$kWh_{Savings,PTHP,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base,C}} - \frac{1}{\eta_{post,C}}\right)$$

$$kWh_{Savings,PTHP,H} = CAP_H \times \frac{1\ kWh}{3{,}412\ \text{BTU}} \times EFLH_H \times \left(\frac{1}{\eta_{base,H}} - \frac{1}{\eta_{post,H}}\right)$$

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \times CF$$

Where:

CAP_C= Rated equipment cooling capacity of the new unit (BTU/hr.)

CAP_H= Rated equipment heating capacity of the new unit (BTU/hr.)

$\eta base$,C = Baseline energy efficiency rating of the baseline cooling equipment (EER)

$\eta post$,C = Nameplate energy efficiency rating of the installed cooling equipment (EER)

$\eta post$,H = Nameplate energy efficiency rating of the installed heating equipment (COP)

Note: heating efficiencies expressed as a heating seasonal performance factor (HSPF) will need to be converted to a coefficient of performance (COP) using the following equation:

$$\text{COP} = \frac{HSPF}{3.412}$$

3.412 = Constant to convert from BTU/hr. to kWh

CF= Coincidence factor (Table 2-31)

EFLHc = Equivalent full-load hours for cooling (Table 2-31)

EFLHh= Equivalent full-load hours for heating (Table 2-31)

Table 2-31 Equivalent Full-Load Hours by Building Type

Building Type	$EFLH_C$	$EFLH_H$	Coincidence Factor
Fast Food	2,375	272	0.78
Grocery	1,526	153	0.90
Health Clinic	1,989	115	0.85
Large Office	1,483	392	0.84
Lodging	2,095	409	0.77
Full Menu Restaurant	1,997	166	0.85
Retail	3,191	513	0.88
School	2,329	140	0.71
Small Office	2,060	255	0.84
University	1,510	604	0.84

2.3.1.5 Incremental Cost

The incremental cost for this equipment is $84/ton[233]. The average tonnage is assumed to be .92 if unknown, resulting in an incremental cost of $77.

2.3.1.6 Future Studies

Though eligible for Energy Smart, this measure has had little-to-no participation. Until such time as participation produces a minimum of 500,000 kWh in a program year, it is recommended that updates be limited to those needed to reflect code changes. If this threshold is met, we recommend focusing M&V to update EFLH estimates.

[233] DEER 2014.

2.3.2 UNITARY AND SPLIT SYSTEM AC/HP EQUIPMENT

2.3.2.1 Measure Description

This measure requires the installation of packaged or split system air conditioners (AC) or heat pumps (HP), excluding PTACs/PTHPs. Unitary or split system ACs/HPs consist of one or more factory-made assemblies that normally include an evaporator or cooling coil(s), compressor(s), and condenser(s). They provide the function of air cooling, and may include the functions of air heating, air circulation, air cleaning, dehumidifying, or humidifying.

2.3.2.2 Baseline and Efficiency Standards[234]

The baseline for units that are used in new construction or are replaced on burnout is energy code IECC 2021, which goes into effect in Louisiana on July 1, 2023. The baseline for early replacement is the previous Louisiana energy code, IECC 2009.

IECC 2021 leverages new DOE testing methods and associated metrics. The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure, but the stipulated baseline is:[235]

$$SEER2 = SEER \times Conversion\ Factor$$

$$EER2 = EER \times Conversion\ Factor$$

$$HSPF2 = HSPF \times Conversion\ Factor$$

Where:

Table 2-32 Efficiency Rating Conversion Factors[236]

System Type	SEER2	EER2	HSPF2
Ducted	0.95	0.95	0.91
Ductless	1.00	1.00	0.95
Packaged	0.95	0.95	0.84

The table below shows the new minimum efficiency levels. All types are Split System and Package System unless otherwise noted.

[234] 2010 U.S. Code: Title 42, Chapter 77, Subchapter III, Part A-1, Section 6313.

[235] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[236] IECC 2012, Table C403.2.3(1) & C403.2.3(2); full-load efficiencies consistent with ASHRAE 90.1-2010, Table 6.8.1A & 6.8.1B and compliant with the federal standard.

Table 2-33 Unitary AC/HP Equipment – Baseline Efficiency Levels[237]

Equipment Type	Capacity (Btu/h)	Heating Section Type	Minimum Efficiency
Air Conditioners, Air Cooled	<65,000	All	13.4 SEER2
	≥65,000 & <135,000	Electric Resistance (or none)	11.2 EER
			14.8 IEER
		All Other	11 EER
			14.6 IEER
	≥ 135,000 & <240,000	Electric Resistance (or none)	11 EER
			14.2 IEER
		All Other	10.8 EER
			14 IEER
	≥240,000 & <760,000	Electric Resistance (or none)	10 EER
			13.2 IEER
		All Other	9.8 EER
			13 IEER
	≥760,000	Electric Resistance (or none)	9.7 EER
			12.5 IEER
		All Other	9.5 EER
			12.3 IEER
Air Conditioners, Water Cooled	<65,000	All	12.1 EER
			12.3 IEER
	≥65,000 & <135,000	Electric Resistance (or none)	12.1 EER
			13.9 IEER
		All Other	11.9 EER
			13.7 IEER
	≥ 135,000 & <240,000	Electric Resistance (or none)	12.5 EER
			13.9 IEER
		All Other	12.3 EER
			13.7 IEER
	≥240,000 & <760,000	Electric Resistance (or none)	12.4 EER
			13.6 IEER
		All Other	12.2 EER
			13.4 IEER
	≥760,000	Electric Resistance (or none)	12.2 EER
			13.5 IEER
		All Other	12 EER
			13.3 IEER
Air Conditioners, Evaporatively Cooled	<65,000	All	12.1 EER
			12.3 IEER
	≥65,000 & <135,000	Electric Resistance (or none)	12.1 EER
			12.3 IEER
		All Other	11.9 EER
			12.1 IEER

[237] IECC 2021, Table C403.2.3(1) & C403.2.3(2.

Equipment Type	Capacity (Btu/h)	Heating Section Type	Minimum Efficiency
	≥ 135,000 & <240,000	Electric Resistance (or none)	12 EER
			12.2 IEER
		All Other	11.8 EER
			12.2 IEER
	≥240,000 & <760,000	Electric Resistance	11.9 EER
			12.1 IEER
		All Other	11.7 EER
			11.9 IEER
	≥760,000	Electric Resistance	11.7 EER
			11.9 IEER
		All Other	11.5 EER
			11.7 IEER
Heat Pumps, Air Cooled (Cooling Mode)	<65,000	All	14.3 SEER2[238]
			13.4 SEER2[239]
	≥65,000 & <135,000	Electric Resistance	11 EER
			14.1 IEER
		All Other	10.8 EER
			13.9 IEER
	≥ 135,000 & <240,000	Electric Resistance	10.6 EER
			13.5 IEER
		All Other	10.4 EER
			13.3 IEER
	≥240,000 & <760,000	Electric Resistance	9.5 EER
			12.5 IEER
		All Other	9.3 EER
			12.3 IEER
Heat Pumps, Air Cooled (Heating Mode)	<65,000	All	7.5 HSPF2
			6.7 HSPF2
	≥65,000 & <135,000		3.4 COP[240]
			2.25 COP[241]
	≥ 135,000 & <240,000		3.3 COP[240]
			2.05 COP[241]
	≥240,000 & <760,000		3.2 COP[240]
			2.05 COP[241]

2.3.2.3 *Estimated Useful Life*

According to the DEER 2014 the EUL for this measure is 15 years.

[238] Split

[239] Package

[240] 47° db/43°F wb

[241] 17° db/15°F wb

2.3.2.4 Deemed Savings Values

Deemed peak demand and annual energy savings for unitary AC and HP equipment should be calculated as shown below. Note that these savings calculations are different depending on whether the measure is replace-on-burnout or early retirement.[242]

$$kWh_{Savings,AC} = CAP \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right)$$

$$kWh_{Savings,HP} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left[\left(\frac{EFLH_C}{\eta_{base,AC}} + \frac{EFLH_H}{\eta_{base,HP}}\right) - \left(\frac{EFLH_C}{\eta_{post,AC}} + \frac{EFLH_H}{\eta_{post,HP}}\right)\right]$$

$$kW_{Savings} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \times CF$$

Where:

CAP = Rated equipment cooling capacity of the new unit (BTU/hr)

$\eta_{base,AC/HP}$ = Baseline energy efficiency rating of the cooling/heating equipment (Table 2-33)

$\eta_{post,AC/HP}$= Nameplate energy efficiency rating of the installed cooling/heating equipment

Note: Use EER for kW savings calculations and SEER/IEER and HSPF for kWh savings calculations.

CF = Coincidence factor (

Table 2-34)

$EFLH_c$ = Equivalent full-load hours for cooling (

[242] Early retirement baseline efficiencies differ because they are based on energy code IECC 2009 and new construction and replace on burnout projects are based on energy code IECC 2021.

Table 2-34)

$EFLH_h$ = Equivalent full-load hours for heating (

Table 2-34)

Table 2-34 Equivalent Full-Load Hours by building type

Building Type	$EFLH_C$	$EFLH_H$	Coincidence Factor
Fast Food	2,375	272	0.78
Grocery	1,526	153	0.90
Health Clinic	1,989	115	0.85

Large Office	1,483	392	0.84
Lodging	2,095	409	0.77
Full Menu Restaurant	1,997	166	0.85
Retail	3,191	513	0.88
School	2,329	140	0.71
Small Office	2,060	255	0.84
University	1,510	604	0.84

2.3.2.5 Incremental Cost

Incremental cost is detailed in Table 2-35 below.

Table 2-35 Unitary AC Incremental Cost

Capacity	**Cost Per Ton per 1.0 SEER above 14.0**
65,000 Btuh or less	$82
65,000 to 240,000 Btuh	$48
240,000 to 760,000 Btuh	$180
760,000 Btuh or more	$181

2.3.2.6 Future Studies

Though eligible for Energy Smart, this measure has had little-to-no participation. Until such time as participation produces a minimum of 500,000 kWh in a program year, it is recommended that updates be limited to those needed to reflect code changes. If this threshold is met, we recommend focusing M&V to update EFLH estimates.

2.3.3 AIR- AND WATER-COOLED CHILLERS

2.3.3.1 Measure Description

This measure requires the installation of any air-cooled or water-cooled chilling package, referred to as a chiller. AHRI Test Standard 550/590-2003 defines a water-chilling package as "a factory-made and prefabricated assembly of one or more compressor, condensers, and evaporators, with interconnections and accessories, designed for the purpose of cooling water. It is a machine specifically designed to make use of a vapor compression refrigeration cycle to remove heat from water and reject the heat to a cooling medium, usually air or water."

The most common applications are for larger cooling loads (e.g., 50 to 100 tons and greater). Chiller types include centrifugal, rotary, screw, scroll, reciprocating, and gas absorption. Absorption chillers are subject to a different AHRI test standard and not reviewed as part of this analysis. When a water-cooled chiller is replacing an air-cooled chiller, the additional auxiliary electrical loads for the condenser water pump and the cooling tower fan have to be considered. Thus, a penalty factor is necessary as a downward adjustment to account for the peak demand and energy savings.

To qualify, the chiller must serve an HVAC load. Chillers used as part of industrial processes require custom analysis.

2.3.3.2 Baseline and Efficiency Standards

The baseline for units that are used in new construction or are replaced on burnout is the current state minimum standard[243] (Table 2-36). Two different paths are proposed. Path A involves installing a chiller that optimizes demand reduction (optimizes EER) whereas Path B involves optimizing total energy savings (optimizes IPLV). If the design path is unknown, use Path A efficiencies or deemed savings values.

Table 2-36 Chillers – Baseline Efficiency Levels for Chilled Water Packages[244]

Equipment Type	Chiller Type	Capacity (Tons)	Path A		Path B	
			IPLV (kW/TON)	EER (kW/Ton)	IPLV (kW/TON)	EER (kW/Ton)
Air Cooled	All	<150	0.960	1.255	0.960	1.255
		≥ 150	0.941	1.255	0.941	1.255
Water Cooled	Rotary/ Screw/Scroll/ Reciprocating	< 75	0.630	0.780	0.600	0.800
		≥ 75 and < 150	0.615	0.775	0.586	0.790
		≥ 150 and < 300	0.580	0.680	0.540	0.718
		≥ 300	0.540	0.620	0.490	0.639
Water Cooled	Centrifugal	< 300	0.596	0.634	0.450	0.639
		≥ 300 and < 600	0.549	0.576	0.400	0.600
		≥ 600	0.539	0.570	0.400	0.590

243 IECC 2009

244 The values in the table reflect IECC 2009, Table 503.2.3(7).

2.3.3.3 Estimated Useful Life

For high-efficiency chillers according to the DEER 2014 the EUL is 20 years.

2.3.3.4 Deemed Savings Values

This measure has significant variability in equipment capacity and thus a per-unit savings value is not likely to be usable by program administrators. Due to this we present savings in a per-ton basis, assuming IECC 2009 efficiencies are the baseline, and the proposed efficiencies are 10% better than the federal minimum EER and IPLV values[245,246].

Table 2-37 Deemed Savings – Air-Cooled Chillers

Building Type	Capacity (Tons)	Path A		Path B	
		Energy (kWh/Ton)	**Demand (kW/Ton)**	**Energy (kWh/Ton)**	**Demand (kW/Ton)**
Fast Food	<150	408	0.169	658	0.110
	> 150	403	0.177	642	0.110
Grocery	<150	262	0.195	423	0.127
	> 150	259	0.204	413	0.127
Health Clinic	<150	341	0.184	551	0.120
	> 150	338	0.192	538	0.120
Large Office	<150	255	0.182	411	0.119
	> 150	252	0.190	401	0.119
Lodging	<150	360	0.167	580	0.109
	> 150	356	0.174	566	0.109
Full Menu Restaurant	<150	343	0.184	553	0.120
	> 150	339	0.192	540	0.120
Retail	<150	548	0.191	884	0.125
	> 150	542	0.199	863	0.125
School	<150	400	0.154	645	0.101
	> 150	395	0.161	630	0.101
Small Office	<150	354	0.182	570	0.119
	> 150	350	0.190	557	0.119
University	<150	259	0.182	418	0.119
	> 150	256	0.190	408	0.119

[245] https://www.energy.gov/eere/femp/purchasing-energy-efficient-air-cooled-electric-chillers

[246] https://www.energy.gov/eere/femp/purchasing-energy-efficient-water-cooled-electric-chillers

Table 2-38 Deemed Savings – Water-Cooled Chillers – Positive Displacement[247]

Building Type	Capacity (Tons)	Path A		Path B	
		Energy (kWh/Ton)	Demand (kW/Ton)	Energy (kWh/Ton)	Demand (kW/Ton)
Fast Food	< 75	214	0.092	356	0.076
	> 75 and < 150	264	0.099	344	0.090
	> 150 and < 300	223	0.073	342	0.083
	> 300	192	0.073	319	0.060
Grocery	< 75	137	0.106	229	0.088
	> 75 and < 150	169	0.114	221	0.104
	> 150 and < 300	143	0.085	220	0.095
	> 300	124	0.084	205	0.069
Health Clinic	< 75	179	0.100	298	0.083
	> 75 and < 150	221	0.108	288	0.098
	> 150 and < 300	187	0.080	286	0.090
	> 300	161	0.079	268	0.065
Large Office	< 75	133	0.099	222	0.082
	> 75 and < 150	165	0.107	215	0.097
	> 150 and < 300	139	0.079	214	0.089
	> 300	120	0.079	199	0.064
Lodging	< 75	189	0.091	314	0.075
	> 75 and < 150	233	0.098	304	0.089
	> 150 and < 300	197	0.072	302	0.082
	> 300	170	0.072	282	0.059
Full Menu Restaurant	< 75	180	0.100	300	0.083
	> 75 and < 150	222	0.108	290	0.098
	> 150 and < 300	188	0.080	288	0.090
	> 300	162	0.079	269	0.065
Retail	< 75	287	0.103	479	0.086
	> 75 and < 150	354	0.112	463	0.101
	> 150 and < 300	300	0.083	460	0.093
	> 300	258	0.082	429	0.067
School	< 75	210	0.083	349	0.070
	> 75 and < 150	259	0.090	338	0.082
	> 150 and < 300	219	0.067	335	0.075
	> 300	189	0.066	313	0.054
Small Office	< 75	185	0.099	309	0.082
	> 75 and < 150	229	0.107	299	0.097
	> 150 and < 300	194	0.079	297	0.089
	> 300	167	0.079	277	0.064
University	< 75	136	0.099	227	0.082
	> 75 and < 150	168	0.107	219	0.097
	> 150 and < 300	142	0.079	217	0.089

[247] Rotary/Screw/Scroll/Reciprocating

	> 300	122	0.079	203	0.064

Table 2-39 Deemed Savings – Water-Cooled Chillers – Centrifugal

Building Type	**CAP**	**Path A**		**Path B**	
		Energy (kWh/Ton)	**Demand (kW/Ton)**	**Energy (kWh/Ton)**	**Demand (kW/Ton)**
Fast Food	< 300	240	0.066	171	0.032
	> 300 and < 600	214	0.056	127	0.054
	> 600	211	0.051	138	0.050
Grocery	< 300	154	0.077	110	0.036
	> 300 and < 600	137	0.065	82	0.062
	> 600	136	0.059	89	0.057
Health Clinic	< 300	201	0.072	143	0.034
	> 300 and < 600	179	0.061	106	0.059
	> 600	177	0.056	115	0.054
Large Office	< 300	150	0.071	107	0.034
	> 300 and < 600	133	0.060	79	0.058
	> 600	132	0.055	86	0.053
Lodging	< 300	212	0.065	151	0.031
	> 300 and < 600	189	0.055	112	0.053
	> 600	186	0.051	122	0.049
Full Menu Restaurant	< 300	202	0.072	144	0.034
	> 300 and < 600	180	0.061	107	0.059
	> 600	178	0.056	116	0.054
Retail	< 300	322	0.075	230	0.036
	> 300 and < 600	287	0.063	171	0.061
	> 600	284	0.058	185	0.056
School	< 300	235	0.060	168	0.029
	> 300 and < 600	210	0.051	125	0.049
	> 600	207	0.047	135	0.045
Small Office	< 300	208	0.071	148	0.034
	> 300 and < 600	185	0.060	110	0.058
	> 600	183	0.055	119	0.053
University	< 300	153	0.071	109	0.034
	> 300 and < 600	136	0.060	81	0.058
	> 600	134	0.055	88	0.053

Deemed peak demand and annual energy savings for chillers should be calculated using the following formulas:

$$kW_{Savings} = CAP \times \left(\eta_{base} - \eta_{post}\right) \times CF$$

$$kWh_{savings} = CAP \times EFLH_C \times \left(\eta_{base} - \eta_{post}\right)$$

Where:

CAP = Rated equipment cooling capacity of the new unit (Tons)

η_{base} = Baseline energy efficiency rating of the baseline cooling equipment (kW/ton or EER converted to kW/ton)

η_{post}= Nameplate energy efficiency rating of the installed cooling equipment (kW/ton)

Note: use full-load efficiency (in units of kW/ton) for kW savings calculations and IPLV (in units of kW/ton) for kWh savings calculations. Cooling efficiencies expressed as an EER will need to be converted to kW/ton using the equation below.

$$\frac{kW}{Ton} = \frac{12}{EER}$$

CF= Coincidence factor (Table 2-40)

$EFLH_c$= Equivalent full-load hours for cooling (Table 2-40)

$EFLH_h$= Equivalent full-load hours for heating (Table 2-40)

Table 2-40 Equivalent Full-Load Hours by Building type

Building Type	**$EFLH_C$**	**$EFLH_H$**	**Coincidence Factor**
Fast Food	2,375	272	0.78
Grocery	1,526	153	0.90
Health Clinic	1,989	115	0.85
Large Office	1,483	392	0.84
Lodging	2,095	409	0.77
Full Menu Restaurant	1,997	166	0.85
Retail	3,191	513	0.88
School	2,329	140	0.71
Small Office	2,060	255	0.84
University	1,510	604	0.84

2.3.3.5 Incremental Cost

Incremental cost is detailed in Table 2-41 below.

Table 2-41 Chiller Incremental Cost

Equipment Type	**Capacity**	**Cost Per Ton**
Air-cooled	All capacities	$127/ton[248]

[248] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008. Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from DEER2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

Water-cooled – reciprocating	All capacities	$22/ton[249]
Water-cooled – rotary & scroll	< 150 tons	$351/ton[250]
	>=150 and < 300 tons	$127/ton
	>= 300 tons	$87/ton

2.3.3.6 *Future Studies*

This is a low-volume, high-savings measure. The TPE recommends that chiller projects be flagged for IPMVP Option C or D analysis when they occur.

[249] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation"

[250] Incremental costs for water-cooled, positive displacement (rotary screw and scroll) from the W017 Itron California Measure Cost Study, accessed via http://www.energydataweb.com/cpuc/search.aspx. The data is provided in a file named "MCS Results Matrix – Volume I".

2.3.4 AIR CONDITIONER AND HEAT PUMP TUNE-UP

2.3.4.1 Measure Description

This measure applies to central air conditioners and heat pumps. An AC tune-up, in general terms, involves checking, adjusting, and resetting the equipment to factory conditions, such that it operates closer to the performance level of a new unit. For this measure, the service technician must complete the following tasks according to industry best practices:

- Inspect and clean condenser, evaporator coils, and blower.
- Inspect refrigerant level and adjust to manufacturer specifications.
- Measure the static pressure across the cooling coil to verify adequate system airflow and adjust to manufacturer specifications.
- Inspect, clean, or change air filters.
- Calibrate thermostat on/off setpoints based on building occupancy.
- Tighten all electrical connections, and measure voltage and current on motors.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the starting cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Provide documentation showing completion of the above checklist to the utility or the utility's representative.

2.3.4.2 Baseline and Efficiency Standards

The baseline is a system with demonstrated imbalances of refrigerant charge.

After the tune-up, the equipment must meet airflow and refrigerant charge requirements. To ensure the greatest savings when conducting tune-up services, the eligibility minimum requirement for airflow is the manufacturer specified design flow rate, or 350 CFM/ton, if unknown. Also, the refrigerant charge must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or a capillary.

The efficiency standard, or efficiency after the tune-up, is assumed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump. The efficiency improvement resulting from the refrigerant charge adjustment depends on the pre-adjustment refrigerant charge.

2.3.4.3 Estimated Useful Life

According to DEER 2014 the EUL for refrigerant charge correction is 10 years.

2.3.4.4 Deemed Savings Values

This measure has significant variability in equipment capacity and thus a per-unit savings value is not likely to be usable by program administrators. Due to this we present savings in a per-ton basis. Savings assume a 15% efficiency loss.

Table 2-42 Deemed Savings by Building Type – Commercial AC Tune-up

Building Type	kWh/Ton	kW/Ton
Fast Food	457	0.1502
Grocery	294	0.1733
Health Clinic	383	0.1636
Large Office	285	0.1617
Lodging	403	0.1482
Full Menu Restaurant	384	0.1636
Retail	614	0.1694
School	448	0.1367
Small Office	397	0.1617
University	291	0.1617
Unknown	396	0.159

Table 2-43 Deemed Savings by Building Type – Commercial Heat Pump Tune-up

Building Type	kWh/Ton	kW/Ton
Fast Food	538	0.1529
Grocery	340	0.1765
Health Clinic	420	0.1667
Large Office	395	0.1647
Lodging	519	0.151
Full Menu Restaurant	436	0.1667
Retail	761	0.1725
School	494	0.1392
Small Office	471	0.1647
University	456	0.1647
Unknown	483	0.162

Deemed peak demand and annual energy savings for unitary AC/HP tune-up should be calculated using the following formulas.

$$kW_{savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times CF$$

$$kWh_{savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right)$$

$$kWh_{savings,H} = CAP_H \times \frac{1\ kW}{1{,}000\ W} \times EFLH_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right)$$

$$kWh_{savings,AC} = kWh_{savings,C}$$

$$kWh_{savings,HP} = kWh_{savings,C} + kWh_{savings,H}$$

Where:

CAP_c= Rated equipment cooling capacity (BTU/hr.)

CAP_h= Rated equipment heating capacity (BTU/hr.)

EER_{pre}= Adjusted efficiency of the equipment for cooling before tune-up (BTU/watt-hr)

EER_{post}= Nameplate efficiency of the existing equipment for cooling; if unknown, use default EER value (BTU/watt-hr) in Table 2-46 and Table 2-47.

Note: Site measurements may be substituted for EER_{pre} and EER_{post}, if the measurements are taken on the same site visit and under similar operating conditions using reliable, industry accepted techniques. If used for measures other than refrigerant charge, then the implementer should use an EUL of three years.

$HSPF_{pre}$ = Efficiency of the equipment for heating before tune-up (BTU/watt-hr)

$HSPF_{post}$ = Nameplate efficiency of the existing equipment for heating; if unknown, use default HSPF value from Table 2-48 (BTU/watt-hr)

CF = Coincidence factor (Table 2-50)

$EFLH_c$= Equivalent full-load hours for cooling (Table 2-49)

$EFLH_h$= Equivalent full-load hours for heating (Table 2-49)

The adjusted EER_{pre} can be calculated using the following equation.

$$EER_{pre} = (1 - EL) * EER_{post}$$

Where:

EL = Efficiency Loss (Fixed Orifice: Table 2-44; TXV: Table 2-45) determined by averaging efficiency losses from multiple studies.[251,252,253,254,255] Interpolation is allowed, extrapolation is not allowed.

Using the COP, HSPF and EER can be calculated by multiplying the COP by 3.413.

Table 2-44 Efficiency Loss Percentage by Refrigerant Charge Level (Fixed Orifice)

% Charged	EL
≤ 70	0.37
75	0.29
80	0.20

[251] Architectural Energy Corporation, managed by New Buildings Institute. “Small HVAC System Design Guide.” Prepared for the California Energy Commission. October 2003. Figure 11.

[252] Davis Energy Group. “HVAC Energy Efficiency Maintenance Study,” California Measurement Advisory Council (CALMAC). December 29, 2010. Figure 14.

[253] Proctor Engineering Group. “Innovative Peak Load Reduction Program CheckMe! Commercial and Residential AC Tune-Up Project.” California Energy Commission. November 6, 2003. Table 6-3.

[254] Proctor Engineering Group. PEG Tune-Up Calculations spreadsheet.

[255] Pennsylvania Technical Reference Manual (TRM). June 2012. Measure 3.3.2, Table 3-96.

85	0.15
90	0.10
95	0.05
100	0.00
> 120	0.03

Table 2-45 Efficiency Loss Percentage by Refrigerant Charge Level (TXV)

% Charged	**EL**
< 70	0.12
75	0.09
80	0.07
85	0.06
90	0.05
95	0.03
100	0.00
> 120	0.04

Table 2-46 Default Air Conditioner EER per Size Category[256]

Size Category (BTU/hr.)	**EER (BTU/watt-hr)**[257]
< 65,000	11.0
> 65,000 and < 135,000	10.8
> 135,000 and < 240,000	9.8
> 240,000 and < 760,000	9.5

Table 2-47 Default Heat Pump EER per Size Category[258]

Size Category (BTU/hr.)	**EER (BTU/watt-hr)**
< 65,000	11.8
> 65,000 and < 135,000	10.8
> 135,000 and < 240,000	10.4
> 240,000	9.3

$$HSPF_{pre} = (HSPF_{post}) \times (1 - M)^{age}$$

Where:

> $HSPF_{post}$= HSPF of pre-tune up equipment when new (use nameplate or default value from Table 2-48)

[256] Code specified SEER or EER value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

[256] Code specified SEER or EER value from ASHRAE 90.1-2010 (efficiency value effective January 1, 2015

[257] SEER values converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[258] Code specified SEER or EER value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

M = Maintenance factor[259], use 0.01 if annual maintenance conducted or 0.03 if maintenance is seldom

Age = Age of equipment in years, up to a maximum of 20 years, use a default of 10 years if unknown.

Table 2-48 Default Heat Pump HSPF per Size Category[260]

Size Category (BTU/hr.)	Subcategory or Rating Condition	Default HSPF[261]
< 65,000	Split System	8.2
	Single Package	8.0
≥ 65,000 and < 135,000	47°F db/43°F wb Outdoor Air	11.3
	17°F db/15°F wb Outdoor Air	7.7
≥ 135,000	47°F db/43°F wb Outdoor Air	10.9
	17°F db/15°F wb Outdoor Air	7.0

Table 2-49 Equivalent Full-Load Hours by Building Type

Building Type	$EFLH_C$	$EFLH_H$
Fast Food	2,375	272
Grocery	1,526	153
Health Clinic	1,989	115
Large Office	1,483	392
Lodging	2,095	409
Full Menu Restaurant	1,997	166
Retail	3,191	513
School	2,329	140
Small Office	2,060	255
University	1,510	604
Unknown	2,056	268

Table 2-50 Commercial Coincidence Factors by Building Type[262]

Building Type	Coincidence Factor
Fast Food	0.78
Grocery	0.90
Health Clinic	0.85
Large Office	0.84
Lodging	0.77
Full Menu Restaurant	0.85

[259] "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. Table 32. Page 40. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[260] Code specified HSPF or COP value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

[261] COP values converted to HSPF using COP=HSPF÷3.412

[262] Values for Assembly and Religious Worship building types developed using an adjustment factor derived through a comparison of average CFs for College/University and Assembly/Religious Worship building types from the Texas state Technical Reference Manual. College/University was selected as a reference building type due to average alignment with Assembly/Religious worship building types in other TRMs, inclusion of a summer session, and increased evening usage.

Retail	0.88
School	0.71
Small Office	0.84
College	0.84
Unknown	0.83

2.3.4.4.1 Partial Savings Based on Tune Up Component

Partial savings may be claimed if the tune-up does not require all components (e.g., a coil cleaning is required but a refrigerant charge correction is not). These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed. See the table below.

Table 2-51 Savings by Component[263]

Tune-Up Component	% Savings
Condenser Cleaning	6.10%
Evaporator Cleaning	0.22%
Refrigerant Charge Off. ≤ 20%	0.68%
Refrigerant Charge Off. > 20%	8.44%
Combined (Refrigerant Off. ≤ 20%)	7.00%
Combined (Refrigerant Off.> 20%)	14.76%

2.3.4.5 Incremental Cost

Full project cost should be used. If not available, use $35/ton[264].

2.3.4.6 Future Studies

The incremental cost value is very sensitive to labor costs, and as such a New Orleans-specific cost study should be conducted to revise this value. Further, due to past realization rate issues with residential AC tune-up if this offering is expanded to the commercial sector the TPE strongly recommends a whole-program billing analysis to support savings estimates.

[263] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

[264] Act on Energy Commercial Technical Reference Manual No. 2010-4

2.3.5 GUEST ROOM ENERGY MANAGEMENT CONTROLS

2.3.5.1 Measure Description

Packaged terminal heat pumps (PTHP) and packaged terminal air conditioners (PTAC) are commonly installed in the hospitality industry to provide heating and cooling of individual guest rooms. Occupancy-based PTHP/PTAC controllers are a combination of a control unit and occupancy sensor that operate in conjunction with each other to provide occupancy-controlled heating and/or cooling. The control unit plugs into a wall socket and the PTHP/PTAC plugs into the control unit. The control unit is operated by an occupancy sensor that is mounted in the room and turns the PTHP/PTAC on and off. The most common application for occupancy-based PTHP/PTAC controls is hotel rooms.

To qualify for savings, equipment must have a setback of at least 5 degrees Fahrenheit. Setbacks greater than 8 degrees Fahrenheit are not recommended due to occupant comfort considerations.

2.3.5.2 Baseline and Efficiency Standards

There is no code requirement for installation of GREM systems. The baseline configuration is a PTAC/PTHP with a manually controlled thermostat.

2.3.5.3 Estimated Useful Life

The EUL of this measure is eight years in accordance with DEER 2014.

2.3.5.4 Deemed Savings Values

Estimated gross annual energy savings is 355 kWh/unit, based on numbers reported by Xcel Energy and scaled appropriately based on New Orleans weather data. There is no peak demand reduction associated with this measure. As these savings estimates are based on a single reference, it is recommended that New Orleans work with early program participants to conduct actual pre- and post-measurement of energy use to verify the accuracy of these values.

2.3.5.5 Incremental Cost

The incremental cost is the difference between a GREM system and a manual thermostat, $260[265].

2.3.5.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values from other programs. If this measure is added to Energy Smart programs, the evaluation should include a metering study to support occupancy estimates.

[265] DEER 2014 value for energy management systems

2.3.6 DEMAND CONTROL VENTILATION

2.3.6.1 *Measure Description*

Commercial Demand Controlled Ventilation (DCV) entails installing CO_2 sensors within occupied zones in a commercial building in order to optimize the amount of outside air supplied to the space. This reduces energy use for space conditioning by reducing the amount of air supplied during unoccupied times. Furthermore, maintaining appropriate airflow can improve occupant health and productivity by ensuring adequate ventilation for pollutant and odor removal, as well as preventing excessive buildup of CO_2[266].

2.3.6.2 *Baseline and Efficiency Standards*

The baseline for this measure was modeled as a prototypical building for 7 different building types that would most benefit from installing DCV due to their high occupancy density as well as significant variability in occupancy patterns. These models were also modified to calculate separate savings for buildings with Gas heat and Air Conditioning, as well as buildings with Heat Pumps. This measure is also only appropriate for retrofit applications. The efficiency standard for this measure, in accordance with IECC 2009, is that DCV is "*required for spaces larger than 500 ft^2 . . . and with an average occupant load of 40 people per 1000 ft^2 of floor area*". Thus, savings cannot be claimed for new construction in spaces that meet this minimum criterion unless the space is exempt in accordance with the exemptions listed in section 503.2.5[267].

2.3.6.3 *Estimated Useful Life*

The EUL for this product is taken to be the life of a typical CO_2 sensor. This was determined to be 10 years[268].

2.3.6.4 *Deemed Savings Values*

The deemed savings values were calculated using DEER prototypical commercial building energy models in eQUEST. Occupant densities were modified in accordance with the DOE prototype buildings[269], and the standard airflow rate per person was input as 15 CFM. For the deemed savings values, the DEER Models assumed a minimum airflow of 0.40 CFM per ft^2, a COP of 3.5 for cooling and heating, and a furnace efficiency of 82%. These parameters can be found in the table below.

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[266] D. P. Wyon. "Indoor Environmental Effects on Productivity." (1996). Johnson Controls Inc. Accessed September 5, 2018 from: 310404371_Indoor_environmental_effects_on_productivity_Proceedings_of_IAQ_1996_Paths_to_better_building_environments

267 IECC 2009 DCV Requirements https://up.codes/viewer/pennsylvania/iecc-2009/chapter/5/commercial-energy-efficiency#503.2.5.1

[268] During the course of conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors have to be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time. Illinois TRM 9.0 Vol. 2 (p285n566)

[269] "Commercial Prototype Building Models." U.S. Department of Energy & Pacific Northwest National Laboratory. Accessed August 27, 2018 from: https://www.energycodes.gov/development/commercial/prototype_models

Table 2-52 Occupant Density by Building Type

Building Type	Building Zones (ft^2)	Occupant Density (ft^2/Person)	Airflow Requirement (cfm/person)	Notes
Assembly	Auditorium: 33,235 Office: 765 Total: 34,000	50	15	DEER Default
Primary School (K-6)	Classroom: 31,500 Dining: 7,500 Gym: 7,500 Kitchen: 3,500 Total: 50,000	40		Office/Gym space densities unchanged
Secondary School (7-12)	Classroom: 31,500 Dining: 7,500 Gym: 7,500 Kitchen: 3,500 Total: 50,000	28.5		
Small Office (<30,000 ft^2)	Office:3,250 Conference:500 Other:6,250 Total:10,000	142		
Large Office (≥30,000 ft^2)	Office:101,500 Support Spaces 56,000 Lobby: 7,200 Mechanical/Electrical: 10,300 Total: 175,000	125		
Restaurant	Dining:2,000 Kitchen: 1,200 Lobby: 600 Restroom: 200 Total: 4,000	25		Kitchen and Bathroom density and airflow unchanged
Retail Stand-Alone	Retail: 6,400 Storage: 1,600 Total: 8,000	67		Storage space left at original occupancy density

Table 2-53 Deemed Savings by Building Type – PTAC

Building Type	kWh/Ton	kW/Ton
Assembly	523	0.100
Primary School (K-6)	73	0.047
Secondary School (7-12)	70	0.035
Small Office (<30,000 ft2)	48	-0.031
Large Office (≥30,000 ft2)	54	-0.035
Restaurant	160	0.017
Retail Stand-Alone	209	0.049

Table 2-54 Deemed Savings by Building Type - PTHP

Building Type	kWh/Ton	kW/Ton
Assembly	894	0.105
Primary School (K-6)	126	0.060
Secondary School (7-12)	125	0.044
Small Office (<30,000 ft2)	56	-0.031
Large Office (≥30,000 ft2)	63	-0.035
Restaurant	256	0.016
Retail Stand-Alone	293	0.356

Table 2-55 Deemed Savings by Building Type – Central AC

Building Type	kWh/1,000 ft²	kW/1,000 ft²
Assembly	165	0.170
Primary School (K-6)	148	0.003
Secondary School (7-12)	118	0.003
Small Office (<30,000 ft2)	231	0.000
Large Office (≥30,000 ft2)	260	0.131
Restaurant	485	0.003
Retail Stand-Alone	111	0.054

Table 2-56 Deemed Savings by Building Type – Roof Top Units

Building Type	kWh/1,000 ft²	kW/1,000 ft²
Assembly	54	0.140
Primary School (K-6)	139	0.003
Secondary School (7-12)	115	0.002
Small Office (<30,000 ft2)	209	0.000
Large Office (≥30,000 ft2)	210	0.106
Restaurant	387	0.002
Retail Stand-Alone	88	0.042

Deemed annual energy savings and peak demand reductions DCV applications should be calculated using the following equations. The energy savings and demand reductions are given as kWh/1,000 ft².

$kWh_{Savings} = Savings\ Multiplier \times$ Square footage covered by HVAC system

$kW_{Reduction} = Savings\ Multiplier \times$ Square footage covered by HVAC system

Where:

> $Savings\ Multiplier$ = Savings per 1,000 ft² based on HVAC configuration/system from Table 2-53 to Table 2-56 above.

2.3.6.5 Incremental Cost

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost ($500) and installation ($1000 labor) for a total of $1,500[270].

2.3.6.6 Future Studies

This measure has had limited participation in Energy Smart. DCV projects should be over-sampled for targeted M&V if this measure has significant participation (at least 250,000 kWh).

[270] Discussion with vendors. Illinois TRM 9.0 Vol. 2 (p285n567)

2.3.7 SMART THERMOSTATS

2.3.7.1 Measure Description

This measure consists of replacing a manually operated or programmable thermostat with an ENERGY STAR certified[271] smart thermostat. If the thermostat is not ENERGY STAR-certified, it must have the following features:[272]

- Automatic scheduling.
- Occupancy sensing (set “on” as a default).
- For buildings with a heat pump, smart thermostats must be capable of controlling heat pumps to minimize the use of backup electric resistance heat.
- Ability to adjust settings remotely via a smart phone or online in the absence of connectivity to the thermostat service provider, retaining the ability for the facility to:
  - View the room temperature,
  - View and adjust the set temperature, and
  - Switch between off, heating and cooling.
- Have a static temperature accuracy ≤ ± 2.0 °F
- Have network standby average power consumption of ≤3.0 W average (including all equipment necessary to establish connectivity to the service provider’s cloud, except those that can reasonably be expected to be present in the home, such as Wi-Fi routers and smart phones.)
- Enter network standby after ≤ 5.0 minutes from user interaction (on device, remote or occupancy detection)
- The following capabilities may be enabled through the connected thermostat (CT) device, CT service or any combination of the two. The CT product shall maintain these capabilities through subsequent firmware and software changes:
  - Ability for consumers to set and modify a schedule.
  - Provide feedback to occupants about the energy impact of their choice of settings.
  - Provide access to information relevant to their HVAC energy consumption (e.g., HVAC run time).

2.3.7.2 Baseline & Efficiency Standard

For retrofit projects, the baseline is the preexisting thermostat equipment configuration. For new construction projects, program administrators should assume a programmable thermostat as baseline (in accordance with IECC 2009).

[271] ENERGY STAR’s qualified products list for smart thermostats: https://data.energystar.gov/dataset/ENERGY-STAR-Certified-Connected-Thermostats/7p2p-wkbf

[272] ENERGY STAR Smart Thermostat Specification:: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0_0.pdf

2.3.7.3 Estimated Useful Life

The EUL for this measure is 11 years.[273]

2.3.7.4 Deemed Savings Values

Deemed savings are based off of a percent reduction of annual use compared to the equivalent full-load cooling and heating consumption for the facility. Savings are calculated as:

$$kWh\ Savings = Capacity(C) \times \frac{1}{SEER \times 1000} \times EFLH_C \times Savings\%_C + Capacity(H) \times \frac{1}{HSPF \times 1000} \times EFLH_H \times Savings\%_H$$

Where:

Capacity(C) = Cooling capacity (BTU)

SEER = Efficiency of controlled AC. Use current code requirements if nameplate actual is not available.

1000 = unit conversion

EFLH(C) = Equivalent Full Load Cooling Hours. See Table 2-57.

Capacity(H) = Heating capacity (BTU)

HSPF = Heating Efficiency of controlled HVAC system. Use current code requirements if nameplate actual is not available.

EFLH(H) = Equivalent Full Load Heating Hours. See Table 2-57.

Savings%(C) = Annual percent cooling savings

Savings%(H) = Annual percent heating savings

Capacity should be collected as part of the project application.

Table 2-57 Equivalent Full-Load Hours by Building Type

Building Type	$EFLH_C$	$EFLH_H$
Fast Food	2,375	272
Grocery	1,526	153
Health Clinic	1,989	115
Large Office	1,483	392
Lodging	2,095	409
Full Menu Restaurant	1,997	166
Retail	3,191	513
School	2,329	140
Small Office	2,060	255
University	1,510	604

273 DEER 2014 EUL tables

Table 2-58 summarizes the annual percent savings for heating and cooling by baseline thermostat. Savings for natural gas are presented so as to allow program administrators to quantify the full benefit from installation of a smart thermostat in a facility with electric cooling and natural gas space heating.

Table 2-58 Savings Percent by Baseline Type

System	Baseline	
	Manual Thermostat[274]	Programmable Thermostat[275]
Electric Cooling	5%	3%
Electric Heating	4%	2%
Natural Gas Heating	5%	2%

2.3.7.4.1 Sample Calculation

For example, assume a small retail facility using an air source heat pump. The equipment is 60,000 BTU in capacity with efficiencies of 13 SEER and 7.7 HSPF. The associated EFLH values are 3,191 for cooling and 513 for heating. The facility uses a manual thermostat in the baseline configuration. The savings for this project would be:

$$Cooling\ Savings = 60{,}000 \times \frac{1}{13 \times 1000} \times 3{,}191 \times 5\% = 736\ kWh$$

$$Heating\ Savings = 60{,}000 \times \frac{1}{7.7 \times 1000} \times 513 \times 4\% = 160\ kWh$$

There are too many possible facility and equipment configuration combinations to provide pre-determined deemed savings. Program administrators should follow the algorithm specified above.

2.3.7.5 Incremental Cost

Actual measure cost should be used where available. If not available, the incremental cost of installing a smart thermostat is $154[276] for new construction and $208[277] for retrofit.

2.3.7.6 Future Studies

Current savings estimates for this measure cite existing studies from other climate zones. This measure should receive a detailed impact evaluation once sufficient participation has occurred.

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[274] The savings percentages claimed for manual thermostats include the savings associated with upgrading from manual thermostats to programmable thermostats, which a 2015 MEMD study reported as about 3% savings for gas customers and 2% savings for electric customers. http://www.michigan.gov/documents/mpsc/CI_Programmable_TStats_MEMD_6_15_15_491808_7.pdf

[275] CLEAResult's "Guide to Smart Thermostats" reports the ranges of savings measured in recent residential evaluations, relative to a baseline that blended programmable and manual thermostats: 10–13% for gas savings; 14–18% for electric cooling savings; and 6–13% for electric heating. This finding is extrapolated to commercial facilities in this analysis. savings.https://www.clearesult.com/insights/whitepapers/guide-to-smart-thermostats

[276] From NEEP's 2016 Incremental Cost Study: http://www.neep.org/incremental-cost-emerging-technology-0, table 3-13 found range of incremental costs to be $80-195 (with baseline as $54 and using Nest/Ecobee at $249). NEEP's more recent list of home energy management systems products (http://neep.org/initiatives/high-efficiency-products/home-energy-management-systems) shows a straight average of 68 products at $210 for the cost of the smart thermostat, bringing the incremental cost assuming $54 for baseline down to $154.

[277] *Ibid.*

2.3.8 VARIABLE SPEED DRIVES

2.3.8.1 Measure Description

This measure is applied to variable speed drives (VSD) which are installed on the following HVAC system applications: chilled water pumps, cooling tower fans, hot water pumps and HVAC fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

2.3.8.2 Baseline & Efficiency Standard

2.3.8.2.1 Definition of Baseline Equipment

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is with no VSD. Retrofit baselines may or may not include inlet guide vanes, throttling valves or other methods of control. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2007 standards which are provided by horsepower. The AC unit has standard cooling efficiency based on IECC 2009. The part-load fan control is an outlet damper, inlet damper, inlet guide vane, or no control (constant volume systems).

Note IECC 2009 became effective July 20, 2011 and is the baseline for all New Construction permits from that date.[278] Installations of new equipment with VSDs which are required by IECC 2009 as adopted by New Orleans are not eligible for incentives.

2.3.8.2.2 Definition of Efficient Equipment

The VSD is applied to a motor which does not have a VSD. This measure is not applicable for replacing failed VSDs. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

When applicable, the existing damper or inlet guide vane will be removed or set completely open permanently after installation. The VFD will maintain a constant static pressure by adjusting fan speed and delivering the same amount of air as the baseline condition.

2.3.8.3 Estimated Useful Life

The EUL for HVAC application is 15 years[279] and the EUL for process is 15 years.[280]

2.3.8.4 Deemed Savings Values

The deemed savings values were calculated using DEER prototypical commercial building energy models in eQUEST.

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[278] Louisiana Energy Code and Links, http://sfm.dps.louisiana.gov/pr_energy.htm

[279] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors

[280] DEER, 2008.

Table 2-59 Deemed Savings by Building Type – Chilled Water Pumps

Building Type	kWh/HP	kW/HP
Assembly	708	0.090
Primary School (K-6)	171	0.038
Secondary School (7-12)	171	0.038
Small Office (<30,000 ft^2)	558	0.087
Large Office (≥30,000 ft^2)	377	0.133
Restaurant	358	0.070
Retail Stand-Alone	377	0.074

Table 2-60 Deemed Savings by Building Type – Condenser Pumps

Building Type	kWh/HP	kW/HP
Assembly	613	0.073
Primary School (K-6)	143	0.034
Secondary School (7-12)	143	0.034
Small Office (<30,000 ft^2)	469	0.072
Large Office (≥30,000 ft^2)	688	0.152
Restaurant	327	0.072
Retail Stand-Alone	328	0.072

Table 2-61 Deemed Savings by Building Type – Cooling Tower Fans

Building Type	kWh/HP	kW/HP
Assembly	449	0.212
Primary School (K-6)	380	0.083
Secondary School (7-12)	380	0.083
Small Office (<30,000 ft^2)	955	0.193
Large Office (≥30,000 ft^2)	619	0.251
Restaurant	540	0.139
Retail Stand-Alone	802	0.136

Table 2-62 Deemed Savings by Building Type – Hot Water Heating Pumps

Building Type	kWh/HP	kW/HP
Assembly	1,251	0.152
Primary School (K-6)	299	0.073
Secondary School (7-12)	299	0.073
Small Office (<30,000 ft^2)	970	0.152
Large Office (≥30,000 ft^2)	306	0.073
Restaurant	595	0.152
Retail Stand-Alone	690	0.152

Table 2-63 Deemed Savings by Building Type – HVAC Fans

Building Type	kWh/HP	kW/HP
Assembly	8	0.001
Primary School (K-6)	2	0.000
Secondary School (7-12)	2	0.000
Small Office (<30,000 ft^2)	7	0.001
Large Office (≥30,000 ft^2)	3	0.001
Restaurant	4	0.001
Retail Stand-Alone	4	0.001

2.3.8.5 Deemed Savings Values

Deemed annual energy savings and peak demand reductions from VSD applications should be calculated using the following equations. The energy savings and demand reductions are given as kWh and kW per rated horsepower of the motor the VSD is controlling.

$$kWh_{Savings} = Savings\ Multiplier \times \text{Rated horsepower of motor VSD is controlling}$$

$$kW_{Reduction} = Savings\ Multiplier \times \text{Rated horsepower of motor VSD is controlling}$$

Where:

Savings Multiplier = Savings per 1 HP HVAC configuration/system from Table 2-59 to Table 2-63 above.

2.3.8.6 Incremental Cost

Customer provided costs will be used when available. Default measure costs[281] are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

Table 2-64 Measure Cost by Horsepower

HP	Cost
1 -5 HP	$1,037
7.5 HP	$1,673
10 HP	$1,803
15 HP	$2,254
20 HP	$2,739

2.3.8.7 Future Studies

Current savings estimates for this measure cite existing studies from other climate zones. This measure should receive a detailed impact evaluation once sufficient participation has occurred.

[281] Material costs from Grainger.com, search for "Variable Frequency Drive" on 7/8/2020. RTF 'https://nwcouncil.app.box.com/v/VariableSpeedDrivev2-0'

2.4 Refrigeration

2.4.1 VARIABLE REFRIGERANT FLOW SYSTEMS

2.4.1.1 Measure Description

This measure entails the installation of a variable refrigerant flow (VRF) multi-split heat pump system. There are numerous configurations of VRF systems. This chapter covers the two most common configurations in the market:

- Air-cooled VRF heat pumps; and
- Water-cooled VRF heat pumps.

2.4.1.2 Baseline and Efficiency Standards

The baseline for units that are used in new construction or are replaced on burnout is shown in Table 2-65. The format of the baseline table is taken from ASHRAE 90.1-2010 Table 6.8.1J Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps – Minimum Efficiency Requirements. This minimum efficiency requirement is based on applied heat pump baseline from Table 6.8.1B from ASHRAE 90.1-2010 where air-cooled VRF system with electric resistance heating references the baseline of applied heat pump with electric resistance heating and VRF with heat recovery with applied heat pump with all other heating types. However, water-cooled VRF baseline was stipulated in ASHRAE 90.1-2010. The current state building energy code is ASHRAE 90.1-2007 and the minimum baseline for applied heat pump from ASHRAE 90.1-2007 to 90.1-2010 didn't change, therefore the table from ASHRAE 90.1-2010 is applicable with an exception of air-cooled VRF system rated for 17°F dry-bulb and 43°F wet-bulb temperature which must comply the federal minimum standard[282] for heat pumps, which went into effect January 1, 2010.

Table 2-65 VRF Heat Pump System– Baseline Efficiency Standards

Equipment Type	Cooling Capacity (Btu/h)	Heating Section Type	Sub-Category	Minimum Efficiency
VRF, Air Cooled (Cooling Mode)	< 65,000	All	VRF Multi-split System	13 SEER
	≥65,000 & <135,000	Electric Resistance (or none)	VRF Multi-split System	11.0 EER
			VRF Multi-split System with Heat Recovery	10.8 EER
	≥135,000 & <240,000		VRF Multi-split System	10.6 EER

[282] 2013 U.S. Code: Title 10, Chapter 2, Subchapter D, Part 431, Subpart F, Table 1 to Page 431.97; Minimum Cooling Efficiency Standards for Air-Conditioning and Heating Equipment

Equipment Type	Cooling Capacity (Btu/h)	Heating Section Type	Sub-Category	Minimum Efficiency
		Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.4 EER
	≥240,000	Electric Resistance (or none)	VRF Multi-split System	9.5 EER
			VRF Multi-split System with Heat Recovery	9.3 EER
VRF, Water Cooled (Cooling Mode)	< 65,000	All	VRF Multi-split system, 86°F entering water	12.0 EER
			VRF Multi-split system with Heat Recovery, 86°F entering water	11.8 EER
	≥65,000 & <135,000	All	VRF Multi-split system, 86°F entering water	12.0 EER
			VRF Multi-split system with Heat Recovery, 86°F entering water	11.8 EER
	≥135,000	All	VRF Multi-split system, 86°F entering water	10.0 EER
			VRF Multi-split system with Heat Recovery, 86°F entering water	9.8 EER
VRF, Air Cooled (Heating Mode)	< 65,000	All	VRF Multi-split system	7.7 HSPF
	≥65,000 & <135,000	All	VRF Multi-split system	3.3 COP
	≥135,000	All	VRF Multi-split system	3.2 COP
VRF, Water Cooled (Heating Mode)	<135,000	All	VRF Multi-split system, 68°F entering water	4.2 COP
	≥135,000	All	VRF Multi-split system, 68°F entering water	3.9 COP

2.4.1.3 Estimated Useful Life

The typical VRF system is a type of heat pump and the same 15 year EUL from DEER 2016 for commercial heat pumps applies to this measure.

2.4.1.4 Deemed Savings Values

This measure has significant variability in equipment efficiency based on system type and equipment capacity and thus we present savings on a per-ton basis. The measure efficiency is based on the average unit efficiency of all AHRI-certified VRF units[283] in the US market at three different cooling capacity bins.

The following tables present per-ton deemed savings.

Table 2-66 Deemed Savings by Building Type – VRF Air-Cooled Heat Pumps

Building Type	Cooling Capacity (tons)	VRF Multi-split System		VRF Multi-split System with Heat Recovery	
		kWh/Ton	kW/Ton	kWh/Ton	kW/Ton
Fast Food	< 11.25	615	0.1898	415	0.1257
	>=11.25 & < 20.00	240	0.0685	283	0.0845
	>= 20.00	300	0.0935	237	0.0746
Grocery	< 11.25	392	0.2190	264	0.1451
	>=11.25 & < 20.00	152	0.0790	180	0.0975
	>= 20.00	191	0.1078	152	0.0861
Health Clinic	< 11.25	500	0.2068	334	0.1370
	>=11.25 & < 20.00	188	0.0746	227	0.0921
	>= 20.00	245	0.1018	195	0.0813
Large Office	< 11.25	415	0.2044	286	0.1354
	>=11.25 & < 20.00	176	0.0737	198	0.0910
	>= 20.00	200	0.1006	156	0.0804
Lodging	< 11.25	566	0.1873	386	0.1241
	>=11.25 & < 20.00	232	0.0676	266	0.0835
	>= 20.00	274	0.0923	215	0.0737
Full Menu Restaurant	< 11.25	509	0.2068	342	0.1370
	>=11.25 & < 20.00	195	0.0746	232	0.0921
	>= 20.00	249	0.1018	197	0.0813
Retail	< 11.25	847	0.2141	575	0.1419
	>=11.25 & < 20.00	340	0.0773	395	0.0954
	>= 20.00	411	0.1054	324	0.0842
School	< 11.25	586	0.1727	392	0.1145
	>=11.25 & < 20.00	221	0.0623	266	0.0770
	>= 20.00	287	0.0851	228	0.0679
Small Office	< 11.25	536	0.2044	362	0.1354
	>=11.25 & < 20.00	211	0.0737	248	0.0910
	>= 20.00	261	0.1006	206	0.0804
University	< 11.25	450	0.2044	315	0.1354
	>=11.25 & < 20.00	203	0.0737	222	0.0910
	>= 20.00	215	0.1006	167	0.0804
Unknown	< 11.25	541	0.2009	367	0.1332
	>=11.25 & < 20.00	216	0.0725	252	0.0895
	>= 20.00	263	0.0990	208	0.0790

[283] 7,974 certified product information pulled from AHRI database on 7/1/2019; AHRI Directory of Certified Product Performance, https://www.ahridirectory.org/NewSearch?programId=72&searchTypeId=3

Table 2-67 Deemed Savings by Building Type – VRF Water Cooled Heat Pump

Building Type	Cooling Capacity (tons)	VRF Multi-split System		VRF Multi-split System with Heat Recovery	
		kWh/Ton	kW/Ton	kWh/Ton	kW/Ton
Fast Food	< 5.42	484	0.1443	N/A	N/A
	>=5.42 & < 11.25	509	0.1552	506	0.1527
	>= 11.25	716	0.2191	751	0.2319
Grocery	< 5.42	307	0.1666	N/A	N/A
	>=5.42 & < 11.25	324	0.1791	322	0.1762
	>= 11.25	456	0.2528	479	0.2676
Health Clinic	< 5.42	387	0.1573	N/A	N/A
	>=5.42 & < 11.25	411	0.1692	407	0.1664
	>= 11.25	579	0.2388	610	0.2528
Large Office	< 5.42	338	0.1554	N/A	N/A
	>=5.42 & < 11.25	347	0.1672	349	0.1645
	>= 11.25	486	0.2360	505	0.2498
Lodging	< 5.42	454	0.1425	N/A	N/A
	>=5.42 & < 11.25	471	0.1532	472	0.1508
	>= 11.25	661	0.2163	690	0.2290
Full Menu Restaurant	< 5.42	396	0.1573	N/A	N/A
	>=5.42 & < 11.25	419	0.1692	416	0.1664
	>= 11.25	591	0.2388	621	0.2528
Retail	< 5.42	674	0.1629	N/A	N/A
	>=5.42 & < 11.25	703	0.1751	702	0.1723
	>= 11.25	988	0.2472	1,033	0.2617
School	< 5.42	454	0.1314	N/A	N/A
	>=5.42 & < 11.25	482	0.1413	477	0.1390
	>= 11.25	679	0.1995	715	0.2111
Small Office	< 5.42	422	0.1554	N/A	N/A
	>=5.42 & < 11.25	444	0.1672	442	0.1645
	>= 11.25	624	0.2360	654	0.2498
University	< 5.42	377	0.1554	N/A	N/A
	>=5.42 & < 11.25	381	0.1672	387	0.1645
	>= 11.25	532	0.2360	548	0.2498
Unknown	< 5.42	429	0.1529	N/A	N/A
	>=5.42 & < 11.25	449	0.1644	448	0.1617
	>= 11.25	631	0.2321	661	0.2456

Deemed peak demand and annual energy savings for unitary AC and HP equipment should be calculated as shown below.

$$kW_{Savings} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{base,Cooling}} - \frac{1}{\eta_{post,Cooling}}\right) \times CF$$

$$kWh_{Savings} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left[\left(\frac{EFLH_C}{\eta_{base,Cooling}} + \frac{EFLH_H}{\eta_{base,Heating} \times 3.413}\right) - \left(\frac{EFLH_C}{\eta_{post,Cooling}} + \frac{EFLH_H}{\eta_{post,Heating} \times 3.413}\right)\right]$$

Where:

CAP = Rated equipment cooling capacity of the new unit (BTU/hr)

$\eta_{base,Cooling/Heating}$ = Baseline energy efficiency rating of the cooling/heating equipment (Table 2-65), EER for cooling and COP for heating

$\eta_{post,Cooling/Heating}$= Nameplate energy efficiency rating of the installed cooling/heating equipment (Table 2-68), EER for cooling and COP for heating

CF = Coincidence factor Table 2-70

$EFLH_c$ = Equivalent full-load hours for cooling (

Table 2-69)

$EFLH_h$ = Equivalent full-load hours for heating (

Table 2-69)

3.413 = kW to Btu/hr Conversion applied to heating COP to heating EER

Table 2-68 Measure Efficiency Assumptions[284]

Equipment Type	Cooling Capacity Category (Btu/h)	Cooling Capacity (Btu/h)	Sub-Category	Average Cooling Efficiency (EER)	Average Heating Efficiency (COP)
VRF, Air Cooled	< 65,000	65,000	All	N/A[285]	N/A[368]
	≥65,000 & <135,000	100,000	VRF Multi-split System	12.5	3.8
			VRF Multi-split System with Heat Recovery	12.6	3.7
	≥135,000 & <240,000	187,500	VRF Multi-split System	11.5	3.6
			VRF Multi-split System with Heat Recovery	11.5	3.5
	≥240,000	240,000	VRF Multi-split System	10.5	3.4
			VRF Multi-split System with Heat Recovery	10	3.3
VRF, Water Cooled	< 65,000	65,000	VRF Multi-split system	14.7	5.2
			VRF Multi-split system with Heat Recovery	N/A[368]	N/A[368]
	≥65,000 & <135,000	100,000	VRF Multi-split system	15	5
			VRF Multi-split system with Heat Recovery	14.9	5.1
	≥135,000	135,000	VRF Multi-split system	13.1	4.9
			VRF Multi-split system with Heat Recovery	12.9	4.8

[284] Average efficiency calculated from AHRI certified products available in US market

[285] Product not available in US in this category

Table 2-69 Equivalent Full-Load Hours by Building Type

Building Type	$EFLH_C$	$EFLH_H$
Fast Food	2,375	272
Grocery	1,526	153
Health Clinic	1,989	115
Large Office	1,483	392
Lodging	2,095	409
Full Menu Restaurant	1,997	166
Retail	3,191	513
School	2,329	140
Small Office	2,060	255
University	1,510	604

Table 2-70 Commercial Coincidence Factors by Building Type[286]

Building Type	Coincidence Factor
Fast Food	0.78
Grocery	0.90
Health Clinic	0.85
Large Office	0.84
Lodging	0.77
Full Menu Restaurant	0.85
Retail	0.88
School	0.71
Small Office	0.84
University	0.84

2.4.1.5 *Incremental Cost*

The incremental cost is $3 per square-foot of conditioned space[287] compared to baseline equipment.

2.4.1.6 *Future Studies*

VRF systems in certain applications has greater energy savings potential than the deemed savings in this version of TRM. For example, if the facility has vacant space that is not heated or cooled, the VRF unit will run in part-load which can operate with greater efficiency. Furthermore, if the facility installs more cooling capacity than required, they can increase their energy savings by running the unit on a lower part-load. Some VRF units can provide simultaneous heating and cooling which can improve overall unit efficiency as well. An example of this application is to install VRF systems in lodging facilities where not

[286] Values for Assembly and Religious Worship building types developed using an adjustment factor derived through a comparison of average CFs for College/University and Assembly/Religious Worship building types from the Texas state Technical Reference Manual. College/University was selected as a reference building type due to average alignment with Assembly/Religious worship building types in other TRMs, inclusion of a summer session, and increased evening usage.

[287] CLEAResult 2016. "Utility Program Cost Effectiveness of Variable Refrigerant Flow Systems". ACEEE Summer Study on Energy Efficiency in Buildings 2016. https://aceee.org/files/proceedings/2016/data/papers/3_345.pdf

all rooms are occupied so the unit will run on part load, as well as having some rooms request heating while other rooms request cooling. Both operational patterns present an opportunity for a VRF system to achieve greater savings. However, this version of TRM does not cover applications such as this as further is needed. It is advised that in large scale projects, program administrators should consider taking a custom savings approach rather than using this deemed savings approach to capture full potential savings.

2.4.2 DOOR HEATER CONTROL FOR REFRIGERATORS AND FREEZERS

2.4.2.1 Measure Description

This measure refers to the installation of anti-sweat door heater controls on glass doors for reach-in commercial refrigerators and freezers. The added control reduces both heater operation time and cooling load.

This measure only qualifies for retrofit applications. New construction applications are not allowed as this measure is standard practice for new construction and comes integrated on most modern glass-door refrigerators and freezers.

2.4.2.2 Baseline and Efficiency Standards

Qualifying equipment includes any controls that reduce the run time of door and frame heaters for refrigerated cases. The baseline efficiency case is a cooler or freezer door heater that operates 8,760 hours per year without any controls. The high efficiency case is a cooler (medium temperature) or freezer (low temperature) door heater connected to a heater control system. There are no state or federal codes or standards that govern the eligibility of equipment.

2.4.2.3 Estimated Useful Life

The EUL is 12 years as defined in the DEER database.[288]

2.4.2.4 Deemed Savings Values

2.4.2.4.1 Energy Savings

A door heater controller senses dew point (DP) temperature in the store and modulates power supplied to the heaters accordingly. DP inside a building is primarily dependent on the moisture content of outdoor ambient air. Because the outdoor DP varies between weather zones, weather data from each weather zone must be analyzed to obtain a DP profile.

Indoor dew point (t_{d-in}) is related to outdoor dew point (t_{d-out}) according to the following equation. Indoor dew point was calculated at each location for every hour in the year.[289]

$$t_{d-in} = 0.005379 \times t_{d-ou}^2 \ + 0.171795 \times t_{d-out} + 19.870006$$

In the base case, the door heaters are all on and have a duty of 100% irrespective of the indoor DP temperature. For the post-retrofit case, the duty for each hourly reading was calculated by assuming a linear relationship between indoor DP and duty cycle for each bin reading. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89°F or lower DP and all on (duty cycle of 100%) at 52.87°F or higher DP for a typical supermarket. Between these values, the door heaters' duty cycle changes proportionally:

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[288] California's Database for Energy Efficiency Resources (DEER 2014).

[289] Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & Electric Company. May 29, 2009.

$$Door\ Heater\ ON\% = \frac{t_{d-in} - All\ OFF\ Setpt\ (42.89°F)}{All\ ON\ Setpt\ (52.87°F) - All\ OFF\ Setpt\ (42.89°F)}$$

Because the controller only changes the run-time of the heaters, instantaneous door heater power (kW_{ASH}) as a resistive load remains constant per linear foot of door heater at:

$$kW_{ASH} = \frac{kW}{ft} \times L_{DH}$$

Where kW/ft. = 0.0368 for medium temperature and 0.0780 for low temperature applications.

Door heater energy consumption for each hour of the year is a product of power and run-time:

$$kWh_{ASH-Hourly} = kW_{Ash} \times Door\ Heater\ ON\% \times 1\ hour$$

Total annual door heater energy consumption (kWh_{ASH}) is the sum of all hourly reading values:

$$kWh_{ASH} = \sum kWh_{ASH-Hourl}$$

Energy savings were also estimated for reduced refrigeration loads using average system efficiency and assuming that 35% of the anti-sweat heat becomes a load on the refrigeration system.[290] The cooling load contribution from door heaters can be given by:

$$Q_{ASH}\left(\frac{ton}{h}\right) = 0.35 \times kW_{ASH} \times \frac{3{,}412\ \frac{Btu}{kWh}}{12{,}000\ \frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from the manufacturers' data. The compressor analysis is limited to the cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

The typical efficiency for a medium temperature case is 9 EER (1.33 kW/ton), and the typical efficiency for a low temperature case is 5 EER (2.40 kW/ton).[291]

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

$$kWh_{Refrig-Hourly} = Q_{ASH} \times \frac{kW}{ton} \times 1\ hour$$

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[290] Southern California Edison (SCE), 1999, *"A Study of Energy Efficient Solutions for Anti-Sweat Heaters."* Prepared for the Refrigeration Technology and Test Center (RTTC). December 14. https://www.sce.com/NR/rdonlyres/B1F7A3B4-719D-4CBB-87EB-E27F7CE7ECE0/0/Anti_Sweat_Heater_Report.pdf.

[291] Chapter 15 of the 2010 ASHRAE Handbook for Refrigeration

Total annual refrigeration energy consumption is the sum of all hourly reading values:

$$kWh_{Refrig} = \sum kWh_{Refrig-Hourly}$$

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of all hourly reading values:

$$kWh_{Total} = kWh_{Refrig} + kWh_{ASH}$$

Once the annual energy consumption (direct door heaters and indirect refrigeration) has been determined for the baseline and post-retrofit case, the total energy savings are calculated by the following equation:

$$Annual\ Energy\ Savings = \Delta kWh = kWh_{Total-Basel} \quad - kWh_{Total-Pos\ \ Retrofit}$$

2.4.2.4.2 Demand Savings

It is important to note that while there might be instantaneous demand reduction as a result of the cycling of the door heaters, peak demand reduction will only be due to the reduced refrigeration load. Peak demand reduction was calculated by the equation shown below:

$$Peak\ Demand\ Savings = \Delta kW = \frac{kWh_{Refrig-Baseline} - kWh_{Refrig-Pos\ \ Retrofit}}{8{,}760\ hr/yr}$$

Annual and peak energy savings due to anti-sweat door heater controls in medium and low temperature refrigerated cases for New Orleans. Deemed savings is calculated using a ratio compared to El Dorado, AR (Zone 6) Savings provided in the table are per linear foot of glass door-controlled heater.

Table 2-71 Anti-Sweat Heater Controls – Savings per Linear Foot of Case by Location

Weather Zone	Med-Temperature		Low-Temperature	
	Annual kWh/ft. Savings	kW/ft. Savings	Annual kWh/ft. Savings	kW/ft. Savings
New Orleans	248	0.0046	259	0.0060

2.4.2.5 Incremental Cost

The full installed cost should be used for this measure. If not available, use $300 per circuit[292].

2.4.2.6 Future Studies

At the time, this measure had low participation in Energy Smart programs. As a result, savings are calculated using weather-adjusted default values from other programs. If participation exceeds 500,000 kWh, the evaluation should include a metering study to support runtime estimates.

[292] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

2.4.3 ENERGY STAR REFRIGERATORS AND FREEZERS WITH SOLID DOORS

2.4.3.1 Measure Description

Commercial refrigerators and freezers are commonly found in restaurants and other food service industries. Reach-in, solid-door refrigerators and freezers are significantly more efficient than regular refrigerators and freezers due to better insulation and higher-efficiency components. These efficiency levels relate the volume of the appliance to its daily energy consumption. To qualify for this measure, new solid-door refrigerators and freezers must meet ENERGY STAR minimum efficiency requirements.

2.4.3.2 Baseline and Efficiency Standards

Baseline efficiency for commercial solid door refrigerators and freezers is defined by federal minimum efficiency levels that went into effect on March 28, 2014 (see Table 2-72 below). Also included are the minimum efficiency levels for the ENERGY STAR specifications version five, effective December 22, 2022.

Table 2-72 Solid-Door Refrigerators and Freezers – Efficiency Levels

Equipment	Baseline	Capacity	ENERGY STAR Max Daily Consumption (kWh/day)
Refrigerator	0.05V + 1.36	0<V<15	0.026V + .08
		15≤V<30	0.05V + 0.45
		30≤V<50	
		50≤V	0.025V + 1.6991
Freezer	0.22V + 1.38	0<V<15	0.21V + 0.9
		15≤V<30	0.12V + 2.248
		30≤V<50	0.2578V-1.8864
		50≤V	0.14V + 4.0

2.4.3.3 Estimated Useful Life

According to DEER 2014 the EUL is 12 years.

2.4.3.4 Deemed Savings Values

$$kWh\ Savings = annual\ kWh_{baseline} - annual\ kWh_{efficient}$$

$$kW\ Reduction = \frac{kWh\ Savings}{hours}$$

Where:

$hours$ = annual hours (365.25 x 24 = 8,766)[293]

[293] Refrigeration is assumed to operate continuously

Deemed measure savings for qualifying solid-door refrigerators and freezers are presented in Table 2-73.

Table 2-73 Solid-Door Refrigerators and Freezers – Deemed Savings Values

Type	Size Range (Cubic Ft)	Baseline Annual Energy Consumption (kWh/unit)	Efficient Annual Energy Consumption (kWh/unit)	Annual kWh Savings	Demand Reduction (kW/unit)
Refrigerator	0-15	634	100	533	0.061
	15-30	908	575	332	0.038
	30-50	1,227	895	332	0.038
	≥50[294]	1,775	1,260	515	0.059
Freezer	0-15	1,107	904	203	0.023
	15-30	2,312	1,807	505	0.058
	30-50	3,718	3,077	641	0.073
	≥50[294]	6,129	5,040	1,088	0.124

2.4.3.4.1 Measure Technology Review

Five primary resources contained data about solid-door refrigerators and freezers. The ENERGY STAR website and the CEE had the same maximum daily energy consumption levels for commercial food-grade refrigerators and freezers. The NPCC report and Ecotrope studies gave savings and cost estimates but did not include the volume of the appliances. NYSERDA's deemed savings and cost database (Nexant, 2005) contained data for both refrigerators and freezers at common sizes.

Table 2-74 Solid-Door Refrigerators and Freezers – Review of Measure Information

Available Resource	Notes
PG&E 2005[41]	Energy savings and cost estimates for refrigerators and freezers at common sizes
DEER 2014[65]	Energy savings and cost estimates for refrigerators and freezers at common sizes
KEMA 2010[24]	Energy savings and cost estimates for refrigerators and freezers at common sizes
CEE[64]	Maximum daily energy consumption levels (kWh/day) for CEE-qualified commercial qualified food-grade refrigerators and freezers
ENERGY STAR[69]	Maximum daily energy consumption levels (kWh/day) for commercial qualified food-grade refrigerators and freezers
NEXANT 2005[31]	Energy savings and cost estimates for refrigerators and freezers at common sizes
PacifiCorp 2009[44]	Unitary savings included in comprehensive potential study

[294] Solid-door refrigerators and freezers were evaluated for four different sizes or volumes (V), 7.5, 22.5, 40 and 70 cubic feet. The unit will be operated for 365.25 days per year.

2.4.3.5 Incremental Cost

The incremental cost is provided in Table 2-75[295].

Table 2-75 Solid-Door Refrigerators and Freezers Incremental Costs

Type	Incremental Cost
Refrigerator	$143
	$164
	$164
	$249
Freezer	$142
	$166
	$166
	$407

2.4.3.6 Future Studies

This measure applies known values from ENERGY STAR; the TPE does not recommend focused study for this measure. Parameters should be updated to correspond to the most recent ENERGY STAR specification.

[295] For the purposes of this characterization, assume and incremental cost adder of 5% on the full unit costs presented in Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.

2.4.4 ADD SOLID DOORS TO OPEN REFRIGERATED AND FREEZER CASES

2.4.4.1 Measure Description

Open display cases are typically found in grocery and convenience stores and have been a preference of store owners because they allow customers a clear view and easy access to refrigerated products. This measure is retrofitting existing vertical, open, refrigerated display cases by adding and installing doors. The baseline equipment is an open vertical display case with no doors or covering. The efficient equipment is the installation of solid doors on the existing display case. Replacement of open display cases with new display cases with doors is not covered under this measure characterization.

This measure is applicable to refrigerated case doors with and without anti-condensation heaters. Standard refrigerated case doors include anti-condensation heaters in the frames, doors, or within the glass to prevent condensation from forming and obstructing view of refrigerated products. High efficiency doors with no anti-condensation heaters use a combination of multiple layers of glass, low-conductivity filler gas, and low-emissivity glass coatings to prevent condensation. This calculation quantifies the infiltration savings seen by the compressor.

If the retrofitted door has LED fixtures and is recommended to leverage Section 2.6 for quantifying savings and measure benefits.

2.4.4.2 Baseline and Efficiency Standards

The baseline condition is an open, refrigerated, display case without any covering. The efficient condition is retrofitting an existing open, refrigerated, display case by adding doors, either standard efficiency or high efficiency. Savings for both efficient cases are provided.

2.4.4.3 Estimated Useful Life

The expected measure life is 15 years[296].

2.4.4.4 Deemed Savings Values

Deemed energy savings per linear foot of case are based on a project that compared a typical open refrigerated display case line-up to a typical glass-doored refrigerated display case line-up.[297]

$$kWh\ Savings = \Delta Energy \times Case\ Width \times \left(1 - \frac{hours_{cooling}}{8{,}766} \times \frac{COP_{ref}}{COP_{HVAC}}\right)$$

$$kW\ Reduction = \frac{Savings_{kWh}}{8{,}766}$$

[296] The measure life is sourced from the PG&E Workpaper, “Add Doors to Open Medium Temperature Cases – PGE3PREF116 R3”, June 2019.

[297] Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. Values derived from Table 1 and the relative width of the display cases used in the study (without anti-sweat heaters). Energy savings assume 365.25 days of annual operation. Demand savings assume flat energy savings throughout the day. http://docs.lib.purdue.edu/iracc/1154

Where:

$\Delta Energy$ =

Equipment	Efficiency Level	kWh/linear foot[298,299]
Refrigerator	Standard	477
	High	747
Freezer	Standard	183
	High	392

$Case\ Width$ = Case width in linear feet (taken from project application)

$hours_{cooling}$= 3,470[300]

8,766 = 24 hours x 365.25 days annually

COP_{ref} = Coefficient of Performance of refrigeration equipment. From application; COP = 3.517/(kW/ton), where kW/ton is the rated efficiency of the compressor in input kW per ton of refrigeration capacity.

COP_{HVAC} = Coefficient of Performance of facility HVAC equipment. From application; COP = EER/3.412. If unknown, use 2.93 for grocery stores, 3.57 for other facility types[301]

2.4.4.5 Incremental Cost

The incremental cost, which includes both material and labor, differs depending on whether or not the installed door is equipped with LED lighting. The estimated incremental cost for doors without LED lighting is $390 per linear foot. The incremental cost for doors with LED lighting is $419 per linear foot.[302]

2.4.4.6 Future Studies

There are no future studies planned for this measure at this time.

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298 Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. Values derived from Table 1 and the relative width of the display cases used in the study (without anti-sweat heaters). Energy savings assume 365.25 days of annual operation. Demand savings assume flat energy savings throughout the day. http://docs.lib.purdue.edu/iracc/1154

299 Energy savings do not include savings from ASH controllers. See sections 'D.4.2 Door Heater Controls for Refrigerators and Freezers' for ASH controller savings.

300 Calculated using New Orleans TMY3 data.

301 ASHRAE 90.1 2010 Standard for Unitary HVAC: Grocery Store default assumes a 25-ton packaged RTU (cooling only); Other default assumes a 10-ton packaged RTU (cooling only)

302 The incremental cost is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116 R3", June 2019. The incremental cost for retrofitting new doors on existing refrigerated display cases is thematerial cost of the door and the labor cost required for installation. The material cost of the doors is $331 per linear foot with LED lighting and $301 per linear foot without LED lighting. And the installation cost is $88 per linear foot. 1225 The change in heat gain is sourced as the typical value for a medium temperature vertical display case adding doors from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116 R3", June 2019. The workpaper assumes a net reduction in heat gain with the installation of doors on open refrigerated display cases. The primary benefits account for the decrease in excess heat entering the display case from air infiltration. Radiation and conduction heat gains were also included in the derivation of this value. Additionally, the net heat gain has built in assumptions on how often the refrigerated case doors will be used and the display case accessed by customers and site associates, reducing some of the air infiltration benefits of the new door.

2.4.5 REFRIGERATED CASE NIGHT COVERS

2.4.5.1 *Measure Description*

This measure applies to the installation of night covers on otherwise open vertical (multi-deck) and horizontal (coffin-type) low-temperature (L) and medium temperature (M) display cases to decrease cooling load of the case during the night. It is recommended that these film-type covers have small, perforated holes to decrease the build-up of moisture.

Cases may be either: Self Contained (SC) having both evaporator and condenser coils, along with the compressor as part of the unit or Remote Condensing (RC) where the condensing unit and compressor are remotely located. Refrigerated case categories[303] are as follows:

- Vertical Open (VO): Equipment without doors and an air-curtain angle ≥ 0° and < 10°
- Semi-vertical Open (SVO): Equipment without doors and an air-curtain angle ≥ 10° and < 80°
- Horizontal Open (HO): Equipment without doors and an air-curtain angle ≥ 80°

The measure is standard practice in new construction and is only eligible for retrofit applications.

2.4.5.2 *Baseline and Efficiency Standards*

The baseline standard for this measure is an open low-temperature or medium temperature refrigerated display case (vertical or horizontal) that is not equipped with a night cover.

The efficiency standard for this measure is any suitable material sold as a night cover. The cover must be applied for a period of at least six hours per night.

2.4.5.3 *Estimated Useful Life*

According to the CA DEER 2014, night covers are assigned an EUL of 5 years.

2.4.5.4 *Deemed Savings Values*

The following outlines the assumptions and approach used to estimate demand and energy savings due to installation of night covers on open low- and medium-temperature, vertical and horizontal, display cases. Heat transfer components of the display case include infiltration (convection), transmission (conduction), and radiation. This deemed savings approach assumes that installing night covers on open display cases will only reduce the infiltration load on the case. Infiltration affects cooling load in the following ways:

- Infiltration accounts for approximately 80% of the total cooling load of open vertical (or multi-deck) display cases.[304]

[303] U.S. DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment, Commercial Refrigeration Equipment, Washington DC, p3-15

[304] ASHRAE 2006. Refrigeration Handbook. Retail Food Store Refrigeration and Equipment. Atlanta, Georgia. pp. 46.1, 46.5, 46.10.

- Infiltration accounts for approximately 24% of the total cooling load of open horizontal (coffin or tub style) display cases.[305]

Installing night covers for a period of 6 hours per night can reduce the cooling load due to infiltration. This was modeled by the U.S. DOE for vertical and semi-vertical cases.

Table 2-76 Vertical & Semi-vertical Refrigerated Case Savings

Case Type[306]	**VO.RC.M**	**VO.RC.L**	**VO.SC.M**	**SVO.RC.M**	**SVO.SC.M**
kWh per day- before Night Curtain	50.52	118.44	38.98	38.48	32.82
kWh per day - with Night Curtain	46.84	111.58	36.99	35.74	31.05
Percent kWh Savings per Day	7%	6%	5%	7%	5%
Annual kWh Savings	1,343	2,504	726	1,000	646
Test Case Length (ft.)	12	12	4	12	4

Table 2-77 Horizontal Refrigerated Case Savings

Case Type[307]	**HO.RC.M**	**HO.RC.L**	**HO.SC.M**	**HO.SC.L**
kWh per day- before Night Curtain[308]	15.44	34.23	16.06	35.02
kWh per day - with Night Curtain	14.05	31.15	14.61	31.87
Percent kWh Savings per Day[309]	9%	9%	9%	9%
Annual kWh Savings	507	1,124	528	1,150
Test Case Length (ft.)	12	12	4	4

While the DOE also modeled the energy consumption for horizontal open cases, there was not an efficient case modeled with a night cover. The 9% energy savings as found by Faramarzi & Woodworth-Szleper[6] was used to determine the post kWh per day.

Due to the relatively consistent summer dry-bulb temperature across the New Orleans weather zone, deemed savings values are only provided for the average dry-bulb temperature of 96°F.

[305] *Ibid.*

[306] U.S. DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment, Commercial Refrigeration Equipment, Washington DC, pp.5-43- 5-47, 5A-5, 5A-6

[307] *Ibid.*

[308] *Ibid.*

[309] ASHRAE 1999 Effects of Low-E Shields on the Performance and Power Use of a Refrigerated Display Case. Faramarzi & Woodworth-Szleper, p.8

Table 2-78 Refrigerated Case Night Covers – Deemed Savings Values (per Linear Foot)[310]

Case Description	Temperature Range (°F)	kWh Savings (kWh/ft.)	kW Savings (kW/ft.)
Vertical Open, Remote Condensing Medium Temperature	10 – 35 °F	112	0.00
Vertical Open, Remote Condensing Low Temperature	< 10 °F	209	0.00
Vertical Open, Self-Contained Medium Temperature	10 – 35 °F	182	0.00
Semi-vertical Open, Remote Condensing Medium Temperature	10 – 35 °F	83	0.00
Semi-vertical Open, Self-Contained Medium Temperature	10 – 35 °F	162	0.00
Horizontal Open, Remote Condensing Medium Temperature	10 – 35 °F	42	0.00
Horizontal Open, Remote Condensing Low Temperature	< 10 °F	94	0.00
Horizontal Open, Self-Contained Medium Temperature	10 – 35 °F	132	0.00
Horizontal Open, Self-Contained Low Temperature	< 10 °F	288	0.00

Table 2-79 Refrigerated Case Night Covers – Deemed Savings Values (per Night Cover)[311]

Case Description	Temp Range (°F)	Length (ft.)	kWh Savings (per cover)	kW Savings (per cover)
Vertical Open, Remote Condensing Medium Temperature	10 – 35 °F	12	1,344	0.00
Vertical Open, Remote Condensing Low Temperature	< 10 °F	12	2,508	0.00
Vertical Open, Self-Contained Medium Temperature	10 – 35 °F	4	728	0.00
Semi-vertical Open, Remote Condensing Medium Temperature	10 – 35 °F	12	996	0.00
Semi-vertical Open, Self-Contained Medium Temperature	10 – 35 °F	4	648	0.00
Horizontal Open, Remote Condensing Medium Temperature	10 – 35 °F	12	504	0.00
Horizontal Open, Remote Condensing Low Temperature	< 10 °F	12	1,128	0.00
Horizontal Open, Self-Contained Medium Temperature	10 – 35 °F	4	528	0.00
Horizontal Open, Self-Contained Low Temperature	< 10 °F	4	1,152	0.00

[310] Pacific Gas & Electric (PG&E), 2009, “Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases).

[311] Pacific Gas & Electric (PG&E), 2009, “Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases), May 29.

2.4.5.5 Incremental Cost

The full measure cost should be used. When not available, use $42 per linear foot (CA DEER 2014). For projects that lack size information, use: remote Condensing: $504; self-contained: $168; and unknown: $336

2.4.5.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure had low participation in Energy Smart programs. As a result, savings are calculated using weather-adjusted default values from other programs. If participation exceeds 500,000 kWh, the evaluation should include a metering study to support coverage time estimates.

2.4.6 STRIP CURTAINS

2.4.6.1 Measure Description

This measure applies to the installation of strip curtains on walk-in coolers and freezers. This reduces the load on the refrigeration system through reduced infiltration of warm ambient air into the walk-in unit. This measure is only eligible for retrofit applications. The measure is standard practice in new construction.

2.4.6.2 Baseline and Efficiency Standards

The baseline standard for this measure is a walk-in cooler or freezer with no preexisting strip curtains or damaged strip curtains.

2.4.6.3 Estimated Useful Life

According to the California Database of Energy Efficiency Resources (DEER, 2014), refrigerated case night covers are assigned an EUL of 5 years.

2.4.6.4 Deemed Savings Values

Calculation of savings from strip curtains is based on Tamm's equation[312] and the ASHRAE handbook[313].

The formula or savings from strip curtains is as follows:

$$\frac{kWh\ Savings}{ft.^2} = \frac{365 \times t_{open} \times (Eff_{new} - E_{old}) \times 20 \times CD \times A \times \left\{\left[\frac{(T_i - T_r)}{T_i}\right] \times g \times h\right\}^{0.5} \times [p_i \times h_i - p_r \times h_r]}{3{,}412\,\frac{BTU}{kWh} \times COP_{adj} \times A}$$

The parameters are defined in the tables below. Infiltration accounts for approximately 80% of the total cooling load of open vertical (or multi-deck) display cases.[314] Table 2-80 summarizes assumptions that are universal across facility types. Table 2-84 summarize assumptions for specific facilities.

Table 2-80 Strip Curtain Universal Input Assumptions

Parameter	Unit	Value	Source
kWh savings / ft.^{2}	kWh savings / ft.^{2}	Calculated	Calculated
kW savings / ft.^{2}	kW savings / ft.^{2}	Calculated	Calculated

[312] Kalterveluste durch kuhlraumoffnungen. Tamm W,. Kaltetechnik-Klimatisierung 1966;18;142-144

[313] ASHRAE 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6

[314] ASHRAE 2006. Refrigeration Handbook. Retail Food Store Refrigeration and Equipment. Pp. 46.1, 46.5, 46.10.

20: product of 60 seconds and integration factor of 1/3	Seconds/minute	20	Tamms equation
g, gravitational constant	ft./seconds^2	32.174	Physics constant
1073,412	BTU/kWh	3,412	Physics constant

Table 2-81 Strip Curtain Input Assumptions for Supermarkets

Parameter	Unit	Value		Source
		Coolers	Freezers	
Eff-new: efficacy for new strip curtain.	% of infiltration blocked	.88	.88	http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
Eff-old: efficacy for preexisting condition	% of infiltration blocked	Old curtain: .58 No curtain: .00 Unknown: .34	Old curtain: .58 No curtain: .00 Unknown: .30	
CD: Discharge Coefficient, an empirically determined scale factor that accounts for difference in infiltration rates predicted by Bernoulli's law and actual observed rates	None	.336	.415	
t-open, minutes/day walk-in door is open	Minutes/day	132	102	
A, doorway area	ft.^{2}	35	35	
H, doorway height	ft.	7	7	
T_i Dry-bulb temp. of infiltrating air	Deg. F	71	67	
T_i Dry-bulb temp. of refrigerated air	Deg. F	37	5	
COP_{adj}, Coefficient of performance of refrigerators and freezers	Unitless ratio	3.07	1.95	
P, Density of infiltration air at 55% RH	lb./ft.^{2}	.074	.074	Psychometric equations based on dry bulb and RH
h, Enthalpy of infiltration air at 55% RH	BTU/ft.^{2}	26.935	24.678	
p_r Density of refrigerated air at 80% RH	lb./ft.^{2}	.079	.085	
h_r Enthalpy of refrigerated air at 80% RH	BTU/ft.^{2}	12.933	2.081	

Table 2-82 Strip Curtain Input Assumptions for Convenience Stores

Parameter	Unit	Value		Source
		Coolers	Freezers	
Eff-new: efficacy for new strip curtain.	% of infiltration blocked	.79	.83	http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
Eff-old: efficacy for preexisting condition	% of infiltration blocked	Old curtain: .58 No curtain: .00 Unknown: .34	Old curtain: .58 No curtain: .00 Unknown: .30	
CD: Discharge Coefficient, an empirically determined scale factor that accounts for difference in infiltration rates predicted by Bernoulli's law and actual observed rates	None	.348	.421	
t-open, minutes/day walk-in door is open	Minutes/day	38	9	
A, doorway area	ft.^{2}	21	21	
H, doorway height	ft.	7	7	
T_i Dry-bulb temp. of infiltrating air	Deg. F	68	64	
T_i Dry-bulb temp. of refrigerated air	Deg. F	39	5	
COP_{adj}, Coefficient of performance of refrigerators and freezers	Unitless ratio	3.07	1.95	
P, Density of infiltration air at 55% RH	lb./ft.^{2}	.074	.074	Psychometric equations based on dry bulb and RH
h, Enthalpy of infiltration air at 55% RH	BTU/ft.^{2}	25.227	23.087	
p_r Density of refrigerated air at 80% RH	lb./ft.^{2}	.079	.085	
h_r Enthalpy of refrigerated air at 80% RH	BTU/ft.^{2}	13.750	2.081	

Table 2-83 Strip Curtain Input Assumptions for Restaurants

Parameter	Unit	Value		Source
		Coolers	Freezers	
Eff-new: efficacy for new strip curtain.	% of infiltration blocked	.80	.81	http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
Eff-old: efficacy for preexisting condition	% of infiltration blocked	Old curtain: .58 No curtain: .00 Unknown: .33	Old curtain: .58 No curtain: .00 Unknown: .26	
CD: Discharge Coefficient, an empirically determined scale factor that accounts for difference in infiltration rates predicted by Bernoulli's law and actual observed rates	None	.383	.442	
t-open, minutes/day walk-in door is open	Minutes/day	45	38	

A, doorway area	ft.^{2}	21	21	
H, doorway height	ft.	7	7	
T_i Dry-bulb temp. of infiltrating air	Deg. F	70	67	
T_i Dry-bulb temp. of refrigerated air	Deg. F	39	8	
COP_{adj}, Coefficient of performance of refrigerators and freezers	Unitless ratio	3.07	1.95	
P, Density of infiltration air at 55% RH	lb./ft.^{2}	.074	.074	Psychometric equations based on dry bulb and RH
h, Enthalpy of infiltration air at 55% RH	BTU/ft.^{2}	26.356	24.678	
p_r Density of refrigerated air at 80% RH	lb./ft.^{2}	.079	.085	
h_r Enthalpy of refrigerated air at 80% RH	BTU/ft.^{2}	13.750	2.948	

Table 2-84 Strip Curtain Input Assumptions for Refrigerated Warehouses

Parameter	Unit	Value	Source
Eff-new: efficacy for new strip curtain.	% of infiltration blocked	.80	http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
Eff-old: efficacy for preexisting condition	% of infiltration blocked	Old curtain: .58 No curtain: .00 Unknown: .54	
CD: Discharge Coefficient, an empirically determined scale factor that accounts for difference in infiltration rates predicted by Bernoulli's law and actual observed rates	None	.425	
t-open, minutes/day walk-in door is open	Minutes/day	494	
A, doorway area	ft.^{2}	80	
H, doorway height	ft.	10	
T_i Dry-bulb temp. of infiltrating air	Deg. F	59	
T_i Dry-bulb temp. of refrigerated air	Deg. F	28	
COP_{adj}, Coefficient of performance of refrigerators and freezers	Unitless ratio	1.91	
P, Density of infiltration air at 55% RH	lb./ft.^{2}	.076	Psychometric equations based on dry bulb and RH
h, Enthalpy of infiltration air at 55% RH	BTU/ft.^{2}	20.609	
p_r Density of refrigerated air at 80% RH	lb./ft.^{2}	.081	
h_r Enthalpy of refrigerated air at 80% RH	BTU/ft.^{2}	9.462	

Table 2-85 summarizes savings by system, baseline, and facility type for strip curtains on a per-square-foot basis.

Table 2-85 Strip Curtains – Deemed Savings Values (per Square Foot)[315]

Case Description	Preexisting Curtains	kWh Savings (kWh/ft.^{2})	kW Savings (kWh/ft.^{2})
Supermarket – Cooler	Yes	62	0.00708
Supermarket – Cooler	No	108	0.01233
Supermarket – Cooler	Unknown	37	0.00422
Supermarket – Freezer	Yes	179	0.02043
Supermarket – Freezer	No	349	0.03984
Supermarket – Freezer	Unknown	61	0.00696
Convenience Store - Cooler	Yes	5	0.00057
Convenience Store - Cooler	No	20	0.00228
Convenience Store - Cooler	Unknown	11	0.00126
Convenience Store - Freezer	Yes	8	0.00091
Convenience Store - Freezer	No	27	0.00308
Convenience Store - Freezer	Unknown	17	0.00194
Restaurant - Cooler	Yes	8	0.00091
Restaurant – Cooler	No	30	0.00342
Restaurant – Cooler	Unknown	18	0.00205
Restaurant - Freezer	Yes	34	0.00388
Restaurant - Freezer	No	119	0.01358
Restaurant - Freezer	Unknown	81	0.00925
Refrigerated Warehouse	Yes	254	0.02900
Refrigerated Warehouse	No	729	0.08322
Refrigerated Warehouse	Unknown	287	0.03276

[315] Pacific Gas & Electric (PG&E), 2009, "Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases).

Table 2-86 summarizes the deemed savings that should be used when project-specific data is not available. These values are per-walk-in door and assume the following:

- Doorway area: Supermarket: 35; Convenience Store: 21; Restaurant: 21; and Refrigerated Warehouse: 80
- Preexisting curtains: Unknown

Table 2-86 Strip Curtains – Deemed Savings Values (per door)[316]

Case Description	Preexisting Curtains	kWh Savings (kWh/door)	kW Savings (kW/door)
Supermarket – Cooler	Unknown	1,295	0.1477
Supermarket – Freezer	Unknown	2,135	0.2436
Convenience Store - Cooler	Unknown	231	0.02646
Convenience Store - Freezer	Unknown	357	0.04074
Restaurant – Cooler	Unknown	378	0.04305
Restaurant - Freezer	Unknown	1,701	0.19425
Refrigerated Warehouse	Unknown	22,960	2.6208

2.4.6.5 Incremental Cost

The full measure cost should be used. When not available, use $10.22 per linear foot (DEER, 2014).

For projects that lack specific inputs for size, the default incremental costs are Supermarket: $358; Convenience Store: $215; Restaurant: $215; and Refrigerated Warehouse: $818

2.4.6.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure had low participation in Energy Smart programs. As a result, savings are calculated using weather-adjusted default values from other programs. If participation exceeds 500,000 kWh, the evaluation should include a metering study to support coverage time estimates.

[316] *Ibid.*

2.4.7 ZERO ENERGY DOORS

2.4.7.1 Measure Description

This measure applies to the installation of zero energy doors for refrigerated cases. Zero energy doors eliminate the need for anti-sweat heaters to prevent the formation of condensation on the glass surface by incorporating heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate glass panes, and/or non-metallic frames.

This measure cannot be used in conjunction with anti-sweat heat (ASH) controls.

2.4.7.2 Baseline and Efficiency Standards

The baseline standard for this measure is a standard vertical reach-in refrigerated cooler or freezer with anti-sweat heaters on the glass surface of the doors.

The efficiency standard for this measure is a reach-in refrigerated cooler or freezer with special doors installed to eliminate the need for anti-sweat heaters. Doors must have either heat reflective treated glass, be gas-filled, or both.

2.4.7.3 Estimated Useful Life

According to the CA DEER, zero energy doors are assigned an EUL of 12 years.

2.4.7.4 Deemed Savings Values

$$kW_{savings} = kW_{door} \times BF$$

$$kWh_{savings} = kW_{savings} \times 8760$$

Where:

kW_{door} = Connected load kW of a typical reach-in cooler or freezer door with a heater

BF = Bonus factor for reducing cooling load from eliminating heat generated by the door heater from entering the cooler or freezer

8760 = Annual operating hours

Table 2-87 Assumptions for Savings Calculations

Variable	Deemed Values
kW_{door}[317]	Cooler: 0.075 Freezer: 0.200

[317] Based on range of wattages from two manufacturers and metered data (cooler 50-130W, freezer 200-320W). Efficiency Vermont Commercial Master Technical Reference Manual No. 2005-37.

BF[318]	Low-Temp Freezer: 1.3 Medium-Temp Cooler: 1.2 High-Temp Cooler: 1.1

Table 2-88 Zero Energy Doors – Deemed Savings Values (per door)[319]

Measure	kWh Savings	kW Savings	Measure
Low-Temperature Freezer (< 25°F)	2,278	0.26	Low-Temperature Freezer (< 25°F)
Medium-Temperature Cooler (25° - 40°F)	2,102	0.24	Medium-Temperature Cooler (25° - 40°F)
High-Temperature Cooler (41° - 65°F)	723	0.08	High-Temperature Cooler (41° - 65°F)

2.4.7.5 Incremental Cost

The incremental cost is $290 per door.[320]

2.4.7.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. If this measure is added to Energy Smart, The TPE recommends a baseline study to capture the market share of ASH-controlled doors versus uncontrolled doors.

[318] Bonus factor (1+0.65/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discuss compressor efficiencies with Saturated Suction Temperatures of -20ºF, 20ºF, and 45ºF, respectively, and a condensing temperature of 90ºF, and manufacturers assumption that 65% of heat generated by door enters the refrigerated case. Efficiency Vermont Commercial Master Technical Reference Manual No. 2005-37.

[319] Temperature ranges based on Commercial Refrigeration Rebate Form, p, 3. Efficiency Vermont. https://www.efficiencyvermont.com/Media/Default/docs/rebates/forms/efficiency-vermont-commercial-refrigeration-rebate-form.pdf.

[320] Vermont TRM

2.4.8 EVAPORATOR FAN CONTROLS

2.4.8.1 Measure Description

This measure applies to the installation of evaporator fan controls. As walk-in cooler and freezer evaporators often run continuously, this measure consists of a control system that turns the fan on only when the unit's thermostat is calling for the compressor to operate.

2.4.8.2 Baseline and Efficiency Standards

The baseline standard for this measure is an existing shaded pole evaporator fan motor with no temperature controls with 8,760 annual operating hours.

The efficiency standard for this measure is an energy management system (EMS) or other electronic controls to modulate evaporator fan operation based on temperature of the refrigerated space.

2.4.8.3 Estimated Useful Life

According to the CA DEER database evaporator fan controls are assigned an EUL of 16 years.[321]

2.4.8.4 Deemed Savings Values

Table 2-89 Evaporator Fan Controls Deemed Savings Values

Measure	kWh Savings	kW Savings
Low-Temperature Freezer (< 25°F)	543	0.062
Medium-Temperature Cooler (25° - 40°F)	501	0.057
High-Temperature Cooler (41° - 65°F)	463	0.053

The energy savings from the installation of evaporator fan controls are a result of savings due to the reduction in operation of the fan. The energy and demand reduction are calculated using the following equations:

$$kW_{savings} = \left[\left(kW_{evap} \times n_{fans}\right) - kW_{circ}\right] \times \left(1 - DC_{comp}\right) \times DC_{evap} \times BF$$

$$kWh_{savings} = kW_{savings} \times 8760$$

Where:

kW_{evap} = Nameplate connected load kW of each evaporator fan = 0.123 kW (default) [322]

kW_{circ} = Nameplate connected load kW of the circulating fan = 0.035 kW (default) [323]

[321] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

[322] Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts.

[323] Wattage of fan used by Freeaire and Cooltrol.

n_{fans} = Number of evaporator fans

DC_{comp} = Duty cycle of the compressor = 50% (default) [324]

DC_{evap} = Duty cycle of the evaporator fan = Coolers: 100%; Freezers: 94% (default) [325]

BF = Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running = Low Temp.: 1.5, Medium Temp.: 1.3, High Temp.: 1.2 (default)[326]

8760 = Annual hours per year

2.4.8.5 Incremental Cost

The incremental cost is $291 per unit[327].

2.4.8.6 Future Studies

At the time of authorship, this measure had low participation in Energy Smart programs. As a result, savings are calculated using weather-adjusted default values from other programs. If participation exceeds 500,000 kWh, the evaluation should include a metering study to support energy savings estimates.

[324] A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (35%-65%), Control (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically adds another 25% safety factor, which results in a 50% overall duty factor.

[325] An evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day).

[326] Bonus factor (1+1/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.

[327] CA DEER, 2014

2.5 Food Service

2.5.1 ENERGY STAR GRIDDLES

2.5.1.1 Measure Description

This measure applies to ENERGY STAR electric commercial griddles in retrofit and new construction applications. This appliance is designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface or a hot channeled cooking surface where plate temperature is thermostatically controlled.

Energy-efficient commercial electric griddles reduce energy consumption primarily through application of advanced controls and improved temperature uniformity. Energy efficient commercial gas griddles reduce energy consumption primarily through advanced burner design and controls.

2.5.1.2 Baseline and Efficiency Standards

Key parameters for defining griddle efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. There are currently no federal minimum standards for Commercial Griddles, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[328] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

ENERGY STAR efficiency requirements apply to single and double-sided griddles. The ENERGY STAR criteria should be reviewed on an annual basis to reflect the latest requirements.

Table 2-90 ENERGY STAR Criteria[329] for Electric and Gas Single- and Double-Sided Griddles

Performance Parameters	**Electric Griddles**
Heavy-Load Cooking Energy Efficiency	≥70%
Idle Energy Rate	≤320 watts per ft^2

2.5.1.3 Estimated Useful Life

According to the CA DEER commercial griddles are assigned an EUL of 12 years.[330]

2.5.1.4 Deemed Savings Values

Annual savings can be calculated by determining the energy consumed by a standard efficiency griddle as compared with an ENERGY STAR rated griddle.

$$\Delta kWh = kWhbase - kWheff$$

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[328] The industry standard for energy use and cooking performance of griddles are ASTM F1275-03: Standard Test Method for the Performance of Griddles and ASTM F1605-01: Standard Test Method for the Performance of Double-Sided Griddles

[329] ENERGY STAR Commercial Griddles Program Requirements Version 1.1, effective May 2009 for gas griddles and effective January 1, 2011 for electric.

[330] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

$$kWh(base\ or\ eff) = kWhcooking + kWhidle + kWhpreheat$$

$$kWhcooking = \left(LBfood \times \frac{Efood}{CookEff}\right) \times Days$$

$$kWhidle = IdleEnergy\ \times\ (DailyHrs - \frac{LBfood}{Capacity} - \frac{PreheatTime}{60}) \times Days$$

$$kWhpreheat = PreheatEnergy\ \times Days$$

Key parameters used to compute savings are defined in Table 2-91.

Table 2-91 Energy Consumption Related Parameters for Commercial Griddles[331]

Parameter	Description	Value	Source
Daily Hrs.	Daily Operating Hours	12 hours	FSTC
Preheat Time	Time to Preheat (Min)	15 Minutes	FSTC
E_{food}	ASTM defined Energy to Food	0.139 kWh/lb., 475 Btu/lb	FSTC
Days	Number of Days of operation	365 Days	FSTC
CookEff	Cooking Energy Efficiency (%)	See Table 2-92	FSTC
IdleEnergy	Idle energy rate (kW), (Btu/h)		FSTC, ENERGY STAR
Capacity	Production capacity (lbs./hr)		FSTC
Preheat Energy	kWh/day, Btu/day		FSTC
LB_{Food}	Food cooked per day (lb/day)		FSTC

General assumptions used for deriving deemed electric and gas savings are values are taken from the Food Service Technology Center (FSTC) work papers.[332] These deemed values assume that the griddles are 3 x 2 feet in size. Parameters in the table are per linear foot, with an assumed depth of 2 feet.

[331] Assumptions based on PG&E Commercial Griddles Work Paper developed by FSTC, May 22, 2012.

[332] FSTC food service equipment work papers submitted to CPUC for Energy Efficiency 2013-2014 Portfolio; document titled EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip

https://www.pge.com/regulation/EnergyEfficiency2013-2014-Portfolio/Testimony/PGE/2012/EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip.

Table 2-92 Baseline and Efficient Assumptions for Electric Griddles

Parameter	Baseline Electric Griddles	Efficient Electric Griddles
Preheat Energy (kWh/ft.)	1.33	0.67
Idle Energy Rate (kW/ft.)	0.8	0.64
Cooking Energy Efficiency (%)	65%	70%
Production Capacity (lbs./h/ft.)	11.7	16.33
Lbs. of food cooked/day/ft.	33.33	33.33

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = (\frac{\Delta kWh}{HOURS}) \times CF$$

Where:

ΔkWh = Annual energy savings (kWh)

4380 = Operating Equivalent hours = 365 x 12 = 4380 hours

0.84[333] = Coincidence Factor (CF)

Deemed savings based on the assumptions above are tabulated below per griddle, per linear foot.

Table 2-93 Deemed Savings for Electric and Gas Commercial Griddles per Linear Foot

Measure Description	Deemed Savings per Griddle per linear foot	
	kW	kWh
Griddle, Electric, ENERGY STAR	0.15	758

2.5.1.5 Incremental Cost

The incremental cost is $60 per linear foot of width of the unit[334].

2.5.1.6 Future Studies

At the time of authorship, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values from FSTC. If this measure is added to Energy Smart programs, the evaluation should include an assessment of actual usage schedules to replace the default FSTC schedule values.

[333] Coincidence factors utilized in other jurisdictions for Commercial Griddles vary from 0.84 to 1.0. The KEMA report titled “Business Programs: Deemed Savings Parameter Development,” November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

[334] Measure cost from ENERGY STAR which cites reference as “EPA research on available models using AutoQuotes, 2010” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

2.5.2 ENERGY STAR CONVECTION OVENS

2.5.2.1 Measure Description

High efficiency ovens exhibit better baking uniformity and higher production capacities while also including high-quality components and controls.

2.5.2.2 Baseline and Efficiency Standards

Efficient convection ovens are defined by ENERGY STAR or its equivalent and apply to electric full-size and half-size convection ovens and gas full-size convection ovens. Full size ovens accept a minimum of five pans measuring 18 x 26 x 1-inch. Half size ovens accept a minimum of five sheet pans measuring 18 x 13 x 1-inch. The ENERGY STAR criteria should be reviewed on an annual basis to reflect the latest requirements.

There are currently no federal minimum standards for Commercial Convection Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[335] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Table 2-94: ENERGY STAR Criteria for Electric Convection Ovens[336]

Performance Parameters	Half Size Electric Ovens	Full Size Electric Ovens ≥ 5 Pans	Full Size Electric Ovens <5 Pans
Heavy-Load Cooking Energy Efficiency	≥71%	≥76%	
Idle Energy Rate	≤1.0 kW	≤1.4 kW	≤1.6 kW

2.5.2.3 Estimated Useful Life

According to the CA DEER, all commercial ovens are assigned an EUL of 12 years.[337]

2.5.2.4 Deemed Savings Values

Annual savings can be calculated by determining the energy consumed by a standard efficiency convection oven as compared with an ENERGY STAR rated convection oven.

$$\Delta kWh = kWhbase - kWheff$$

$$kWh(base\ or\ eff) = kWhcooking + kWhidle + kWhpreheat$$

[335] The industry standard for energy use and cooking performance of convection ovens is ASTM F-2861-10, Standard Test Method for Enhanced Performance of Combination Oven in Various Modes.

[336] ENERGY STAR Commercial Ovens Version 1.1, effective May 2009; Version 2.0 is currently under development to be released by 2013. New efficiency levels will be identified and scope will add Combination Ovens.

[337] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

$$kWhcooking = \left(LB \times \frac{Efood}{CookEff}\right) \times Days$$

$$kWhidle = IdleEnergy \times \left(DailyHrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

$$kWhpreheat = PreheatEnergy \times Days$$

General assumptions in Table 2-95 are from the ENERGY STAR *Commercial Kitchen Equipment Savings Calculator – Convection Ovens* which refers to the Food Service Technology Center (FSTC) work papers and research.[338]

Table 2-95 Baseline and Efficient Assumptions for Electric Convection Ovens

Parameter	Half Size Electric Ovens		Full Size Electric Ovens	
	Baseline Model	Efficient Model	Baseline Model	Efficient Model
Preheat Energy (kWh/day)	0.89	0.7	1.563	1.389
Idle Energy Rate (kW)	1.03	1.00	2.00	< 5 pans: 1.0 ≥ 5 pans: 1.4
Cooking Energy Efficiency (%)	68%	71%	65%	76%
Production Capacity (lbs./hour)	45	50	90	90
Lbs. of food cooked/day	100	100	100	100
Efood (kWh/lb)	0.0732	0.0732	0.0732	0.0732
Days	365	365	365	365
Daily Hours	12	12	12	12
Preheat Time	9	8	9	9

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

338 FSTC food service equipment workpapers submitted to CPUC for Energy Efficiency 2013-2014 Portfolio; document titled EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip

Where:

ΔkWh = Annual energy savings (kWh)

$HOURS$ = Operating Equivalent hours = 365 x 12 = 4,380 hours[339]

CF = Coincidence Factor = 0.84[340]

Deemed savings based on the assumptions above are tabulated below for electric convection ovens.

Table 2-96 Deemed Savings Estimates for Electric Convection Ovens

Measure Description	Deemed Savings per Oven	
	kWh	kW
Half Size Electric Ovens	254	0.049
Full Size Electric Ovens < 5 Pans	4,578	0.878
Full Size Electric Ovens ≥ 5 Pans	3,010	0.577

2.5.2.5 Incremental Cost

The incremental cost for this measure is $1,022.[341]

2.5.2.6 Future Studies

There are currently no future studies planned for this measure at this time.

339 ENERGY STAR Commercial Kitchen Equipment Savings Calculator – Convection Ovens assumes an operating time of 12 hours.

340 KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

341 Measure cost from ENERGY STAR which references the "2016 IMC Analysis – For Cal TF (Energy Solutions)" document from: https://www.caetrm.com/media/reference-documents/2016_IMC_Analysis_-_For_Cal_TF_Energy_Solutions.xlsx

2.5.3 ENERGY STAR COMBINATION OVENS

2.5.3.1 Measure Description

Combination ("combi") ovens are convection ovens with a steam cooking mode.

2.5.3.2 Baseline and Efficiency Standards

There are currently no federal minimum standards for Commercial Combination Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods611 that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

As of January 12, 2023, ENERGY STAR 3.0 specification applies to electric combination ovens. Combination ovens combines the function of hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating, to perform steaming, baking, roasting, rethermalizing, and proofing of various food products.

Table 2-97 High Efficiency Requirements for Electric Combination Ovens by Pan Capacity

Mode	Idle Rate	Cooking Efficiency (%)
Full and Half Size5-40 Pan Capacity (P)		
Steam Mode	≤ 0.133P + 0.64 kW	≥ 55%
Convection Mode	≤ 0.083P + 0.35 kW	≥ 78%
3 – 4 Pan Capacity and 2/3rd Size with 3-5 Pan Capacity		
Steam Mode	≤ 0.60P	≥ 51%
Convection Mode	≤ 0.05P + 0.55	≥ 70%

2.5.3.3 Estimated Useful Life

According to the CA DEER, all commercial ovens are assigned an EUL of 12 years.[342]

2.5.3.4 Deemed Savings Values

Annual savings can be calculated by determining the energy consumed by a standard efficiency combination oven as compared with a high efficiency combination oven.

$$\Delta kWh = kWhtotal, base - kWhtotal, eff$$

$$kWh(total, base\ or\ total, eff) = kWhoven + kWhsteam + kWhpreheat$$

$$kWh(oven\ or\ steam) = kWhcooking + kWhidle$$

[342] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

$$kWhcooking\ (oven\ or\ steam) = (LBoven\ or\ steam \times \frac{Efood}{\text{CookEff}}) \times Days$$

Where:

LB_{oven} = LB × (1-% Steam) and LB_{steam} = LB × % Steam

$$kWhidle(oven)$$
$$= (1 - \%Steam) \times IdleEnergy \times (DailyHrs - LBovenCapacity$$
$$- nP \times PreheatTime60) \times Days$$

$$kWhidle(steam)$$
$$= (\%Steam) \times IdleEnergy\ \times\ (DailyHrs - LBsteamCapacity$$
$$- np \times PreheatTime60) \times Days$$

$$kWhpreheat = nP \times PreheatEnergy\ \times Days$$

For kWh_{idle} calculations below, use the correct oven/steam specific parameters as outlined in Table 2-98

$$kWh_{idle}\ (oven)$$
$$= (1 - \%Steam) \times IdleEnergy \times (DailyHrs - LBCapacity$$
$$- PreheatTime60) \times Days$$

$$kWh_{idle}\ (steam)$$
$$= (\%Steam) \times IdleEnergy\ \times\ (DailyHrs - LBCapacity$$
$$- PreheatTime60) \times Days$$

$$kWhpreheat = PreheatEnergy\ \times Days$$

Key parameters used to compute savings are listed in Table 2-98.

Table 2-98 Energy Consumption Parameters for Commercial Combination Ovens[343]

Parameter	Description	Baseline	Efficient
CookEffoven 3-4 pans	Cooking efficiency (%) Convection Mode	69%	70%
CookEffoven 5-40 pans	Cooking efficiency (%) Convection Mode	69%	78%
CookEffsteam 3-4 pans	Cooking efficiency (%) Steam Mode	45%	51%
CookEffsteam 5-40 pans	Cooking efficiency (%) Steam Mode	45%	55%
IdleEnergyoven	Idle energy rate (kW)	1.32	1.299
IdleEnergysteam		5.26	1.97
Capacityoven	Production capacity (lbs./hr)	79	119
Capacitysteam		126	177
PreheatTime	Time to Preheat (Min)	15	
PreheatEnergy	kWh/day	3	1.5
% Steam	Percent of time in Steam Mode	50%	
Efoodoven	ASTM defined Convection Oven Energy to Food (kWh/lb)	0.0732	
Efoodsteam	ASTM defined Energy to Food for Steam Cookers (kWh/lb)	0.0308	

343 All baseline and efficient data in this table are extracted from the ENERGY STAR Commercial Food Service Calculator and have been modified based on the ENERGY STAR V.3 Commercial Oven Program Requirements from: https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf

LB	Food cooked per day (lb/day) in steam mode or oven mode	100
DailyHrs	Daily Operating Hours	12
Days	Number of days of operation	365

General assumptions used for deriving deemed savings are defined in the following tables. These values were taken from the ENERGY STAR Food Service Appliance Calculator as well as the Food Service Technology Center (FSTC) Life Cycle and Energy Cost Calculator.

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

Where:

ΔkWh = Annual energy savings (kWh)

$HOURS$ = Operating Equivalent hours = 365 x 12 = 4,380 hours[344]

CF = Coincidence Factor = 0.84[345]

2.5.3.5 Deemed Savings Estimates for Combination Ovens

Deemed savings values are listed below:

- Combination Oven, Electric, ENERGY STAR Deemed Savings kWh – 6,368
- Combination Oven, Electric, ENERGY STAR Deemed Peak Demand Savings kW – 1.22

2.5.3.6 Incremental Cost

The incremental cost is $2,000 for electric combination ovens[346].

2.5.3.7 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values from Energy Star. If this measure is added to Energy Smart programs, the evaluation should include an assessment of actual usage schedules to replace the default Energy Star schedule values.

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[344] ENERGY STAR Commercial Kitchen Equipment Savings Calculator – Convection Ovens assumes an operating time of 12 hours.

[345] KEMA report titled “Business Programs: Deemed Savings Manual V1.0,” March 2010 conducted for State of Wisconsin Public Service Commission of Wisconsin lists Coincidence Factors by building type and identifies food service at 0.84.

[346] Incremental cost for combination oven is from the ENERGY STAR Commercial Food Service Calculator, which references the “Combi 2016 Prices Updated” document from: https://www.caetrm.com/media/reference-documents/Combi_2016_Prices_Updated.xlsx

2.5.4 FRYERS

2.5.4.1 Measure Description

This measure applies to ENERGY STAR or its equivalent electric commercial open-deep fat fryers in retrofit and new construction applications. Commercial fryers consist of a reservoir of cooking oil that allows food to be fully submerged without touching the bottom of the vessel. Electric fryers use a heating element immersed in the cooking oil.

High efficiency standard and large vat fryers offer shorter cook times and higher production rates through the use of advanced burner and heat exchanger design. Standby losses are reduced in more efficient models through the use of fry pot insulation.

2.5.4.2 Baseline & Efficiency Standard

Key parameters for defining fryer efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. ENERGY STAR requirements apply to a standard fryer and a large vat fryer. A standard fryer measures 14 to 18 inches wide with a vat capacity from 25 to 60 pounds. A large vat fryer measures 18 inches to 24 inches wide with a vat capacity greater than 50 pounds. The ENERGY STAR criteria should be reviewed on an annual basis to reflect the latest requirements.

There are currently no federal minimum standards for Commercial Fryers, however, ASTM publishes Test Methods[347] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Table 2-99 ENERGY STAR Criteria[348] and FSTC Baseline for Open Deep-Vat Electric Fryers

Performance Parameters	**ENERGY STAR Electric Fryer Criteria**	
	Standard Fryers	**Large Vat Fryers**
Heavy-Load Cooking Energy Efficiency	> 83%	> 80%
Idle Energy Rate	< 800 W	<1,100 W

2.5.4.3 Estimated Useful Life

According to DEER 2014, commercial fryers are assigned an EUL of 12 years.[349]

2.5.4.4 Deemed Savings Values

Annual savings can be calculated by determining the energy consumed by a standard efficiency fryer as compared with an ENERGY STAR rated fryer.

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[347] The industry standards for energy use and cooking performance of fryers are ASTM Standard Test Method for the Performance of Open Deep Fat Fryers (F1361) and ASTM Standard Test Method for the Performance of Large Vat Fryers (FF2144).

[348] ENERGY STAR Program Requirements for Commercial Fryers, Version 3.0 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Commercial%20Fryers%20Version%203.0%20%28Rev.%20December%20-%202020%29%20Specification.pdf

[349] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

$$\Delta kWh = kWhbase - kWheff$$

$$kWh(base\ or\ eff) = kWhcooking + kWhidle + kWhpreheat$$

$$kWhcooking = \left(LB \times \frac{Efood}{CookEff}\right) \times Days$$

$$kWhidle = IdleEnergy\ \times \left(DailyHrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

$$kWhpreheat = PreheatEnergy\ \times Days$$

Key parameters used to compute savings are defined in Table 2-100.

Table 2-100 Energy Consumption Related Parameters for Commercial Fryers[350]

Parameter	Description	Value	Source
Daily Hrs.	Daily Operating Hours	12 hours	FSTC
Preheat Time	Time to Preheat (Min)	15 Minutes	FSTC
E_{food}	ASTM defined Energy to Food	0.167 kWh/lb, 570 Btu/lb.	FSTC
Days	Number of Days of operation	365 Days	FSTC
CookEff	Cooking Energy Efficiency (%)	See Table 2-101	FSTC
IdleEnergy	Idle energy rate (kW), (Btu/h)		FSTC, ENERGY STAR
Capacity	Production capacity (lbs./hr)		FSTC
Preheat Energy	kWh/day, Btu/day		FSTC
LB	Food cooked per day (lb/day)		FSTC

General assumptions used for deriving deemed electric and gas savings are defined in the following tables. These values are taken from the ENERGY STAR *Commercial Kitchen Equipment Savings* Calculator as well as the Food Service Technology Center (FSTC) work papers and research.

[350] Assumptions based on PG&E Commercial Fryers Work Paper developed by FSTC, June 13, 2012

Table 2-101 Baseline and Efficient Assumptions for Electric Standard and Large Vat Fryers

Parameter	Baseline Electric Fryers		Efficient Electric Fryers	
	Standard	Large Vat	Standard	Large Vat
Preheat Energy (kWh/lb)	2.3	2.5	1.7	2.1
Idle Energy Rate (kW)	1.05	1.35	0.80	1.10
Cooking Energy Efficiency (%)	75%	70%	83%	80%
Production Capacity (lbs./hour)	65	100	70	110
Lbs. of food cooked/day	150	150	150	150

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

Where:

ΔkWh = Annual energy savings (kWh)

$HOURS$ = Operating equivalent hours = 365 x 12 = 4,380

CF = Coincidence factor = 0.84[351]

Deemed savings using the assumptions above are tabulated below. These values are per installed unit based on the type of fryer.

Table 2-102 Deemed Savings per Fryer Vat

Measure Description	Deemed Savings per Fryer Vat	
	kWh	kW
Fryer, Electric, ENERGY STAR	2,208	0.42
Fryer, Large Vat, Electric, ENERGY STAR	2,659	0.51

2.5.4.5 Incremental Cost

The incremental cost is $1,200[352].

2.5.4.6 Future Studies

At the time of authorship, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values from FSTC. If this measure is added to Energy Smart programs, the evaluation should include an assessment of actual usage schedules to replace the default FSTC schedule values.

[351] Coincidence factors utilized in other jurisdictions for Commercial Fryers vary from 0.84 to 1.0. The KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

[352] Cost from ENERGY STAR which cites reference as "EPA research on available models using AutoQuotes, 2010" http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

2.5.5 STEAM COOKERS

2.5.5.1 Measure Description

This measure applies to ENERGY STAR or its equivalent electric steam cookers in retrofit and new construction applications. Commercial steam cookers, also known as “compartment steamers,” vary in configuration and size based on the number of pans. High efficiency steam cookers offer shorter cook times, higher production rates and reduced heat loss due to better insulation and more efficient steam delivery system.

2.5.5.2 Baseline & Efficiency Standard

Key parameters for defining steam cookers efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. ENERGY STAR requirements apply to steam cookers based on the pan capacity. These criteria should be reviewed on an annual basis to reflect the latest ENERGY STAR requirements.

There are currently no federal minimum standards for Commercial Steam Cookers, however, ASTM publishes Test Methods[353] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Table 2-103 ENERGY STAR Criteria for Electric Steam Cookers[354]

Pan Capacity	Cooking Efficiency	Idle Rate (watts)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Table 2-104 ENERGY STAR Criteria for Gas Steam Cookers[355]

Pan Capacity	Cooking Efficiency	Idle Rate (Btu/h)
5-pan	38%	10,400
6-pan and larger	38%	12,500

2.5.5.3 Estimated Useful Life

According to DEER 2014 steam cookers are assigned an EUL of 12 years.

2.5.5.4 Deemed Savings Values

Energy savings for steam cookers is derived by determining the total energy consumed by standard steam cooker as compared with an ENERGY STAR rated steam cooker. Total energy for a steam cooker includes the energy used during cooking, the energy used when the equipment is idling, the energy spent when set in a constant steam mode and the energy required during pre-heat.

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[353] The industry standard for steam cookers energy use and cooking performance is ASTM Standard F1484-99, Test Method for the Performance of Steam Cookers/

[354] ENERGY STAR Commercial Steam Cookers Version 1.2, effective August 1, 2003.

[355] ENERGY STAR provides criteria for 3-pan, 4-pan but availability of products in this range is limited or unavailable.

$$\Delta Energy = Energybase, total - Energyeff, total$$

$$Energy(base, total\ or\ eff, total)$$

$$= Energycooking + Energyidle + Energysteam + Energypreheat$$

Where:

$$Energycooking = LB\ food \times EfoodCook\ Eff \times Days$$

$$Energyidle = (1 - \%Steam) \times IdleEnergy \times (DailyHrs - \frac{LBfood}{Capacity} - \frac{PreheatTime}{60}) \times Days$$

$$Energysteam = (\%Steam) \times \frac{Capacity \times Efood}{Cook\ Eff} \times \left(DailyHrs - \frac{LBfood}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

$$Energypreheat = PreheatEnergy \times Days$$

General assumptions used for deriving deemed electric savings are defined in the following tables. These values are taken from the ENERGY STAR *Commercial Kitchen Equipment Savings* Calculator as well as the Food Service Technology Center (FSTC) work papers and research.

Table 2-105 Energy Consumption Related Parameters for Commercial Steam Cookers

Parameter	Description	Value	Source/Approach
Daily Hrs.	Daily Operating Hours	12 hours	FSTC
Preheat Time	Steam Cooker Preheat Time (Min)	15 min	FSTC
E_{food}	ASTM defined Energy to Food	0.0308 kWh/lb, 105 Btu/lb	FSTC
Days	Number of days of operation	365 days	FSTC
CookEff	Cooking energy efficiency (%)	See Table 2-106	FSTC
IdleEnergy	Idle energy rate (kW), (Btu/h)		FSTC, ENERGY STAR
%Steam	Constant Steam energy use		FSTC
Capacity	Production capacity (lb/hr)		ENERGY STAR
Preheat Energy	kWh/day, Btu/day		ENERGY STAR
LB_{food}	Food cooked per day (lb/day)		ENERGY STAR

Table 2-106 Deemed Savings Assumptions for Electric Steam Cookers

Parameter	Baseline Model	Efficient Electric Model
Cooking Efficiency (%)	26%	50%
Preheat Energy (kWh)	1.5	1.5
Constant Steam Mode Time (%)	90%	10%
Lbs. of food Cooked/Day	100	100
Production Capacity (lbs./hr/pan)	23.33	16.67
Idle Energy Rate (kW/pan)	0.33	0.13

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

Where:

ΔkWh = Annual energy savings (kWh)

4380 = Operating Equivalent hours = 365 x 12 = 4380 hours

0.84[356] = Coincidence Factor (CF)

Deemed savings are per installed unit based on the number of pans per steam cooker.

Table 2-107 Deemed Savings for Steam Cookers

Number of Pans	kW	kWh
Steam Cooker, Electric, 3-pan - ENERGY STAR	5.4	28,214
Steam Cooker, Electric, 4-pan - ENERGY STAR	7.3	38,081
Steam Cooker, Electric, 5-pan - ENERGY STAR	9.2	47,948
Steam Cooker, Electric, 6-pan - ENERGY STAR	11.1	57,815

2.5.5.5 Incremental Cost

The incremental cost is $2,490[357].

2.5.5.6 Future Studies

At the time of authorship, this measure was not implemented in Energy Smart programs. As a result, savings are calculated using default values from FSTC.

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[356] Coincidence factors utilized in other jurisdictions for Commercial Steam Cookers vary from 0.84 to 1.0. The KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

[357] 32Source for efficient electric steamer incremental cost is $2,490 per 2009 PG&E Workpaper - PGECOFST104.1 - Commercial Steam Cooker - Electric and Gas as reference by KEMA in the ComEd C & I TRM.

2.5.6 PRE-RINSE SPRAY VALVES

2.5.6.1 Measure Description

This measure consists of installing low-flow pre-rinse spray valves which reduce hot water use and save energy associated with heating the water. The low-flow pre-rinse spray valves have the same cleaning effect as the existing standard spray valves even though they use less water.

Savings are shown assuming two possible delivery channels:

- Direct install retrofit of functioning equipment
- Downstream rebate measure, replacing failed equipment, new construction.

2.5.6.2 Baseline & Efficiency Standard

For direct install (DI) PRSVs, a the pre-2019 code of 1.60 GPM may be used. For downstream rebates or replace on burnout, the baseline is 1.28 GPM[358].

The maximum flow rate of program-qualifying low-flow pre-rinse spray valves is 1.07 GPM. To qualify for savings the facility must have electric domestic hot water equipment.

2.5.6.3 Estimated Useful Life

The EUL of a PRSV is 5 years.[359] DI PRSV may claim two years of RUL at the 1.60 baseline, while the last three years must use the 1.28 GPM baseline. This results in a weighted EUL of 3.19 years for DI PRSV, using the early replacement baseline.

2.5.6.4 Deemed Savings Values

Table 2-108 Deemed Savings – Direct Install

Facility Type	Days/Year	Minutes/Day	kWh	kW
Fast Food	365	45	980	0.134
Casual Dining	365	105	2,287	0.251
Institutional	365	210	4,574	0.376
Dormitory	274	210	3,434	0.501
K-12 School	200	105	1,253	0.313

Table 2-109 Deemed Savings – Rebate/ROB/NC

Facility Type	Days/Year	Minutes/Day	kWh	kW
Fast Food	365	45	388	0.053
Casual Dining	365	105	906	0.099
Institutional	365	210	1,813	0.149
Dormitory	274	210	1,361	0.199
K-12 School	200	105	497	0.124

[358] FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-13: Standard Test Method for Pre-Rinse Spray Valves.

[359] FEMP Purchasing Specification for Energy-Efficiency Products, Pre-Rinse Spray Valves: http://www1.eere.energy.gov/femp/pdfs/pseep_spray_valves.pdf

Annual kWh electric and peak kW savings can be calculated using the following equations and Table 2-110 summarizes the needed variables:

$$\Delta kWh = \frac{\rho \times CP \times U \times (FB - FP) \times (TH - TSupply) \times \frac{1}{Et} \times \frac{Days}{Year}}{3412BTU/kWh}$$

$$\Delta kW = \frac{\rho \times CP \times U \times (FB - FP) \times (TH - TSupply) \times \frac{1}{Et} \times P}{3412BTU/kWh}$$

Table 2-110 Variables for the Deemed Savings Algorithm

Parameter	Description	Value
F_B	Direct Install Average baseline flow rate (GPM) Downstream Rebate Average baseline flow rate (GPM)	1.60 1.28
F_P	Average post measure flow rate of sprayer (GPM)	1.07
Days/Year	Annual Operating Days for the applications: See Table 2-111 for building type definitions:	
	1. Fast Food Restaurant	365[360]
	2. Casual Dining Restaurant	365
	3.Institutional	365
	4. Dormitory	274[361]
	5. K-12 School	200
T_{supply}	Average supply (cold) water temperature (°F)	74.8
T_H	Average mixed hot water (after spray valve) temperature (°F)	120[362]
U_B	Baseline water usage duration for the following applications:	
	1. Fast Food Restaurant (see Table 2-112)	45 min/day/unit[363]
	2. Casual Dining Restaurant (see Table 2-112)	105 min/day/unit
	3. Institutional (see Table 2-112)	210 min/day/unit

[360] Osman S &. Koomey, J. G. , . Lawrence Berkeley National Laboratory 1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting. December.

[361]For dormitories with few occupants in the summer: 365 x (9/12) = 274.

[362] According to ASTM F2324 03 Cleanability Test the optimal operating conditions are at 120ºF.

[363] CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Valves.

	4. Dormitory (see Table 2-112)	210 min/day/unit
	5. K-12 School (see Table 2-112)	105 min/day/unit[364]
ρ	Density of water 8.33 lbs./Gallon	8.33
C_P	Heat capacity of water, 1 BTU/lb·°F	1
E_t	Thermal efficiency of water heater	0.98 electric & 0.80 gas
P	Hourly peak demand as a fraction of daily water consumption for the following applications:	
	1. Fast food restaurant (Fast Food)	0.05[365]
	2. Casual Dining Restaurant (Sit Down Rest.)	0.04
	3. Institutional (Nursing Home)	0.03
	4. Dormitory (Sit Down Rest.)	0.04
	5. K-12 School (High School)	0.05

Table 2-111 Building Type Definitions

Building Type	Operating Days per Year	Representative PRSV Usage Examples
1. Fast food restaurant	365	Establishments engaged in providing food services where patrons order and pay before eating. These facilities typically use disposable serving ware. PRSV are used for rinsing cooking ware, utensils, trays, etc. Examples: Fast food restaurant, supermarket food preparation and food service area, drive-ins, grills, luncheonettes, sandwich, and snack shops.
2. Casual dining restaurant	365	Establishments primarily engaged in providing food services to customers who order and are served while seated (i.e. waiter/waitress service). These facilities typically use chinaware and use the PRSV to rinse dishes, cooking ware, utensils, trays, etc. Example: Full meal restaurant.
3. Institutional	365	Establishments located in institutional facilities (e.g. nursing homes, hospitals, prisons, military) where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, tray, etc. Examples: Nursing home, hospital, prison cafeteria, and military barrack mess hall.

[364] School mealtime duration is assumed to be half of that of institutions, assuming that institutions (e.g. prisons, university dining halls, hospitals, nursing homes) serve three meals per day at 70 minutes each, and schools serve breakfast to half of the students and lunch to all, yielding 105 minutes per day.

[365] ASHRAE Handbook 2011. HVAC Applications. Chapter 50 –Service Water Heating. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA.

4. Dormitory	274	Establishments located in higher education facilities where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, trays, etc. Example: University dining halls.
5. K-12 school	200	Establishments located in K-12 schools where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, trays, etc. Example: K-12 school cafeterias

Table 2-112 Daily Operating Hours

Food Service Operation	Min (Min/Day)	Max (Min/Day)	Average (Min/Day)
Small Service (e.g., quick-service restaurants)	30	60	45
Medium Service (e.g., casual dining restaurants)	90	120	105
Large Service (e.g., institutional: cafeterias in universities, prisons, and nursing homes, etc.)	180	240	210

The following are example calculations for a fast food restaurant in New Orleans using the previous equations.

$$Direct\ Install\ \Delta kWh$$

$$= \frac{8.33\ BTU/Gal\ x\ 45\ minday\ x\ (1.60 - 1.07)GPM\ x\ (120 - 74.8°\text{F})x\ \left(\frac{1}{0.98}\right)\ x \frac{365\ days}{year}}{3412\ BTU/kWh}$$

$$= 980\ kWh$$

$$Direct\ Install\ \Delta kW = \frac{0.05\ x\ 8.33\ x\ 45\ minday\ x\ (1.60 - 1.07)GPM\ x\ (120 - 74.8°\text{F})\ x\ \left(\frac{1}{0.98}\right)}{3412\ BTU/kWh}$$

$$= 0.134\ kW$$

$ROB\ \Delta kWh$

$$= \frac{8.33\ BTU/Gal\ x\ 45\ minday\ x\ (1.28 - 1.07)GPM\ x\ (120 - 74.8°\text{F})x\ \left(\frac{1}{0.98}\right)\ x \frac{365\ days}{year}}{3412\ BTU/kWh}$$

$$= 388\ kWh$$

$$Direct\ Install\ \Delta kW = \frac{0.05\ x\ 8.33\ x\ 45\ minday\ x\ (1.28 - 1.07)GPM\ x\ (120 - 74.8°\text{F})\ x\ \left(\frac{1}{0.98}\right)}{3412\ BTU/kWh}$$

$$= 0..053\ kW$$

$$Lfetime\ \Delta kWh = 980\ kWh * 2\ years\ RUL + 388 * 3\ years = 3{,}124\ kWh$$

2.5.6.5 Incremental Cost

For direct install, program-actual costs should be used when available. If unknown, use a default value of \$92.90[366]. For downstream rebate, replace on burnout, or new construction use \$46.12.[367]

2.5.6.6 Future Studies

At the time of authorship, this measure was not implemented in Energy Smart programs. If this measure is incorporated into Energy Smart, the TPE recommends studying the following parameters: DHW setpoint; flow rate of installed PRSVs; and the flow rate of baseline PRSVs (to be collected by the program implementer and sent to the TPE for testing).

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

[367] CA DEER Workpaper SWFS013-01, authored by Southwest Gas (2010)

2.5.7 DEMAND CONTROL VENTILATION FOR KITCHENS

2.5.7.1 Measure Description

Commercial Demand Control Kitchen Ventilation (DCKV) systems are a technology implemented in a variety of commercial kitchen types in order to reduce energy use associated with ventilation fan energy use as well as the HVAC energy use associated with conditioning the requisite make up air (MAU). The systems incorporate sensors and variable speed controls to operate the ventilation equipment only when it is necessary.

2.5.7.2 Baseline and Efficiency Standards

The baseline for this measure is a commercial kitchen exhaust fan controlled with a simple on/off switch that operates at one fixed speed and can optionally include an MAU to resupply a portion of the ventilation air. The efficient case is a ventilation fan controlled by a DCKV system which modifies the fan speed depending on the requirements within the kitchen and cooking appliances.

2.5.7.3 Estimated Useful Life

According to DEER 2014 the EUL of this measure is 15 years[368].

2.5.7.4 Deemed Savings Values

Table 2-113 Rated Exhaust kW by Building Type, with or without Dedicated MAU

Building Type	Energy Savings ($kWh/kW_{exhaust}$)		Demand Savings ($kW/kW_{exhaust}$)		Heating Savings[369] ($kWh / kW_{exhaust}$)	Cooling Savings ($kWh / kW_{exhaust}$)
	MAU	No MAU	MAU	No MAU		
Supermarket	4,731	3,519	0.975	0.725	1,479	1,925
Restaurant[370]	5,492	4,085	0.975	0.725	1,717	2,235
Hotel	8,022	5,967	0.975	0.725	2,507	3,264
Campus	4,808	3,576	0.975	0.725	1,503	1,957
K-12 School, Inc Summer Sessions	3,205	2,384	0.975	0.725	1,002	1,304
K-12 School, No Summer Sessions	2,340	1,740	0.975	0.725	731	952

Note: If exhaust fan is only rated in horsepower, use the conversion 1 hp = 0.746 kW

[368] DEER 2014 for Variable Speed Drive controlled by CO2 sensor for HVAC-VSD-DCV

[369] Heating and cooling savings are assumed to be the same with or without an MAU. This is because any exhaust air will be replaced with outside air by the MAU or via increased infiltration proportional to exhaust airflow and thus will result in the same impact on heating and cooling equipment regardless of infiltration method. The savings calculation methodology was obtained from Work Paper SCE13CC008 (discussed below) and the AR TRM which also did not differentiate between MAU and non-MAU facilities.

[370] Source data (discussed below) included various restaurant types thus this value is applicable for all full service and fast-food kitchens.

Deemed demand and annual savings are based on average fan kW reductions, HVAC savings, and hours of use by kitchen type as calculated using Southern California Edison work paper SCE13CC008[371], and the AR TRM 8.1. Average fan energy savings (kW/kW) were calculated based on whether the kitchen had a dedicated MAU or not. The hours of use and annual days of operation were calculated from 72 surveyed sites with DCKV systems as well as 11 metered sites. For the School hours of use and days of operation, the AR TRM 8.1 was referenced.

Table 2-114 Annual Hours of Operation by Building Type

Building Type	Annual Operating Hours
Supermarket	4,864
Restaurant	5,652
Hotel	8,226
College / University	4,939
Institutional	6,789
K-12 School, Inc Summer Sessions	3,288
K-12 School, No Summer Sessions	2,400

Using the savings data from SCE13CC008 for 16 climate zones in CA, along with Heating Degree Day (HDD) and Cooling Degree Day (CDD) data for these climate zones[372], a linear regression was performed to calibrate heating and cooling load with New Orleans weather. The subsequent regression models had R-square values of 0.969 and 0.890 for heating and cooling energy load respectively thus indicating a high degree of confidence in calculated loads for New Orleans. The regressed values were then normalized to the average rated exhaust horsepower of 14.3 HP based on the 72 sites' data in SCE13CC008 and divided by the 17 hours per day and 365 days per year as input into the Outdoor Air Calculator by the work paper author. Thus, using these HVAC load values, the operation profiles calculated in the table above, and the average 25% reduction in exhaust fan airflow as calculated in SCE13CC008, the deemed HVAC savings values were calculated for each building type.

Table 2-115 Regressed Load Savings Calibrated for NOLA

Fan Type	Demand Savings ($kW/kW_{exhaust}$)	Heating Savings (kWh/kW/hr/day)	Cooling Savings (kWh/kW/hr/day)
MAU	0.975	0.305	0.397
No MAU	0.725	0.305	0.397

$$Savings_{kWh} = Demand\ Savings \times CAP \times AOH$$

[371] "Commercial Kitchen Exhaust Hoods Demand Controlled Ventilation." Work Paper SCE13CC008. Southern California Edison Company. 11 June, 2014 Accessed from: http://www.deeresources.net/workpapers

[372] "The Pacific Energy Center's Guide to: California Climate Zones and Bioclimatic Design." October 2006. Retrieved from: https://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf

$$Savings_{kW} = Demand\ Savings \times CAP$$

Where:

Demand Savings = Fan demand reduction per rated kW of exhaust fan, kW/kW$_{exhaust}$. See Table 2-115.

CAP = Rated capacity of exhaust fan, kW

AOH = Annual Operating Hour of operation, day(s). See Table 2-114.

$$kWh\ Savings_{Heating} = \frac{Heating\ Savings \times kW_{exhaust} \times AOH}{Eff_{heat}}$$

$$kWh\ Savings_{Cooling} = \frac{Cooling\ Savings \times kW_{exhaus} \times AOH}{Eff_{cool}}$$

Where:

Heat Reduction = Heating energy savings per rated exhaust kW, kWh/kW/hr/day. See Table 2-115.

Cool Reduction = Cooling energy savings per rated exhaust kW, kWh/kW/hr/day. See Table 2-115.

$kW_{exhaust}$ = Rated kW of the installed exhaust fan, kW

AOH = Annual Operating Hour of operation. See Table 2-114.

Eff_{heat} = Efficiency of heating system (%)

Eff_{cool} = Efficiency of cooling system (%)

2.5.7.5 Incremental Cost

The incremental cost is $2,383 per exhaust fan rated HP[373].

2.5.7.6 Future Studies

There are no future studies planned at this time for this measure at this time.

[373] "Commercial Kitchen Exhaust Hoods Demand Controlled Ventilation." Work Paper SCE13CC008. Southern California Edison Company. 11 June, 2014

2.5.8 ENERGY STAR HOT FOOD HOLDING CABINETS

2.5.8.1 Measure Description

Hot Food Holding Cabinets (HFHC) keep cooked foods hot, fresh, and out of temperature danger zones until customers are ready to order. Cabinets that meet the ENERGY STAR requirements often incorporate 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 cabinets may include additional energy saving devices such as magnetic door gaskets, auto-door closures, or Dutch doors. Savings occur from reduced idle energy consumption. ENERGY STAR models are, on average, 70 percent more energy efficient than standard models.

2.5.8.2 Baseline and Efficiency Standard

To qualify for this measure the installed equipment must be an ENERGY STAR certified HFHC. Qualification is based upon idle energy consumption per given interior cabinet volumes, measured in cubic feet. Measuring cabinet interior volume: commercial hot food holding cabinet interior volume shall be calculated using straight-line segments following the gross interior dimensions of the appliance and using the equation below. Interior volume shall not account for racks, air plenums or other interior parts.

$$Interior\ Volume = Interior\ Height \times Interior\ Width\ \times Interior\ Depth$$

Table 2-116 Maximum Idle Energy Requirements for ENERGY STAR Qualification

Product Interior Volume (Cubic Feet)	Product Idle Energy Consumption Rate (Watts)
0 < Volume < 13	≤ 21.5 x Volume
13 ≤ Volume <28	≤ (2.0 x Volume) + 254.0
28 ≤ Volume	≤ (3.8 x Volume) + 203.5

The baseline equipment is an electric HFHC that's not ENERGY STAR certified and at end of its life. Baseline energy use is 40 watts per cubic foot[374].

2.5.8.3 Estimated Useful Life

According to ENERGY STAR[375] the EUL for HFHC is 12 years.

2.5.8.4 Deemed Savings Values

Custom calculation below; otherwise use deemed values depending on HFHC size.

[374] https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx

[375] ENERGY STAR Commercial Kitchen Equipment Calculator: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx

Table 2-117 HFHC Deemed Savings

Cabinet Size	Savings (kWh)	Savings (kW)
Full Size (20 cubic feet) HFHC	2,772	0.204
¾ Size (12 cubic feet) HFHC	1,216	0.090
½ Size (8 cubic feet) HFHC	811	0.060

2.5.8.4.1 Energy Savings

$$kWh_{savings} = Baseline_{kW} - Efficient_{kW}$$

$$Baseline_{kWh} = \frac{Power_{\ Baseline} \times Hours_{\ Day} \times Days}{1000}$$

$$Efficient_{kW} = \frac{Power_{\ ENERGY\ STAR} \times Hours_{\ Day} \times Days}{1000}$$

Where:

$Hours_{Day}$= Custom. If Unknown, use 15[376]

$Days$ = Custom. If Unknown, use 365.25

$Power_{Baseline}$ = Baseline power consumption = Cubic feet × 40W/ft^3

$Power_{ENERGY\ STAR}$ = Custom idle power consumption using ENERGY STAR idle power consumption (see Table 2-116).

2.5.8.4.2 Demand Reductions

Demand is calculated using the following equation:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Where:

CF = Coincidence factor[377]

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

[377] Values taken from Minnesota Technical Reference Manual, 'Electric Oven and Range' measure and is based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

Table 2-118 HFHC Peak Coincidence Factors

Location	CF
Fast Food Limited Menu	0.30
Fast Food Expanded Menu	0.40
Pizza	0.50
Full Service Limited Menu	0.50
Full Service Expanded Menu	0.40
Cafeteria	0.40

For example, if an 18ft^3 HFHC is installed in a cafeteria the measure would save the following.

$$\text{kWh} = ((18*40)\text{-}((18*2.0)+254)) \times 15 \times 365.25/1000 = (720 - 290) \times 15 \times 365.25/1000 = 2{,}356\ \text{kWh}$$

$$\text{kW} = (2{,}356\text{kWh}/(15*365.25)) \times 0.40 = 0.43 \times 0.40 = 0.17\ \text{kW}$$

2.5.8.5 Incremental Cost

The incremental cost is $902[378].

2.5.8.6 Future Studies

There are no future studies planned for this measure at this time.

[378] Based on the difference between a similar ENERGY STAR and non-qualifying model, EPA research using AutoQuotes, July 2016

2.5.9 ENERGY STAR DISHWASHERS

2.5.9.1 Measure Description

This measure defines energy savings and peak reductions from ENERGY STAR commercial dishwashers in retrofit and new construction applications. Commercial dishwashers, also known as “ware washers,” fall into two categories of machine type: stationary rack machines (under counter, single tank/door type, glass washing, and pot, pan and utensil) and conveyor machines (rack and rack free/flight type, single and multiple tank). Key parameters used to characterize the efficient performance of commercial dishwashers are Idle Energy Rate and Water Consumption Rate. Energy savings from commercial dishwashers is primarily attributed to reducing the amount of water used which reduces the energy consumed to heat that water. This is accomplished via combinations of the following:

- Improved nozzle and rinse arm design
- Auxiliary pre-rinse section
- Heat recovery technology
- Sophisticated controls and sensors
- Effective curtain designs to minimize airflow
- Auto-mode capabilities, including low power mode during long periods of idle

Eligible Products: High temp (hot water sanitizing), low temp (chemical sanitizing) machines, and dual sanitizing machines.

Ineligible Products: Steam, gas, and other non-electric models; dishwashers intended for use in residential or laboratory applications.

2.5.9.2 Baseline & Efficiency Standard

Descriptions of commercial dishwasher configurations, as defined by ENERGY STAR, are as follows:

Stationary Rack Machines – A dishwashing machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles.

- Under Counter – A stationary rack machine with an overall height of 38 inches or less, designed to be installed under food preparation workspaces. Under counter dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Stationary Single Tank Door – A stationary rack machine designed to accept a standard 20” x 20” dish rack, which requires the raising of a door to place the rack into the wash/rinse chamber. Closing of the door typically initiates the wash cycle. Single tank door type models can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Pot, Pan, and Utensil – A stationary rack, door type machine designed to clean and sanitize pots, pans, and kitchen utensils.

Conveyor Machines – A dishwashing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine.

- Single Tank Conveyor – A conveyor machine that includes a tank for wash water followed by a sanitizing rinse (pumped or fresh water). This type of machine does not have a pumped rinse tank. This type of machine may include a pre-washing section ahead of the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the power rinse and sanitizing rinse sections. Single tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Multiple Tank Conveyor – A conveyor type machine that includes one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a sanitizing rinse. This type of machine may include a pre-washing section before the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the power rinse and sanitizing rinse sections. Multiple tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

Each of these machines are further classified by their rinse water washing strategies; high temperature, sanitized by heat with boost heating (~180^{o}) and low temperature, sanitized by chemicals (~120^{o}-140^{o}). While less common, dual-method sanitization machines are also available.

There are currently no federal minimum standards for Commercial Dishwashers, however, the ASTM and the National Sanitation Foundation (NSF) publishes Test Methods[379] that allow uniform procedures to be applied to each commercial dishwasher for a fair comparison of performance results. To meet the strict efficiency requirements developed by the U.S. Environmental Protection Agency's ENERGY STAR program, manufacturers use high quality components and employ innovative designs. All ENERGY STAR certified machines are certified to NSF 3 sanitation standards.

Table 2-119 ENERGY STAR[380] Requirements for Commercial Dishwashers[381]

Machine Type	High Temp Efficiency Requirements (~180°F)		Low Temp Efficiency Requirements (~120°F – 140°F)	
	Tank Heater Idle Energy Rate (kW)	Water Consumption	Tank Heater Idle Energy Rate (kW)	Water Consumption
Under Counter	≤ 0.30	≤ 0.86	≤ 0.25	≤ 1.19
Stationary Single Tank Door	≤ 0.55	≤ 0.89	≤ 0.30	≤ 1.18
Pot, Pan, and Utensil	< 0.90	< 0.58 GPSF	≤ 0.85	≤ 0.79
Single Tank Conveyor	≤ 1.20	≤ 0.70	≤ 1.00	≤ 0.54
Multiple Tank Conveyor	≤ 1.85	≤ 0.54	≤ 0.25	≤ 1.19

[379] The industry standards for energy use is ASTM Standard F1920, Standard Test Method for Energy Performance of Rack Conveyor, Hot Water Sanitizing, Commercial Dishwashing Machines, ASTM Standard F1696, Standard Test Method for Energy Performance of Single-Rack Hot Water Sanitizing, Door-Type Commercial Dishwashing Machines and NSF/ANSI 3-2007 Standard, Commercial Warewashing Equipment.

[380] ENERGY STAR Commercial Dishwashers Version 2.0 effective as of February 1, 2013. http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers.

[381] ENERGY STAR Commercial Dishwashers Version 2.0 includes 3 new dishwasher types: 1) Pot, Pan, and Utensil, 2) Single Tank Flight Type, and 3) Multiple Tank Flight Type. These new dishwasher types will be incorporated into the measure once they are incorporated into the ENERGY STAR Commercial Dishwasher Savings Calculator.

Where:

GPR = Gallons per Rack

GPSF = Gallons per Square Foot of Rack

GPH = Gallons per Hour

2.5.9.3 Estimated Useful Life[382]

The estimated useful life (EUL) of commercial dishwashers vary based on the machine type. Under Counters have an EUL of 10 years, Door-Types have an EUL of 15 years and Conveyor Types have an EUL of 20 years.

2.5.9.4 Deemed Savings Values[383]

Annual savings were calculated by determining the energy consumed for baseline commercial dishwashers compared against ENERGY STAR performance requirements. The annual energy consumption for commercial dishwashers was determined by the summation of the annual energy used for water heating, the booster heater and when the machine is in idle mode.

$$E_{total} = E_{DHW} + E_{boost} + E_{idle}$$

These are defined as follows for both gas and electric calculations:

$$E_{DHW} = \frac{(RPD \times GPR \times Days \times d \times c_p \times \Delta T_{DHW})}{EF_{DHW} \times Conversion\ Factor}$$

$$E_{BOOST} = \frac{(RPD\ x\ GPR\ x\ Days\ x\ d\ x\ c_p\ x\ \Delta T_{BOOST})}{EF_{BOOST}\ x\ Conversion\ Factor}$$

(*only* applicable in High Temperature Machines)

$$E_{idle} = kW_{\mathrm{idle}} \times \left(HRS - \frac{(RPD \times MPR)}{60}\right) \times \mathrm{Days}$$

Where:

RPD = Average number of racks washed per day, varies by machine

GPR = Average gallons per rack used by dishwasher, varies by machine

Days = Operating Day per Year = 365 days/yr.

382 EUL values from CEE Program Design Guidance-Commercial Dishwashers, updated 5/11/2009.

383 Assumptions from the ENERGY STAR Commercial Dishwashers Savings Calculator (May 2013 update).

d = Density of water, constant value 8.34 lb/gal

c_p = Specific heat of water, 1 Btu/lb-^{o}F

ΔT_{DHW} = Temperature rise at primary water heater, 70^{o}F (default)

ΔT_{BOOST} = Temperature rise at booster heater, 40^{o}F (default)

EF_{DHW}= Efficiency of building water heater, 98% for electric (default), 80% for gas

EF_{BOOST} = Efficiency of booster water heater, 98% for electric (default), 80% for gas

$Conversion\ Factor$ = 100,000 Btu/therm or 3,413 Btu/kWh.

kW_{idle} = Energy consumed while idle, varies by machine

HRS = Hours per day dishwasher operates, 18 hours (default)

MPR = Time to wash one rack of dishes, minutes per rack, varies by machines

60 = Minutes per hour

To determine electric savings for the different types of commercial dishwashers, Table 2-120 and Table 2-121 list the assumptions made for the machine dependent parameters; Idle Power, Racks per Day, Minutes per Rack and Gallons per Rack. Table 2-120 lists the parameters for machines that employ Low Temperature cleaning and Table 2-121 lists parameters for machines that employ High Temperature cleaning.

Table 2-120 Default Assumptions for Low Temperature, Electric and Gas Water Heaters

Performance	Under Counter		Single Tank Door		Single Tank Conveyor		Multi Tank Conveyor	
	Base	Change	Base	Change	Base	Change	Base	Change
Idle Power	0.5	0.5	0.6	0.6	1.6	1.5	2.0	2.0
Racks/Day	75	75	280	280	400	400	600	600
Min/Rack	2.0	2.0	1.5	1.5	0.3	0.3	0.3	0.3
Gal/Rack	1.73	1.19	2.1	1.18	1.31	0.79	1.04	0.54

Table 2-121 Default Assumptions for High Temperature, Electric and Gas Water Heaters[4]

Performance	Under Counter		Single Tank Door		Single Tank Conveyor		Multi Tank Conveyor		Pot, Pan, and Utensil	
	Base	Change	Base	Change	Base	Change	Base	Change	Base	Change
Idle Power	0.76	0.5	0.87	0.7	1.93	1.5	2.59	2.25	1.2	1.2
Racks/Day	75	75	280	280	400	400	600	600	280	280
Min/Rack	2.0	2.0	1.0	1.0	0.3	0.3	0.2	0.2	3.0	3.0
Gal/Rack	1.09	0.86	1.29	0.89	0.87	0.70	0.97	0.54	0.70	0.58

Peak Demand Savings can be derived by dividing the annual energy savings by the operating hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HRS}\right) \times CF$$

Where:

ΔkWh = Annual energy savings (kWh)

HRS = Operating hours = 365 x 18 = 6,570 hours (default)

CF = Coincidence Factor = 0.84 (default)[384]

If specific equipment data is not available for use with the measure savings calculations described above, deemed electric and gas savings from ENERGY STAR commercial dishwashers can be seen in Table 2-122. Equipment savings are defined based on the following information:

- Dishwasher Type (Under Counter, Stationary Single Tank Door, Pots, Pans, and Utensils, Single Tank Conveyor, or Multiple Tank Conveyor)
- Water Temperature (Low Temperature or High Temperature)
- Building Water Heater Fuel (Electric or Gas)
- Booster Water Heater Fuel (Electric or Gas): Only applicable in High Temperature Units
- Default Assumptions from ENERGY STAR Commercial Dishwasher Savings Calculator

[384] The KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

Table 2-122 Deemed Savings for Commercial Dishwashers

Water Temperature	Water Heater Fuel/Booster Heater Fuel	Measure Description	kWh	kW
High Temperature	Electric / Electric	Under Counter	4,305	0.6
		Stationary Single Tank Door	12,602	1.6
		Pots, Pans, and Utensils	3,364	0.4
		Single Tank Conveyor	10,971	1.4
		Multiple Tank Conveyor	29,764	3.8
	Gas / Electric	Under Counter	2,099	0.3
		Stationary Single Tank Door	4,905	0.6
		Pots, Pans, and Utensils	1,223	0.2
		Single Tank Conveyor	4,987	0.6
		Multiple Tank Conveyor	11,378	1.5
	Gas / Gas	Under Counter	2,604	0.2
		Stationary Single Tank Door	1558	0.1
		Pots, Pans, and Utensils	438	0.1
		Single Tank Conveyor	4,266	0.5
		Multiple Tank Conveyor	4,325	0.6
Low Temperature	Electric / No Booster	Under Counter	3,957	0.5
		Stationary Single Tank Door	17,369	2.2
		Pots, Pans, and Utensils	17,434	2.2
		Single Tank Conveyor	24,303	3.1
	Gas/ No Booster	Multiple Tank Conveyor	1,415	0.2
		Under Counter	4,383	0.6
		Stationary Single Tank Door	5,479	0.7
		Pots, Pans, and Utensils	3,957	0.5

2.5.9.5 Incremental Cost

The incremental capital cost for this measure is provided below:[385]

Table 2-123 Incremental Cost

Dishwasher Type		Incremental Cost
Low Temp	Under Counter	$234
	Stationary Single Tank Door	$662
	Single Tank Conveyor	$0

[385] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA research on available models using AutoQuotes, 2012”

Dishwasher Type		Incremental Cost
	Multi Tank Conveyor	$970
High Temp	Under Counter	$2,025
	Stationary Single Tank Door	$995
	Single Tank Conveyor	$2,050
	Multi Tank Conveyor	$970
	Pot, Pan, and Utensil	$1,710

2.5.9.6 Future Studies

This measure uses ENERGY STAR default inputs. Deemed savings should be updated to align with any applicable code updates.

2.5.10ENERGY STAR ICE MAKERS

2.5.10.1 Measure Description

This measure involves ENERGY STAR air-cooled commercial ice makers in retrofit and new construction applications. Eligible equipment types are batch type (also known as cube-type) and continuous type (also known as nugget or flakers). Batch-type ice makers harvest ice with alternating freezing and harvesting periods and can be used in a variety of applications but are generally used to generate ice for use in beverages. Both types of equipment qualify based on their configuration as ice-making heads (IMHs), remote condensing units (RCUs) and self-contained units (SCUs). Remote condensing units designed for connection to a remote condenser rack are also eligible.

2.5.10.2 Baseline and Efficiency Standards

The ENERGY STAR[386] criteria for ice makers define efficiency requirements for both energy and potable water use. The baseline standard for batch ice makers are federal minimum levels that went into effect January 28, 2018. The following four tables show the standards and requirements for equipment manufactured on or after January 28, 2018.

Table 2-124 Federal Minimum Standards for Air-Cooled Batch Ice Makers

Equipment Type	Ice Harvest Rate (H) (lbs. of ice / 24 hrs.)	Batch Ice Makers Consumption Rate (kWh/100 lbs. ice)
Ice Making Heads	< 300	10.0 – 0.01233H
	≥ 300 and < 800	7.05 – 0.0025H
	≥ 800 and < 1,500	5.55 – 0.00063H
	≥ 1,500	4.61
Remote Condensing Units (w/out remote compressor)	< 988	7.97 – 0.00342H
	≥ 988 and < 4,000	4.59
Remote Condensing Units (w/ remote compressor)	< 930	7.97 – 0.00342H
	≥ 934 and < 4,000	4.79
Self-Contained Units	< 110	14.79 – 0.0469H
	≥ 110 and < 200	12.42 – 0.02533H
	≥ 200 and < 4,000	7.35

[386] ENERGY STAR Commercial Ice Makers Version 3.0, effective on January 28, 2018.

Table 2-125 Federal Minimum Standards for Air-Cooled Continuous Ice Makers

Equipment Type	Ice Harvest Rate (H) (lbs. of ice / 24 hrs.)	Batch Ice Makers Consumption Rate (kWh/100 lbs. ice)
Ice Making Heads	<310	9.19– 0.00629H
	≥310 and <820	8.23-0.0032H
	≥4,000	5.61
Remote Condensing Units (w/out remote compressor)	<800	9.7– 0.0058H
	≥800 and <4,000	5.06
Remote Condensing Units (w/ remote compressor)	<800	9.9– 0.0058H
	≥800 and <4,000	5.26
Self-Contained Units	<200	14.22–0.03H
	≥200 and <700	9.47-0.00624H
	≥700 and <4,000	5.1

Table 2-126 ENERGY STAR Requirements for Air-Cooled Batch Ice Makers

Equipment Type	Ice Harvest Rate (H) (lbs. of ice / 24 hrs.)	Batch Ice Makers Consumption Rate (kWh/100 lbs. ice)	Potable Water Use (gal/100 lbs. ice)
Ice Making Heads	≤ 300	≤ 9.2– 0.01134H	≤ 20.0
	≥ 300 and ≤ 800	≤ 6.49-0.0023H	≤ 20.0
	≥ 800 and ≤ 1,500	≤ 5.11-0.00058H	≤ 20.0
	≥ 1,500 and ≤ 4,000	≤ 4.24	≤ 20.0
Remote Condensing Units (w/out remote compressor)	≤988	≤ 7.17– 0.00308H	≤ 20.0
	≥988 and ≤4,000	≤ 4.13	≤ 20.0
Remote Condensing Units (w/ remote compressor)	≤988	≤ 7.17– 0.00308H	≤ 20.0
	≥988 and ≤4,000	≤ 4.13	≤ 20.0
Self-Contained Units	≤110	≤ 12.57 – 0.0399H	≤ 25.0
	≥110 and ≤200	≤ 10.56-0.0215H	≤ 25.0
	≥200 and ≤4,000	≤ 6.25	≤ 25.0

Table 2-127 ENERGY STAR Requirements for Air-Cooled Continuous Ice Makers

Equipment Type	Ice Harvest Rate (H) (lbs. of ice / 24 hrs.)	Batch Ice Makers Consumption Rate (kWh/100 lbs. ice)	Potable Water Use (gal/100 lbs. ice)
Ice Making Heads	< 310	≤ 7.90– 0.005409H	≤ 15.0
	≥ 310 and < 820	≤ 7.08-0.002752H	≤ 15.0
	≥ 4,000	≤ 4.82	≤ 15.0
Remote Condensing Units (w/out remote compressor)	< 800	≤ 7.76– 0.00464H	≤ 15.0
	≥ 800 and < 4,000	≤ 4.05	≤ 15.0
Remote Condensing Units (w/ remote compressor)	< 800	≤ 7.76– 0.00464H	≤ 15.0
	≥ 800 and < 4,000	≤ 4.05	≤ 15.0
Self-Contained Units	< 200	≤ 12.37–0.0261H	≤ 15.0
	≥ 200 and < 700	≤ 8.24-0.005429H	≤ 15.0
	≥ 700 and < 4,000	≤ 4.44	≤ 15.0

2.5.10.3 *Estimated Useful Life*

According to DEER 2011 the commercial ice maker will have an EUL of 10 years.

2.5.10.4 *Deemed Savings Values*

Energy savings and demand reductions for commercial ice makers are based on the energy consumption from the harvesting of ice, either in batches or continuously. The following subsections outline deemed calculations for energy savings and demand reductions, respectively.

Annual electric savings are calculated by determining the energy consumed for baseline ice makers compared against the energy consumed by qualifying ENERGY STAR product using the harvest rate of the more efficient unit.

The following two equations show how energy savings and demand reductions can be calculated, respectively:

$$\Delta kWh = \frac{\left(kWh_{base,per\ 100\ lb} - kWh_{ee,per\ 100\ lb}\right)}{100} \times DC \times H \times 365$$

$$\Delta kW = \left(\frac{\Delta kWh}{HRS}\right) \times CF$$

Where:

$kWh_{base,per\ 100\ lb}$ = calculated on the harvest rate and type of ice machine from the Federal Minimum Energy Consumption Rate relationships in Table 2-124 and Table 2-125.

$kWh_{ee,per\ 100\ lb}$ = Qualifying energy efficient model consumption found in the AHRI directory of certified products by model information.

$100\ =$ conversion factor to convert $kWh_{base,per\ 100\ lb}$ and $kWh_{ee,per\ 100\ lb}$ into maximum kWh consumption per pound of ice

DC = Duty Cycle of the ice maker representing the percentage of time the ice machine is making ice = 0.75

H = Harvest Rate (lbs. of ice made per day)

365 = days per year

HRS = Annual operating hours = 365 * 24 = 8,760 hours/year

CF = 1.0

For example, the annual energy savings and demand reductions for a batch type IMH commercial ice maker with an ice harvest rate (H) of 550 lbs. of ice per day and a consumption rate of kWh/100 lbs. ice of 4.45 are calculated as:

$$\Delta kWh = \frac{\left((7.05 - 0.0025 \times 550\ ) - 4.45\right)}{100} \times 0.75 \times 550 \times 365 = 1{,}844\ kWh$$

$$\Delta kW = \left(\frac{1{,}844\ kWh}{8{,}760\ hr/yr}\right) \times 1.0 = 0.2105\ kW$$

2.5.10.5 Incremental Cost[387]

Incremental costs are presented in the table below.

Table 2-128 Incremental Costs

Ice Harvest Rate (H)	Incremental Cost
100-200 lb. ice maker	$296
201-300 lb. ice maker	$312
301-400 lb. ice maker	$559
401-500 lb. ice maker	$981
501-1000 lb. ice maker	$1,485
1001-1500 lb. ice maker	$1,821
<1500 lb. ice maker	$2,194

[387] These values are from electronic work papers prepared in support of San Diego Gas & Electric's "Application for Approval of Electric and Gas Energy Efficiency Programs and Budgets for Years 2009-2011", SDGE, March 2, 2009. https://www.sdge.com/node/709

2.5.10.6 Future Studies

At the time of authorship, this measure was not implemented in Energy Smart programs. Thus, savings are calculated using ENERGY STAR default values. If this measure is added to Energy Smart programs, the evaluation should include a review of actual efficiency levels and costs of units rebated in the program. Deemed parameters should be updated whenever DOE standards or other applicable codes warrant it.

2.6 Lighting

2.6.1 LIGHTING EFFICIENCY

2.6.1.1 Measure Description

This chapter provides energy and demand reduction calculations for the replacement of commercial lighting equipment with energy efficient lamps or fixtures. The operating hours and demand factors are based on primary research in the New Orleans market. This chapter now incorporates the 2007 Energy Independence & Security Act (EISA) Phase II standards (also known as the “EISA Backstop”).

This chapter applies to high performance and reduced wattage T8s, fluorescent delamping, high output LED fixtures, HID fixtures and some GSLs. It is applicable only to manually controlled (switches and dimmers) residential lighting, and not LED fixtures or connected, ‘smart’ or otherwise automatically controlled lighting.

2.6.1.1.1 Fixture-Level Deemed Savings

Due to the myriad of possible baseline lighting configurations, efficient configurations and facility parameters that contribute to a commercial lighting savings calculation, the TPE has opted to not include deemed savings per-fixture. Such a value would require too many assumptions and is likely to be too in accurate to provide a fixed estimate. If the needed data cannot be collected by program implementers, then the project in question is ineligible for savings. The data requested to calculate deemed savings is consistent with what program implementers have historically collected in implementing Energy Smart programs and align with industry best practices for deemed savings for commercial lighting.

2.6.1.2 Baseline & Efficiency Standard

The following sections explain the various codes, standards, and required processes to establish the applicability of the Lighting Efficiency savings calculation method.

2.6.1.2.1 State Commercial Energy Codes

Louisiana’s state commercial energy code recognizes ASHRAE 90.1-2007 for commercial structures. These standards specify the maximum lighting power densities (LPDs) by building type (building area method) and interior space type (space-by-space method). LPDs apply to all new construction and major renovation projects. The ASHRAE 90.1-2007 LPDs for various building types are outlined in Appendix F. Agricultural lighting for animals will utilize recognized industry standards unique to the requirements of that animal to determine the LPD for the building housing those animals.

2.6.1.2.2 Retrofit Baseline Summary

For all retrofit projects, the baseline is the current federal efficacy standard. If the replacement system is a T8, then it must meet Consortium for Energy Efficiency (CEE) specification requirements for High Performance and Reduced Wattage T8 systems. Other high-performance systems, including but not limited to T5 and LED systems, are allowed. T12s are no longer an eligible baseline technology.

2.6.1.2.3 Federal Efficacy Standards

The Energy Independence and Security Act (EISA) of 2007 mandates minimum efficacy standards for general service incandescent lamps, modified spectrum general service incandescent lamps, incandescent reflector lamps, fluorescent lamps, and metal halide lamps.

Effective January 1, 2010, EISA increased minimum ballast efficacy factors and established pulse-start metal halides (PSMHs) as the new industry standard baseline for the metal halide technology (< 500 W). New construction projects must use PSMHs in metal halide applications.

The Energy Policy Act (EPAct) of 2005 and EISA of 2007 are two energy legislative rulings enacted to establish energy reduction targets for the United States. On July 14, 2009, the Department of Energy published a final rule for energy conservation standards for general service fluorescent lamps (GSFLs). These standards are shown in Table 2-129. As a result of this rule, all GSFLs manufactured in the United States, or imported for sale into the United States on or after July 14, 2012 (three years from the ruling date) must meet new, more stringent efficacy standards (measured in lumens per watt, LPW).

Table 2-129 Lighting Efficiency – Current Federal Efficiency Standards for GSFL

Lamp Type	Nominal Lamp Wattage	Minimum Color Rendering Index (CRI)	Minimum Average Lamp Efficacy (Lumens/ Watt/ LPW)
4-foot Medium Bi-Pin	> 35W	69	75.0
	≤ 35 W	45	75.0
2-foot U-Shaped	> 35W	69	68.0
	≤ 35W	45	64.0
8-foot Slimline	> 65W	69	80.0
	≤ 65W	45	80.0
8-foot High Output	> 100W	69	80.0
	≤ 100W	45	80.0

Facilities with 4-foot and 8-foot T12s or with 2-foot U-Shaped T12s are still eligible to participate in lighting retrofit projects, but an assumed electronic T8 baseline should be used in place of the existing T12 equipment. These T12 fixtures will remain in the standard wattage table with the label "T12 (T8 baseline)" and will include adjusted wattages assumptions consistent with a T8 fixture with an equivalent length and lamp count. T12 fixtures not specified above will remain an eligible baseline technology.

Table 2-130 Adjusted Baseline Wattages for T12 Equipment

T12 Length	Lamp Count	Revised Lamp Wattage	Revised System Wattage
48 inch-Std, HO, and VHO (4 feet)	1	32	31
	2	32	58
	3	32	85
	4	32	112
	6	32	170
	8	32	224
96 inch-Std (8 feet)	1	59	69
	2	59	110

T12 Length	Lamp Count	Revised Lamp Wattage	Revised System Wattage
60/75W	3	59	179
	4	59	219
	6	59	330
	8	59	438*
96 inch-HO and VHO (8 feet) 95/110W	1	86	101
	2	86	160
	3	86	261
	4	86	319
	6	86	481
	8	86	638
2 ft. U-Tube	1	32	32
	2	32	60
	3	32	89

* 8 lamp fixture wattage approximated by doubling 4 lamp fixture wattage.
Key: HO = high output, VHO = very high output

2.6.1.2.4 Fixture Qualification Process – High Performance and Reduced Wattage T-8 Equipment

CEE develops and maintains energy specifications for High Performance and Reduced Wattage T8 equipment. CEE high performance and reduced wattage T8 specifications can be found at:

- http://www.cee1.org/com/com-lt/com-lt-specs.pdf (High Performance products)
- http://www.cee1.org/com/com-lt/lw-spec.pdf (Reduced Wattage products)

CEE compiles a list of approved lamps and ballasts for T8 systems that are eligible for incentives for retrofits which is available for download on CEE's website at http://library.cee1.org/content/commercial-lighting-qualifying-products-lists.

2.6.1.2.5 Fixture Qualification Process – LED and Pin-Based CFL Products:

LED and pin-based CFL products must be pre-qualified under one of the following options:

- Product is on the ENERGY STAR Qualified Product List or ENERGY STAR Qualified Light Fixtures Product List (http://www.energystar.gov)
- Product is on the Northeast Energy Efficiency Partnerships (NEEP) DesignLights Consortium™ (DLC) Qualified Products Listing (www.designlights.org)
- Exceptions to the ENERGY STAR and/or DLC requirements are allowed for unlisted lamps and fixtures that have already been submitted to either ENERGY STAR or DLC for approval. If the lamp or fixture does not achieve approval within the AR DSM program year, however, then the lamp or fixture must immediately be withdrawn from the program. If withdrawn, savings may be claimed up to the point of withdrawal from the program. For Agricultural uses where the fixture is designed for animal use, if an LED bulb does not meet ENERGY STAR and/or DLC requirements, the bulb can be utilized if a thorough review of the bulb is conducted and verified by the TPE.
- Screw-based CFLs are no longer qualified for Energy Smart programs (see next section).

2.6.1.2.6 General Service Lamps

The first of two advances of lighting standards from EISA 2007 Regulations were phased in from January 2012 to January 2014 and dictated higher efficiency for General Service Lamps (GSLs). The baseline equipment was originally assumed to be an incandescent or halogen lamp with adjusted baseline wattages compliant with EISA 2007 Regulations.

Phase II takes effect on July 25, 2022, stipulating that all GSLs sold in the United States (US) must achieve a minimum efficacy of 45 lumens/watt. The ruling also significantly expands the definition of GSLs, extending the covered lumen range, base types, and shapes, while reducing the types of bulbs exempted.

"General Service Lamp" means a lamp that it:

- Has an [American National Standards Institute] (ANSI) base;
- Is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or at 277 volts for integrated lamps, or is able to operate at any voltage for non-integrated lamps;
- Has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens;
- Is not a light fixture;
- Is not an LED downlight retrofit kit; and
- Is used in general lighting applications."

Previously exempt lamps that are now subject to regulations under the expanded GSL definition include:

- Reflectors: The following three reflector lamp types (which represent most reflectors) are no longer exempt from GSL standards:
    - (A) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps;
    - (B) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or
    - (C) R20 incandescent reflector lamps rated 45 watts or less;
- Lumen maximums: The lumen maximum subject to the EISA GSL definition has been increased from 2,600 to 3,300 lumens;
- Base types: All standard bulb bases are included (small screw base and candelabra); and
- Others lamp types: 3-way, decorative (including globes <5", flame shapes and candelabra shapes), T-lamps (≤40w OR ≥ 10"), vibration service, rough service, and shatter resistant bulb exemptions are also discontinued.

The 45 lumen/watt efficacy requirement inherently disallows incandescent and halogen lamps, but the EISA backstop does not directly specify a technological standard to satisfy the efficacy requirement. LEDs are well beyond 45 lumens/W (very often operating at greater than 60 lumens/watt), and alternative technologies all fall below the new EISA backstop, effectively meaning that general service lamps which operate at 45 lumens/watts for common lighting categories are not available for purchase[388].

[388] Notable exceptions include some compact fluorescent bulbs (CFL).

This precludes savings from being claimed in new construction and most retrofit applications. Savings can still be realized through early replacement, where existing incandescent, halogen, CFL and other inefficient technologies can be directly identified. Custom projects which involve to early retirement of incandescent, halogen and CFL lamps may continue after June 30, 2023. However, all projects that occur after June 30, 2023, will require that the TPA “bag and tag” the old lamps, to be stored until a quarterly verification inspection is conducted by TPE staff. To claim savings, implementation staff must record as-found lamp types and wattages and use Table 2-131, Table 2-132, and Table 2-133 below to determine the baseline.

Table 2-131 Baseline Wattage by Lumen Output for Omni-Directional Lamps[389]

Minimum Lumens	Maximum Lumens	EISA Phase I W_{base}	EISA Phase II W_{base}
310	749	29	12
750	1,049	43	20
1,050	1,489	53	28
1,490	2,600	72	45

Table 2-132 Baseline Wattage by Lumen Output for Directional/Reflector Lamps[390]

Lamp Type	Incandescent Equivalent (Pre-EISA)	EISA Phase I W_{base}	EISA Phase II W_{base}
PAR20	50	35	23
PAR30	50	35	23
R20	50	45	29
PAR38	60	55	35
BR30	65	EXEMPT	38
BR40	65	EXEMPT	38
ER40	65	EXEMPT	38
BR40	75	65	42
BR30	75	65	42
PAR30	75	55	35
PAR38	75	55	35
R30	75	65	42
R40	75	65	42
PAR38	90	70	45
PAR38	120	70	45
R20	≤ 45	EXEMPT	23
BR30	≤ 50	EXEMPT	EXEMPT
BR40	≤ 50	EXEMPT	EXEMPT
ER30	≤ 50	EXEMPT	EXEMPT
ER40	≤ 50	EXEMPT	EXEMPT

389 Wattages developed using the 45 LPW standard.

390 Based on manufacturer available reflector lighting products as available in August 2013; using 45 lumens/watt.

Table 2-133 Baseline Wattage by Lumen Output for Exempt Lamps[391]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent (W_{base})
310	749	40
750	1,049	60
1,050	1,489	75
1,490	2,600	100

2.6.1.2.7 Input Wattages

Input wattages for pre-retrofit and qualifying fixtures are included in the Standard Fixture Wattage Table (Appendix E). This is a relatively comprehensive list of both old and new lighting technologies that could be expected for inclusion in a project. If there are fixtures identified that are not included in this table, those fixtures should be submitted to the TPE for review and incorporation into subsequent TRM updates. Interim approval may be made for certain fixtures at the discretion of the TPE. However, there may be eligible products that are not on the list. If a product is not on the list, then manufacturer's data should be reviewed prior to accepting the product into a program. LED products should be approved by DLC or ENERGY STAR before being recognized as an eligible product.

2.6.1.3 Estimated Useful Life

The table below shows the EUL by lamp type.

Table 2-134 Estimated Useful Life by Lamp Type

Lamp Type	EUL	Source[392]
High Intensity Discharge (HID)	16.0	Based upon 50,000 hour manufacturer rated life and weighted-average 3,205 annual operating hours from Navigant U.S. Lighting Study.
Integrated-Ballast Cold-Cathode Fluorescent Lamps (CCFL)	5.0	Based upon 25,000 hour manufacturer rated life and weighted-average 5,493 annual operating hours from Navigant U.S. Lighting Study.
Integrated-Ballast LED Lamps	9.0	Based on 30,000 hour manufacturer rated life and weighted-average 3,260 annual operating hours from Navigant U.S. Lighting Study.
Light Emitting Diode (LED)	15.0	Based upon 50,000 hour manufacturer rated life and weighted-average 3,260 annual operating hours from Navigant U.S. Lighting Study.
General Service Lamp LED	1.0	The EUL for LED replacement under the auspices of EISA Phase II is based on the remaining useful life of the baseline lamp. The EUL for incandescent and halogen lamps is less than one year in commercial applications.

[391] Lumen bins and incandescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.0 http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Lamps%20V1.0%20Final%20Draft%20Specification.pdf EISA Standards from: United States Department of Energy. Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.

[392] Navigant Consulting, "U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate, Final Report." U.S. DOE. September 2002.

		With a final sale date of June 30, 2023, this puts the "savings ending date" for savings with an incandescent or halogen baseline on June 30, 2025. If a CFL baseline is used, the EUL will assume a CFL with an 8,000-hour rated life, which results in an EUL of one year[393]. With a final sale date of June 30, 2023, this puts the "savings ending date" for savings with an incandescent or halogen baseline on June 30, 2028.
Linear Fluorescents (T5, T8)	16.0	Based upon 50,000 hour manufacturer rated life and weighted-average 3,211 annual operating hours from Navigant U.S. Lighting Study.
Modular CFL and CCFL	16.0	Based upon 60,000 hour manufacturer rated life and weighted-average 3,251 annual operating hours from Navigant U.S. Lighting Study.

2.6.1.4 Deemed Savings Values

2.6.1.4.1 New Construction

The following formulas are to calculate deemed savings for new construction.

$$kW_{savings} = \left(\left(SF \times \frac{LPD}{1000}\right) - \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right)\right) \times CF \times IEF_D$$

$$kWh_{savings} = \left(\left(SF \times \frac{LPD}{1000}\right) - \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right)\right) \times AOH \times IEF_E$$

Where:

SF = Total affected square footage of the new construction facility

LPD = Maximum allowable power density by building type (W/ft^2) (Volume 3, *Appendices*)

$N_{fixt(i),post}$ = Post-retrofit # of fixtures of type i

$W_{fixt(i),post}$ = Rated wattage of post-retrofit fixtures of type i (Volume 3, *Appendices*)

CF = Peak demand coincidence factor (Table 2-136)

AOH = Annual operating hours for specified building type (Table 2-136)

IEF_D = Interactive effects factor for demand reduction (Table 2-137)

IEF_E = Interactive effects factor for energy savings (Table 2-137)

2.6.1.4.2 Retrofit with No Existing Controls

The following formulas are to calculate deemed savings for retrofits without existing controls.

[393] EUL based on 8,000 hours and 11.49 hours per day (an average of commercial space types), with a .526 "switching degradation factor" for CFL.

$$kW_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times CF \times IEF_D$$

$$kWh_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times AOH \times IEF_E$$

2.6.1.4.3 Retrofit with Existing Controls

For lighting systems with existing controls, no additional control savings should be claimed with the savings specified by the equations below.

$$kW_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times IEF_D \times CF_{controls}$$

$$kWh_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times IEF_E \times AOH \times PAF$$

Where:

$N_{fixt(i),pre}$ = Pre-retrofit number of fixtures of type i

$N_{fixt(i),post}$ = Post-retrofit number of fixtures of type i

$W_{fixt(i),pre}$ = Rated wattage of pre-retrofit fixtures of type i (Volume 3, *Appendices*)

$W_{fixt(i),post}$ = Rated wattage of post-retrofit fixtures of type i (Volume 3, *Appendices*)

CF = Peak demand coincidence factor (Table 2-136)

$CF_{controls}$ = Controls peak demand coincidence factor = 0.26[394]

AOH = Annual operating hours for specified building type (Table 2-136)

PAF = Power adjustment factor for specified control type (Table 2-144)

IEF_D = Interactive effects factor for demand reduction (Table 2-137)

IEF_E = Interactive effects factor for energy savings (Table 2-137)

2.6.1.4.4 Operating Hours & Coincidence Factors (CF)

If the annual operating hours and/or CF for the specified building are not known, use the deemed average annual hours of operation and/or peak demand CF from Table 2-136 summarizes the general transferability ratings for the lighting end-use. Due to the low variability of schedules and weather for both indoor and outdoor lighting, there is a high degree of data transferability across regions, and it is

[394] RLW Analytics, "*2005 Coincidence Factor Study,*" Connecticut Energy Conservation Management Board. January 4, 2007. Default value applicable to all building types. This coincidence factor is a combination of the savings factor and peak coincidence factor.

appropriate to assume very similar annual operating hours across different regions.[395] To the extent that utility system peak periods are similar, it is also appropriate to assume very similar peak CFs across different regions.

Table 2-135 Transferability of Data across Geographic Regions

Analysis Group	Schedule Variability	Weather Variability	Transferability Rating
Lighting – Exterior	Low	Low	High
Lighting – Interior	Low	Low	High

Operating hours are the number of hours that a particular equipment type is in use over the course of a year. For these recommendations, raw building lighting operating hour data were adjusted by Frontier Associates according to the percentage of wattage consumed by each space within a building. Subsequently, weighted average operating hours (AOH) were developed for a range of building types.

The CF for lighting is the ratio of the lighting kW demand during the utility's peak period (New Orleans does not have a specific peak period definition, and CF values are assumed to reflect peak loads of similar utilities) to the connected lighting kW (∑(Ni xWi/ 1000) as defined above. Other issues are automatically accounted for, such as diversity and load factor. A portion of the CF values were arrived at through secondary research. In the cases where acceptable values were not available through other sources, Frontier Associates calculated values comprised of CF and building operating hour data available for the types of building spaces that would likely be found within that building type.

Deemed annual operating hours from the Arkansas TRM (AR TRM) were used as a basis for New Orleans AOH. These hours were originally developed by Frontier Associates for the AR TRM. The TPE used these values in conjunction with on-site monitoring from facility types commonly found New Orleans commercial lighting program participant populations. Direct monitoring data was collected from 210 loggers placed in 59 New Orleans and other major Louisiana utility territories. A total of (14) facility types received updated hours, and (10) new generic space types common in New Orleans area-projects were created.

Table 2-136 Annual Operating Hours (AOH) and Coincidence Factors (CF)[396]

Facility or Space Type	AOH	CF
Leisure Dining: Bar Area	2,676*	0.81
Corridor/Hallway/Stairwell	5,233*	0.90
Education: College/University	3,577	0.69

[395] KEMA. End-Use Load Data Update Project Final Report: Phase 1: Cataloguing Available End-Use and Efficiency Measure Load Data. 2009. Prepared for the Northwest Power and Conservation Council and Northeast Energy Efficiency Partnerships, November.

[396] Unless otherwise noted, deemed AOH and CF values are based on Frontier Associates on behalf of Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to Revise Existing Measurement & Verification Guidelines for Lighting Measures for Energy Efficiency Programs: Docket No. 39146." Public Utility Commission of Texas. Approved June 6, 2011. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp

Education: K-12	2,333*	0.47
Exterior	4,319*	0.00
Food Sales: 24-Hour Supermarket	6,900	0.95
Food Sales: Non-24-Hour Supermarket	4,706	0.95
Food Service: Fast Food	6,473*	0.81
Food Service: Sit-Down Restaurant	4,731*	0.81
Health Care: In-Patient	4,019*	0.78
Health Care: Nursing Home	4,271*	0.78
Health Care: Out-Patient	3,386	0.77
Convenience Store (non-24 hour)	4,245*	0.90
Lodging (Hotel/Motel/Dorm): Common Areas	4,127*	0.82
Lodging (Hotel/Motel/Dorm): Room	3,370*	0.25
Manufacturing	5,740	0.73
Multi-family Housing: Common Areas	5,703*	0.87
Non-Warehouse Storage (Generic)	4,207*	0.77
Office	5,159*	0.77
Office (attached to other facility)	4,728*	0.77
Parking Structure	7,884	1.00
Public Assembly	2,638	0.56
Public Order and Safety	3,472	0.75
Religious Gathering	3,174*	0.53
Restroom (Generic)	3,516*	0.90
Retail: Enclosed Mall	4,813	0.93
Retail: Freestanding	3,515*	0.90
Retail: Other	4,312*	0.90
Retail: Strip Mall	3,965	0.90
Service: Excluding Food	3,406	0.90
Warehouse: Non-Refrigerated	2,417*	0.77
Warehouse: Refrigerated	3,798	0.84

*Annual operating hours with an asterisk (*) were developed using primary data collected in the ENO territory.

2.6.1.4.5 Interactive Effects

Lighting in air conditioned and refrigerated spaces adds heat to the space, increasing the cooling requirement during the cooling season and decreasing the heating requirement during the heating season. The decrease in waste heat from lighting mitigates these effects, thus reducing electricity used for cooling and increasing electricity or gas used for heating.

Deemed interactive effects factors for both demand and energy savings are presented in Table 2-137. These factors represent the percentage increase or decrease in energy savings for the refrigeration system's electric load attributed to the heat dissipated by the more efficient lighting system. For example, a factor of 1.20 indicates a 20% savings. The methodology for applying these Interactive Effects Factors to calculate savings is discussed in 2.6.1.4 *Deemed Savings*.

A detailed description of the derivation of interactive effects is available in Volume 3, *Appendices*.

Table 2-137 Commercial Conditioned and Refrigerated Space Interactive Effects Factors

Building Type	Temperature Description	Heating Type	IEF$_D$	IEF$_E$
All building types (Except Outdoor & Parking Structure)	Air Conditioned Space Normal Temps. (> 41°F)	Gas	1.20	1.09
		Electric Resistance		0.87
		Heat Pump		1.02
		Heating Unknown [397]		0.98
	Refrigerated Space Med. Temps. (33-41°F)	All	1.25	1.25
	Refrigerated Space Low Temps. (-10-10°F)	All	1.30	1.30

2.6.1.5 *Incremental Costs*

Incremental costs by lighting category are as follows.

2.6.1.5.1 High Performance and Reduced Wattage T8s

Incremental costs are detailed in Table 2-138[398].

Table 2-138 T8 Linear Fluorescent Incremental Costs

Measure	Watts	Baseline	Incremental Cost
4-lamp HPT8 High-bay	128	200W Pulse Start MH	$75
4-lamp HPT8 High-bay	128	250W Pulse Start MH	$75
6-lamp HPT8 High-bay	192	320W Pulse Start MH	$75
6-lamp HPT8 High-bay	192	400W Pulse Start MH	$75
8-lamp HPT8 High-bay	256	320W Pulse Start MH	$75
8-lamp HPT8 High-bay	256	400W Pulse Start MH	$75
1-lamp HPT8 – 32W	32	1-lamp standard F328- Electronic ballast	$15
1-lamp HPT8 – 28W	28	1-lamp standard F328- Electronic ballast	$15
1-lamp HPT8 – 25W	25	1-lamp standard F328- Electronic ballast	$15
2-lamp HPT8 – 32W	64	2-lamp standard F328- Electronic ballast	$18

[397] These values should be used for programs where heat type cannot be determined.

[398] Illinois TRM V10.0

Measure	Watts	Baseline	Incremental Cost
2-lamp HPT8 – 28W	56	2-lamp standard F328- Electronic ballast	$18
2-lamp HPT8 – 25W	50	2-lamp standard F328- Electronic ballast	$18
3-lamp HPT8 – 32W	96	3-lamp standard F328- Electronic ballast	$20
3-lamp HPT8 – 28W	84	3-lamp standard F328- Electronic ballast	$20
3-lamp HPT8 – 25W	75	3-lamp standard F328- Electronic ballast	$20
4-lamp HPT8 – 32W	128	4-lamp standard F328- Electronic ballast	$23
4-lamp HPT8 – 28W	112	4-lamp standard F328- Electronic ballast	$23
4-lamp HPT8 – 25W	100	4-lamp standard F328- Electronic ballast	$23
2-lamp HPT8 Troffer	64	3-lamp standard F328- Electronic ballast	$100
RW T8-F28 Lamp	28	F32 T8 Standard lamp	$2
RW T8-F28 Extra Life Lamp	28	F32 T8 Standard lamp	$2
RW T8-F32/25W Lamp	25	F32 T8 Standard lamp	$2
RW T8-F32/25 xtra Life Lamp	285	F32 T8 Standard lamp	$2
RWT8 F17T8 Lamp - 2 ft.	16	F17 T8 Standard lamp – 2 ft.	$2
RWT8 F25T8 Lamp - 3 ft.	23	F25 T8 Standard lamp – 3 ft.	$2
RWT8 F30T8 Lamp - 6' Utube	30	F32 T8 Standard Utube	$2
RWT8 F29T8 Lamp - Utube	29	F32 T8 Standard Utube	$2
RWT8 F96T8 Lamp - 8 ft.	65	F96 T8 Standard lamp – 8 ft.	$2

2.6.1.5.2 T5 Linear Fluorescent Fixtures

Incremental costs are detailed in Table 2-139.

Table 2-139 T5 Linear Fluorescent Incremental Costs

EE Measure	Watts	Baseline	Incremental Cost
2-lamp T5 High-bay	180	200W Pulse Start MH	$100
3-lamp T5 High-bay	180	200W Pulse Start MH	$100
4-lamp T5 High-bay	240	320W Pulse Start MH	$100
6- lamp T5 High-bay	192	320W Pulse Start MH	$100
1-lamp T5 Troffer	32	3-lamp T8	$40
2-lamp T5 Troffer	64	3-lamp T8	$80
1-lamp T5 Industrial/Strip	32	3-lamp T8	$30

EE Measure	Watts	Baseline	Incremental Cost
2- lamp T5 Industrial/Strip	64	3-lamp T8	$60
3- lamp T5 Industrial/Strip	96	3-lamp T8	$90
4- lamp T5 Industrial/Strip	187	3-lamp T8	$120
1-lamp T5 Indirect	32	3-lamp T8	$30
2-lamp T5 Indirect	64	3-lamp T8	$60

2.6.1.5.3 LED Lamps

Incremental costs are detailed in Table 2-140 and Table 2-141.

Table 2-140 GSL LED Incremental Costs[399]

Lamp Type	Location	NPV of Replacement Costs for Period 2022	Levelized Annual Replacement Cost Savings 2022
Omnidirectional	Commercial	$11.88	$2.18
	Multifamily Common Areas	$19.57	$5.88
Decorative	Commercial	$15.91	$3.43
	Multifamily Common Areas	$22.77	$8.04
Directional	Commercial	$41.54	$6.11
	Multifamily Common Areas	$73.43	$17.69

Table 2-141 Non-GSL LED Incremental Costs[400]

LED Category	LED Measure Description	Incremental Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	$27
LED Interior Directional	LED Track Lighting	$59
	LED Wall-Wash Fixtures	$59
LED Display Case	LED Display Case Light Fixture	$11/ft.
	LED Undercabinet Shelf-Mounted Task Light Fixtures	$11/ft.
	LED Refrigerated/Freezer Case light	$11/ft.
	LED 4’ Linear Replacement Lamp	$13

[399] IL TRM v10.0

[400] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1. See "LED Lighting Systems TRM Reference Tables.xlsx" for more information and specific product links.

LED Category	LED Measure Description	Incremental Cost
LED Linear Replacement Lamps	LED 2’ Linear Replacement Lamp	$13
LED Troffers	LED 2x2 Recessed Light Fixture, 2,000-3,500 Lumens	$53
	LED 2x2 Recessed Light Fixture, 3,501-5,000 Lumens	$69
	LED 2x4 Recessed Light Fixture, 3,000-4,500 Lumens	$55
	LED 2x4 Recessed Light Fixture, 4,501-6,000 Lumens	$76
	LED 2x4 Recessed Light Fixture, 6,001-7,500 Lumens	$104
	LED 1x4 Recessed Light Fixture, 1,500-3,000 Lumens	$22
	LED 1x4 Recessed Light Fixture, 3,001-4,500 Lumens	$75
	LED 1x4 Recessed Light Fixture, 4,401-6,000 Lumens	$83
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <=3,000 Lumens	$10
	LED Surface & Suspended Linear Fixture, 3,001-4,500 Lumens	$52
	LED Surface & Suspended Linear Fixture, 4,501-6,000 Lumens	$78
	LED Surface & Suspended Linear Fixture, 6,001-7,500 Lumens	$131
	LED Surface & Suspended Linear Fixture, >7,500 Lumens	$173
LED Low Bay & High Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 Lumens	$44
	LED High-Bay Fixtures, 10,001-15,000 Lumens	$137
	LED High-Bay Fixtures, 15,001-20,000 Lumens	$202
	ED High-Bay Fixtures, 20,001-30,000 lumens	$264
	LED High-Bay Fixtures, 30,001-40,000 lumens	$400
	LED High-Bay Fixtures 40,001-50,000 lumens	$425
	ED High-Bay Fixtures >50,000 lumens	$550
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 Lumens	$18
	LED Ag Interior Fixtures, 2,001-4,000 Lumens	$48
	LED Ag Interior Fixtures, 4,001-6,000 Lumens	$57
	LED Ag Interior Fixtures, 6,001-8,000 Lumens	$88
	LED Ag Interior Fixtures, 8,001-12,000 Lumens	$168
	LED Ag Interior Fixtures, 12,001-16 ,000 Lumens	$151
	LED Ag Interior Fixtures, 16,001-20,000 Lumens	$205
	LED Ag Interior Fixtures, > ,000 Lumens	$356
LED Exterior Fixtures	LED Exterior Fixtures, <=5,000 Lumens	$80
	LED Exterior Fixtures, 5,001-10,000 Lumens	$248
	LED Exterior Fixtures, 10,001-15,000 Lumens	$556
	LED Exterior Fixtures, 15,001-30,000 lumens	$946

LED Category	LED Measure Description	Incremental Cost
	LED Exterior Fixtures, 30,001-40,000 lumens	$700
	LED Exterior Fixtures, 40,001-50,000 lumens	$850
	ED Exterior Fixtures, > 50,000 lumens	$1,100

2.6.1.6 Future Studies

This measure category constitutes over 90% of C&I savings historically in Energy Smart. As a result, this category should be a primary focus of EM&V research. The TPE recommends the following:

- Conduct metering studies for commercial facilities not captured in EM&V to-date.
- Conduct an incremental cost study reflect New Orleans prices, sales tax, and labor costs.
- Conduct focused metering for lighting that is not listed in Energy Start or CEE lists.
- Conduct a market assessment for advanced lighting controls; mature lighting programs have begun further incorporation of Wi-Fi-enabled control schemes where lighting is incorporated into the Energy Management System (EMS). The TPE recommends a market assessment for advanced lighting control adoption in New Orleans.
- Conduct preliminary research to assess whether certain lighting categories would be better-served with a midstream program approach.

2.6.2 LIGHTING CONTROLS

2.6.2.1 Measure Description

Automatic lighting controls save energy by switching off or dimming lights when they are not necessary. Some lighting control techniques, such as using photocell controls, can be coupled with a variety of control strategies, including daylighting controls, occupancy controls, timer controls, and time clocks.

2.6.2.1.1 Stepped Lighting Control Systems

When switching systems are used with entire circuits of lights, as opposed to individual light fixtures, the control protocol is usually described in terms of steps, with each "step" referring to a percentage of full lighting power.

2.6.2.1.2 Continuous Dimming Control Systems

Continuous dimming control systems are designed to adjust electric lighting to maintain a designated light level. Continuous dimming systems eliminate distracting and abrupt changes in light levels, provide appropriate light levels at all times, and provide an increased range of available light level. Cost is the major disadvantage of this control.

2.6.2.1.3 Occupancy Sensors

Occupancy sensors use motion detection to control lights in response to the presence or absence of occupants in a space. Many different varieties of sensors are available, including passive infrared (PIR), Ultrasound detecting, dual-technology, and integral occupancy sensors. Occupancy sensors are most effective in spaces with sporadic or unpredictable occupancy levels.

2.6.2.1.4 Daylighting Sensors

Daylighting controls switch or dim electric lights in response to the presence or absence of daylight illumination in the space. Advanced daylighting controls incorporate occupancy and daylighting sensors into the same control.

2.6.2.2 Baseline & Efficiency Standard

IECC 2003 (Section 805.2) and IECC 2009 (Section 505.1) specify the conditions under which light reduction and automatic controls are mandatory for new construction and affected retrofit projects. See the Measure Baseline section under the lighting efficiency measure for a discussion of updated lighting fixture wattages.

There are no minimum efficiency requirements for lighting controls.

2.6.2.3 Estimated Useful Life

According to DEER 2014, the estimated useful life (EUL) is eight years for Daylighting Sensors and eight years for Occupancy Sensors.

2.6.2.4 Deemed Savings

Due to the myriad of possible lighting configurations upon which occupancy sensors may be installed, the TPE has opted to not include deemed savings per-control. Such a value would require too many assumptions and is likely to be too inaccurate to provide a fixed estimate. If the needed data cannot be collected by program implementers, then the project in question is ineligible for savings. The data requested to calculate deemed savings is consistent with what program implementers have historically collected in implementing Energy Smart programs and align with industry best practices for deemed savings for commercial lighting.

2.6.2.5 Calculation of Deemed Savings

2.6.2.5.1 Measure/Technology Review

There have been many in-depth studies performed on the energy savings associated with occupancy and daylighting controls. Research by various organizations – including the Illuminating Engineering Society (IES), Canada National Research Council (CNRC), New Buildings Institute (NBI), Lighting Research Center (LRC) and multiple utilities – was included in this review. A summary of the findings of these reports are located in Table 2-142 and Table 2-143.

Table 2-142: Lighting Controls – Energy Saving Estimates for Occupancy Sensors

Location	IES[401]	CNRC[402]	NBI[403]	LRC[404]
Break Room	22%	-	-	-
Classroom	45%	63%	25%	-
Conference Room	43%	-	-	-
Corridor	-	24%	-	-
Office	32%	44%	35-45%	43%
Restroom	41%	-	-	-

Table 2-143: Lighting Controls – Energy Saving Estimates for Daylighting Sensors

Location	CNRC	NBI	SoCal Edison[405]	LRC
Classroom	16%	40%	-	-
Corridor	25%	-	-	-
Office	22%	35-40%	74%	24-59%
Grocery Stores	-	40%	-	-
Big Box Retail	-	60%	-	-

Lighting energy savings can be calculated using the following formula. The kWh savings for each combination of fixture type, fixture location, building type, and refrigeration type must be calculated separately:

The following formulas are to calculate deemed savings for the installation of the new sensors:

$$kW_{reduction} = N_{fixt} \times \frac{W_{fixt}}{1000} \times CF \times IEF_D$$

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[401] IES HB-9-2000. "Illuminating Engineering Society Lighting Handbook 9th Edition". 2000.

[402] Canada National Research Center, "Energy Savings from Photosensors and Occupant Sensors/Wall Switches". September 2009.

[403] New Buildings Institute. 2010. http://buildings.newbuildings.org/.

[404] Lighting Research Center (LRC), Solid State Lighting Program. http://www.lrc.rpi.edu/researchareas/leds.asp.

[405] Southern California Edison, "Energy Design Resources: Design Brief Lighting Controls". February 2000.

$$kWh_{savings} = N_{fixt} \times \frac{W_{fixt}}{1000} \times (1 - PAF) \times AOH \times IEF_E$$

Where:

N_{fixt} = Number of fixtures

W_{fixt} = Rated wattage of post-retrofit fixtures (Appendix E)

Note: If the fixture was retrofitted, use the installed fixture wattage; if fixture was not retrofitted, use the existing fixture wattage

PAF = Stipulated power adjustment factor based on control type (Table 2-144)

CF = Peak demand coincidence factor = 0.26[406]

PAF = Power adjustment factor for specified control type (Table 2-144)

AOH = Annual operating hours for specified building type (Table 2-136)

IEF_D = Interactive effects factor for demand reduction (Table 2-137)

IEF_E = Interactive effects factor for energy savings (Table 2-137)

Table 2-144 Lighting Controls – Power Adjustment Factors[407]

Control Type	Power Adjustment Factor (PAF)
No controls measures	1.00
Daylighting Control – Continuous Dimming	0.70
Daylighting Control – Multiple Step Dimming	0.80
Daylighting Control – ON/OFF (Indoor)	0.90
Daylighting Control – ON/OFF (Outdoor) 408	1.00
Occupancy Sensor	0.70
Occupancy Sensor w/ Daylighting Control – Continuous Dimming	0.60
Occupancy Sensor w/ Daylighting Control – Multiple Step Dimming	0.65
Occupancy Sensor w/ Daylighting Control – ON/OFF	0.65

2.6.2.6 Incremental Costs

Incremental costs for lighting controls should use the full project cost. If not available, use the table below.

406 RLW Analytics, "*2005 Coincidence Factor Study,*" Connecticut Energy Conservation Management Board. January 4, 2007. Default value applicable to all building types. This coincidence factor is a combination of the savings factor and peak coincidence factor.

407 ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

408 ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

Table 2-145 Lighting Controls – Incremental Costs

Control Type	Power Adjustment Factor (PAF)
Daylighting Control – Continuous Dimming	$274[409]
Daylighting Control – Multiple Step Dimming	$274
Daylighting Control – ON/OFF (Indoor)	$274
Daylighting Control – ON/OFF (Outdoor) 410	$274
Occupancy Sensor	$42[411]
Occupancy Sensor w/ Daylighting Control – Continuous Dimming	$316
Occupancy Sensor w/ Daylighting Control – Multiple Step Dimming	$316
Occupancy Sensor w/ Daylighting Control – ON/OFF	$316

[409] Consistent with the Multi-level Fixture measure with reference to Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009. Also consistent with field experience of about $250 per fixture and $25 install labor.

[410] ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

[411] DEER 2014

2.6.3 BI-LEVEL LIGHTING FIXTURES IN PARKING GARAGES

2.6.3.1 Measure Description

Automated bi-level lighting fixture with motion sensors installed in a parking garage. The fixture provides lower levels of lighting during unoccupied periods. This measure covers savings from operational changes. Savings are fixture operation only. Retrofit savings from fixture replacement should be calculated using section 2.6.1 Lighting Efficiency.

2.6.3.2 Baseline and Efficiency Standards

Savings for retrofit only. The baseline equipment is assumed to be an uncontrolled lighting system operating continuously in an unconditioned space. Parking garage lighting zones must be controlled by a device that reduces power by a minimum of 30% after 20 minutes of vacancy[412]. Lighting must comply with IECC 2009 guidelines and must otherwise comply with program eligibility requirements.

2.6.3.3 Estimated Useful Life (EUL)

The average lifetime of this measure is 8 years, which is consistent with the DEER 2014 EUL for occupancy and daylighting sensors.

2.6.3.4 Percent Time in Reduced Power State

The average percentage of time spent in high (occupied) and low-power (unoccupied) states was derived from an analysis of metered studies of commercial bi-level retrofit projects conducted for the DOE[413], and case studies by the California Energy Commission[414].

Table 2-146: Estimated Percent Time in "Low Power" (unoccupied) State

Factor	DOE Study	CEC Case Study 1	CEC Case Study 2	CEC Case Study 3	Value used for New Orleans
Percent time luminaries operate in low power or "dimmed" mode	45%	60%	52%	47%	51%

2.6.3.5 Calculation of Deemed Savings

$$kW_{reduction} = \frac{CL_{High} - CL_{Low} \times \%_{Low}}{1{,}000}$$

$$kWh_{savings} = \frac{(CL_{High} \times 8{,}760) - (CL_{Low} \times \%_{Low} \times 8{,}760)}{1{,}000}$$

Where:

CL_{High} = Connected load at full power (watts)

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412 ASHRAE 90.1

413 PG&E Emerging Technologies Program, 2009. "Application Assessment of Bi-Level LED Parking Lot Lighting." https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_raleys.pdf

414 CEC PIER Buildings Program, "Bi-level LED Parking Garage Luminaries." https://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf

CL_{Low} = Connected load at low power or "dimmed" mode (fixture-dependent, ≤70% of full power) (watts)

$8{,}760$ = Annual hours of continuous operation

$\%_{Low}$ = Percent time in lower power or "dimmed" mode (51%)

2.6.3.6 Incremental Cost

The incremental cost is $107.75.[415]

2.6.3.7 Future Studies

Given sufficient participation, the TPE recommends a metering study be conducted to measure percent time in high/low operating modes, as well as peak CF in New Orleans parking structures. Fixture receipts from projects should be recorded so that should the chapter receive a future update, cost information can be used to supplement the incremental cost estimate.

[415] Due to lack of prior studies, the TPE conducted a brief benchmark study comparing bi-level LED fixtures marketed as parking garage fixtures with comparable standard or 'always-on' fixtures.

2.6.4 LED REFRIGERATED CASE LIGHTING

2.6.4.1 Measure Description

This measure relates to the installation of LED lamps with and without motion sensors in vertical display refrigerators, coolers, and freezers replacing T8 or T12 linear fluorescent lamp technology. LED lamps should be systems intended for this application. LED lamps not only provide the same light output with lower connected wattages, but also produce less waste heat which decreases the cooling load on the refrigeration system and energy needed by the refrigerator compressor. Additional savings can be achieved from the installation of a motion sensor which automatically dims the lighting system when the space is unoccupied. Retrofit projects must completely remove the existing fluorescent fixture end connectors and ballasts to qualify, though wiring may be reused. Eligible fixtures include new, replacement, and retrofit. Savings and assumptions are based on a per door basis.

2.6.4.2 Baseline and Efficiency Standards

The baseline equipment is assumed to be T8 or T12 linear fluorescent lamps without occupancy sensors.

2.6.4.3 Estimated Useful Life (EUL)

The expected measure life is assumed to be 8 years.[416]

2.6.4.4 Calculation of Deemed Savings

$$kW\ Reduction = \frac{(Watts_{base} - Watts_{efficient}) \times N_{doors} \times CF \times ESF \times IEF_D}{1{,}000}$$

$$kWh\ Savings = \frac{(Watts_{base} - Watts_{efficient}) \times N_{doors} \times Hours \times ESF \times IEF_E}{1{,}000}$$

Where:

$Watts_{base}$ = Connected wattage of baseline fixtures for each door

$Watts_{efficient}$ = Connected wattage of efficient fixtures for each door

N_{doors} = Number of doors

$Hours$ = Annual operating hours (6,205)[1]

ESF = Energy Savings Factor (No occupancy sensors = 1.00, Occupancy sensors = 1.43[417])

CF = peak coincidence factor (0.99)[418]

IEF_D = Interactive Effects Factor. Waste heat factor for energy to account for cooling savings from efficient lighting (1.25 for medium-temperature cases; 1.30 for low-temperature cases)

[416] Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes annual operating hours of 6,205. <http://www.etcc-ca.com/images/stories/pdf/ETCC_Report_204.pdf>. The lifetime of the motion sensors is assumed to be equal to the lifetime of the LED lighting.

[417] D. Bisbee, Sacramento Municipal Utilities District, "Customer Advanced Technologies Program Technology Evaluation Report: LED Freezer Case Lighting Systems", July 2008.

[418] Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. https://www.puc.pa.gov/pcdocs/1340978.pdf.

IEF_E = Interactive Effects Factor. Waste heat factor for energy to account for cooling savings from efficient lighting (1.25 for medium-temperature cases; 1.30 for low-temperature cases)

2.6.4.5 Incremental Cost

The incremental capital cost for lighting fixtures is $250 per door (retrofit), and $150 (time of sale, new construction)[419].

If a motion sensor is installed, add an additional cost of $130 per 25ft of case[420].

[419] Based on a review of TRM incremental cost assumptions from Oregon and Vermont, supplemented with completed project information from New York.

[420] "LED Case Lighting With and Without Motion Sensors" presentation, Michele Friedrich, PECI, January 2010

2.6.5 LED TRAFFIC SIGNALS

2.6.5.1 Measure Description

This measure involves the installation of LED traffic signals, typically available in red, yellow, green, and pedestrian format, at a traffic light serving any intersection in retrofit applications. New construction applications are not eligible for this measure, as incandescent traffic signals are not compliant with the current federal standard[421,] effective January 1, 2006.

2.6.5.2 Baseline and Efficiency Standards

For all retrofit projects, the baseline is a standard incandescent fixture.

Due to the increased federal standard for traffic signals, the ENERGY STAR® LED Traffic Signal specification was suspended effective May 1, 2007.[422] ENERGY STAR® chose to suspend the specification rather than revise it due to minimal additional savings that would result from a revised specification. Because the ENERGY STAR® specification no longer exists, the efficiency standard is considered to be an equivalent LED fixture for the same application. The equivalent LED fixture must be compliant with the federal standard. There is no current federal standard for yellow “ball” or “arrow” fixtures.

Table 2-147 Federal Standard Maximum Nominal Wattages[423], Wattages[424], and Deemed savings

Measure	Nominal Wattage	Maximum Wattage
12” Red Ball	17	11
12” Green Ball	15	15
8” Red Ball	13	8
8” Green Ball	12	12
12” Red Arrow	12	9
8” Green Arrow	11	11
Combination Walking Man/Hand	16	13
Walking Man	12	9
Orange Hand	16	13

Typical incandescent and LED traffic signal fixture wattages can be found in the following table. These fixture wattages should be used in the absence of project specific fixture wattages.

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[421] Current federal standards for traffic and pedestrian signals can be found at the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/32.

[422] Memorandums related to this decision can be found on the ENERGY STAR® website at: https://www.energystar.gov/index.cfm?c=archives.traffic_signal_spec.

[423] Nominal wattage is defined as power consumed by the module when it is operated within a chamber at a temperature of 25 °C after the signal has been operated for 60 minutes.

[424] Maximum wattage is the wattage at which power consumed by the module after being operated for 60 minutes while mounted in a temperature testing chamber so that the lensed portion of the module is outside the chamber, all portions of the module behind the lens are within the chamber at a temperature of 74 °C, and the air temperature in front of the lens is maintained at a minimum of 49 °C.

Table 2-148 Incandescent/LED Traffic Signal Fixture Wattages

Measure	Incandescent. Wattage[425]	LED Wattage[426]	kWh Savings	kW Savings
Replace 12" Red Incandescent Ball with 12" Red LED Ball	149	9	664.44	0.0756
Replace 12" Yellow Incandescent Ball with 12" Yellow LED Ball		17	34.716	0.0040
Replace 12" Green Incandescent Ball with 12" Green LED Ball		11	517.638	0.0593
Replace 8" Red Incandescent Ball with 8" Red LED Ball	86	6	379.68	0.0432
Replace 8" Yellow Incandescent Ball with 8" Yellow LED Ball		12	19.462	0.0022
Replace 8" Green Incandescent Ball with 8" Green LED Ball		6	300.08	0.0344
Replace 12" Red Incandescent Arrow with 12" Red LED Arrow	128	5	955.833	0.1095
Replace 12" Yellow Incandescent Arrow with 12" Yellow LED Arrow		8	31.56	0.0036
Replace 12" Green Incandescent Arrow with 12" Green LED Arrow		5	89.298	0.0098
Replace Large (16"x18") Incandescent Pedestrian Signal with LED Pedestrian Signal (with Countdown)	149	17	1140.744	0.1307
Replace Small (12"x12") Incandescent Pedestrian Signal with LED Pedestrian Signal (with Countdown)	107	10	838.274	0.0960
Replace Large (16"x18") Incandescent Pedestrian Signal with LED Pedestrian Signal (without Countdown)	116[427]	6	950.62	0.1089
Replace Small (12"x12") Incandescent Pedestrian Signal with LED Pedestrian Signal (without Countdown)	68[428]	5	544.446	0.0624

425 Northwest Power & Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37.

426 Typical practice for estimating fixture wattages is to take an average of the three leading manufacturers: GE, Philips, and Sylvania. Of the three, GE is the only manufacturer providing LED traffic signals. Other manufacturers excluded from averages. http://www.gelightingsolutions.com/products--solutions/transportation-led-lighting/traffic-signals.

427 Average high wattage A19, A21, and A23 incandescent fixture from Philips and Sylvania.

428 Ibid.

2.6.5.3 Estimated Useful Life (EUL)

According to the Northwest Power & Conservation Council Regional Technical Forum, the estimated useful life (EUL) is 5 to 6 years, as shown in the following table.

Table 2-149 Estimated Useful Life by Measure

Measure	EUL[429] (Years)
Replace 12” Red Incandescent Ball with 12” Red LED Ball	6
Replace 12” Yellow Incandescent Ball with 12” Yellow LED Ball	
Replace 12” Green Incandescent Ball with 12” Green LED Ball	
Replace 8” Red Incandescent Ball with 8” Red LED Ball	
Replace 8” Yellow Incandescent Ball with 8” Yellow LED Ball	
Replace 8” Green Incandescent Ball with 8” Green LED Ball	
Replace 12” Red Incandescent Arrow with 12” Red LED Arrow	
Replace 12” Yellow Incandescent Arrow with 12” Yellow LED Arrow	
Replace 12” Green Incandescent Arrow with 12” Green LED Arrow	
Replace Large (16”x18”) Incandescent Pedestrian Signal with LED Pedestrian Signal	5
Replace Small (12”x12”) Incandescent Pedestrian Signal with LED Pedestrian Signal	

[429] Northwest Power & Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37. EUL is determined by LED Traffic Signal replacement schedule, which is set to precede earliest burnout. All fixtures will be replaced at the same time to minimize maintenance interruptions.

2.7 Other Measures

2.7.1 WINDOW FILM

2.7.1.1 Measure Description

This measure consists of the addition of solar film to the outside of glazing on the east, west or south-facing windows of small commercial buildings less than 15,000 gross square feet (any direction except 45 degrees of true north). This measure is based on square footage of qualifying windows.

2.7.1.2 Baseline and Efficiency Standards

This measure is applicable to existing commercial buildings with clear single- or double-pane glazing with a solar heat gain factor (SHGC) greater than 0.66. Existing Low E windows, windows with existing solar films or solar screens are not eligible for this measure.

To qualify for deemed savings, window film should be applied to glass facing east, west or south. The SHGC of the proposed films must be less than 0.50.

The windows must not be shaded by existing awnings, exterior curtains or blinds or any other shading device. They must be installed in a space conditioned by refrigerated air conditioning (central, window or wall unit).

The windows must meet all applicable codes and standards, including:

- ASTM-408: Standard Method for Total Normal Emittance by inspection meter.
- ASTM E-308: Standard Recommended Practice for Spectro-Photometry and Description of Color in CIE1931 (this is an indicator of luminous reflection and visibility).
- ASTM-E903: Standard Methods of Test for Solar Absorbance, Reflectance and Transmittance using an integrated sphere.
- ASTM G-90: Standard Practice for Performing Accelerated Outdoor Weatherizing for Non-Metallic Materials Using Concentrated Natural Light.
- ASTM G26: Xenon arc weathering to accelerate natural aging.
- ASTM E-84: Flammability for commercial and residential structures.

2.7.1.3 Estimated Useful Life

The EUL of this measure is 10 years, according to DEER 2008.

2.7.1.4 Deemed Savings Values

Deemed savings values for annual energy (kWh) and peak demand (kW) are provided in the tables on the following pages. Energy savings are calculated with kWh / sq. ft; demand reductions are kW / 1000 sq. ft.

Table 2-150 Window Film Deemed Savings by Direction and Heating Type

Direction of Window Film	DX Coils with Furnace		Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
East	10.24	2.54	3.08	2.59	5.04	2.59
West	12.32	5.29	6.13	5.43	7.76	5.43
South	17.08	5.66	1.68	5.80	5.81	5.80

Deemed savings are applicable to commercial buildings and were calculated using two representative buildings: a strip mall and a small office building. Estimated savings for the east, west, and south window surfaces were based on a small office building with equal window surfaces on all four sides and for strip malls having glazing on one side. The deemed savings values presented herein represent the average savings per square foot of glazing for windows in each weather zone facing east, west, and south.

2.7.1.5 Incremental Cost

The incremental cost is $2-2.50 per square foot[430].

2.7.1.6 Future Studies

There are currently no future studies planned for this measure at this time.

[430] https://www.energystar.gov/ia/new_homes/comments/Background2.pdf

2.7.2 COMPRESSED AIR LEAK REPAIR

2.7.2.1 Measure Description

This measure consists of identifying and repairing air leaks in compressed air systems. A compressed air system is used in a commercial or industrial system for pneumatic controls of processes that require compressed air such as air dryers and cleaners. The air compressor is programed to maintain a set air pressure in the system during operating hours and air leaks in the system cause the pressure to drop requiring the system to cycle on or operate at a higher load to maintain the pressure causing the system efficiency to decrease. Air leaks are generally located at hose connections, valves, filters, condensate traps, and end use equipment. The most common method to repair a leak in the compressed air system is by tightening connections, replacing worn-out equipment, replacing cracked gaskets, and isolating unused equipment. This measure can only be applied to a compressed air leak repair cost that includes leak detection and repair.

2.7.2.2 Baseline & Efficiency Standard

The savings values for compressed air leak repair are applicable for existing operational compressed air systems. New construction does not qualify for this measure since it is expected to have no air leaks in the system when newly constructed.

2.7.2.3 Estimated Useful Life

The EUL for this measure is 3 years[431].

2.7.2.4 Deemed Savings Values

Due to the large variability in potential energy savings, the TPE has opted to not include deemed savings per leak repair. Such a value would require too many assumptions and the calculated savings has a large range depending on the system pressure, operating hours, and most importantly the leakage rate.

Annual electric kWh and peak kW savings can be calculated using the following equations and Table 2-110 summarizes the needed variables.

$$\Delta kWh = CFM \times kW_{cfm} \times AOH$$

$$CFM = TCFM \times \left(Leak\%_{pre} - Leak\%_{post}\right)$$

$$\Delta kW = CFM \times kW_{cfm}$$

431 http://ilsagfiles.org/SAG_files/Evaluation_Documents/Draft%20Reports%20for%20Comment/ComEd_Drafts_EPY10/ComEd_EUL_CY2019_CompAir_Evaluation_Research_Plan_Draft_2019-06-07.pdf

Table 2-151 Variables for the Deemed Savings Algorithm

Parameter	Description	Value
CFM	Average leak flow rate, cubic feet per minute	Based on Table 2-152
kW_{cfm}	Average compressed air system, kW per CFM	0.107 default, Table 2-153
AOH	Annual hours of operation, hours per year	5702 default, Table 2-154
TCFM	Total system flow rate, cubic feet per minutes	Site measured
$Leak\%_{pre}$	Baseline system leakage percentage	25% default
$Leak\%_{post}$	Repaired system leakage percentage	10% default

Table 2-152 Estimated Leakage Rate[432]

Gauge Pressure Before Leak	Diameter of Orifice				
	1/64"	1/32"	1/16"	1/8"	1/4"
50	0.229	0.916	3.66	14.7	58.6
60	0.264	1.06	4.23	16.9	67.6
70	0.3	1.2	4.79	19.2	76.7
80	0.335	1.34	5.36	21.4	85.7
90	0.37	1.48	5.92	23.7	94.8
100	0.406	1.62	6.49	26	104
150	0.582	2.37	9.45	37.5	150
200	0.761	3.1	12.35	49	196
300	0.995	4.88	18.08	71.8	287

Table 2-153 Air Compressor Efficiency by Control Type[433]

Control Type	Compressor Efficiency	Weighted Average Percentage
Reciprocating - On/off control	0.184	0%
Reciprocating - Load/Unload	0.136	40%
Screw - Load/Unload	0.152	0%
Screw - Inlet Modulation	0.055	0%
Screw - Inlet Modulation w/	0.055	40%
Screw - Variable Displacement	0.153	20%
Screw - VSD	0.178	0%
Unknown / Weighted Average	0.107	

432 UE Systems Inc. Compressed Air Ultrasonic Leak Detection Guide

433 Illinois Technical Reference Manual Version 3.0 Section 4.7.1 VSD Air Compressor

Table 2-154 Annual Operating Hours[434]

Building Type	Hours/Days	EFLH	Average Weight
Single shift	8/5	1,976	16%
2-shift	16/5	3,952	23%
3-shift	24/5	5,928	25%
4-shift	24/7	8,320	36%
Unknown / Average		5,702.32	

2.7.2.5 Incremental Cost

Actual program costs should be used. Deemed costs may be applied once program-average cost estimates have been developed (minimum of 20 projects).

2.7.2.6 Future Studies

There are currently no future studies planned for this measure at this time.

[434] Illinois Technical Reference Manual Version 3.0 Section 4.7.1 VSD Air Compressor

2.7.3 COOL ROOFS

2.7.3.1 Measure Description

This measure consists of replacing at least 75 percent of the roof area with a cool roof. A cool roof is a material of low specific heat and high reflectivity. The primary action of structure heat rejection is the reflection of solar heat back into the atmosphere, but additional heat rejection is realized by the low specific heat of the material quickly radiating any accumulated heat within it out into the atmosphere. A cool roof is defined by ASHRAE 90.1 as a roof having a minimum solar reflectivity of 0.55 and a minimum thermal emittance of 0.75. ASHRAE 90.1-2007 provides an alternative approach allowing products with a minimum Solar Reflective Index (SRI) of 64. The Cool Roof Rating Council (www.coolroofs.org) maintains an SRI database.

2.7.3.2 Baseline & Efficiency Standard

The savings values for cool roof replacement repairs are applicable for all existing baseline roofs. The baseline efficiency is estimated with a solar reflectance of 0.23 and thermal emittance of 0.90.[435]

2.7.3.3 Estimated Useful Life

The effective useful life EUL for this measure is 15 years.[436]

2.7.3.4 Deemed Savings Values

Deemed savings values for annual electric energy use (kWh) and peak demand (kW) is provided in the following tables, arranged by HVAC configuration.

Table 2-155 DX Cooling with Gas Heating

Building Type		kWh/sq. ft.^{2}	kW/1000 ft.^{2}.
Education	Primary School	0.0838	0.0065
	Secondary School	0.0753	0.0047
	Community College	0.1320	0.0372
	University	0.1438	0.0398
Office	Large	0.2346	0.0622
	Small	0.0983	0.0294
Retail	3-Story Large	0.1605	0.0428
	Single-Story Large	0.2685	0.0756
	Small - Retail	0.1125	0.0293
Restaurant	Fast Food	0.1099	0.0299

[435] Average reflectance properties of roofing material as obtained from the publication *Laboratory Testing and Reflectance Properties of Roofing Material* by Florida Solar Energy Center and the predominant roof material used in west south central region for non-small commercial buildings as obtained from CBECS 2003, Table B4

[436] DEER 2014 EUL tables

Table 2-156 DX Cooling with Electric Resistance Heating

Building Type		kWh/sq. ft.[2]	kW/1000 ft.[2]
Education	Primary School	0.0544	0.0065
	Secondary School	0.0558	0.0047
	Community College	0.1164	0.0348
	University	0.1339	0.0398
Office	Large	0.2168	0.0622
	Small	0.0785	0.0295
Retail	3-Story Large	0.1488	0.0428
	Single-Story Large	0.2381	0.0750
	Small - Retail	0.0808	0.0295
Restaurant	Fast Food	0.0743	0.0298

Table 2-157 Heat Pump

Building Type		kWh/sq. ft.[2]	kW/1000 ft.[2]
Education	Primary School	0.0718	0.0065
	Secondary School	0.0684	0.0047
	Community College	0.1312	0.0372
	University	0.1431	0.0398
Office	Large	0.2346	0.0622
	Small	0.0785	0.0295
Retail	3-Story Large	0.1605	0.0428
	Single-Story Large	0.2566	0.0750
	Small - Retail	0.0978	0.0295
Restaurant	Fast Food	0.0963	0.0298

Table 2-158 Chiller Loop Cooling W/ HW Boiler Loop Heating

Building Type		kWh/ ft.[2]	kW/1000 ft.[2]
Education	Secondary School	0.1126	0.0111
	Community College	0.0890	0.0228
	University	0.1088	0.0331
Office	Large	0.1780	0.0637
Retail	3-Story Large	0.1059	0.0301

eQUEST was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since Cool Roof savings are sensitive to weather, available TMY3 weather data specific to New Orleans was used for the analysis. The prototype building characteristics used in the building model are outlined in Appendix A.

2.7.3.5 Incremental Cost

Actual measure cost should be used where available. If not available, the incremental cost of a installing a cool roof is $8.45 per square foot. [437]

2.7.3.6 Future Studies

There are currently no future studies planned for this measure at this time.

[437] 2005 Database for Energy-Efficiency Resources (DEER), version 2005.2.01, "Technology and Measure Cost Data", California Public Utilities Commission, October 26, 2005

2.7.4 AIR CURTAINS

2.7.4.1 Measure Description

This measure applies to buildings with exterior entryways that utilize overhead doors. All other air curtain applications, such as through sliding door entryways or conventional foot-traffic entryways, require custom analysis as air curtain designs must often accommodate other factors that may change their effectiveness.

The use of overhead doors within exterior entryways during the heating season leads to the exfiltration of warm air from the upper portion of the door opening and the infiltration of colder air from the lower portion of the door opening. This results in increase heating energy use to compensate for heat losses every time a door is opened. By reducing heat losses, air curtains can also enhance the physical comfort of employees or customers near the entryway as there will be reduced temperature fluctuations when the door is opened and closed. In addition, in some cases excess heating capacity may be installed in buildings to meet this larger heating load. The addition of air curtains to exterior entryways that currently utilize overhead doors will result in energy savings and enhanced personal comfort, and also possibly in reduced equipment sizing and corresponding costs.

The primary markets for this measure are commercial and industrial facilities with overhead doors in exterior entryways, including but not limited to the following building types: retail, manufacturing, and warehouse (non-refrigerated).

Limitations:

- For use in conditioned spaces with an overhead door in an exterior entryway. This measure does include other door types such doorways to commercial spaces such as retail.
- This measure should only be applied to spaces in which the overhead door separates a conditioned space and an unconditioned space.
- Installation must follow manufacturer recommendations to attain proper air velocity, discharge angle down to the floor level, and unit position.
- Certain heating systems may not be a good fit for air curtains, such as locations with undersized heating capacity. In these cases, the installation of an air curtain may not effectively reduce heating system cycling given the inappropriately sized heating capacity.
- Buildings with slightly positive to slightly negative (~5 Pa to -10 Pa). For all other scenarios, custom analysis is recommended.
- Measure assumes that wind speeds near ground level are less than or equal to 12 mph for 90% of the heating or cooling season. For areas with more extreme weather, custom analysis is necessary.

2.7.4.2 Baseline and Efficiency Standards

No air curtain or other currently installed means to effectively reduce heat loss and air mixing during door openings, such as a vestibule or strip curtain.

Overhead air curtains designed for commercial and industrial applications that have been tested and certified in accordance with ANSI/AMCA 220 and installed following manufacturer guidelines. The measure is for standard models without added heating.

2.7.4.3 Estimated Useful Life

The EUL is assumed to be 15 years.[438]

2.7.4.4 Deemed Savings Values

Deemed savings values are found in the table below.

Table 2-159 Deemed Savings Values

Door Size	**kWh/ft²**	**kW/ft²**
Egress	293	0.046
8’w x 8’h	309	0.048
10’w x 10’h	344	0.053
10’w x 12’h	365	0.055
12’w x 14’h	392	0.059
16’w x 16’h	417	0.062

The following methodology is highly complex and requires significant data collection. It is hoped that simplifying steps can be made in future iterations based on metering and evaluation of installations. The data collected through implementing the measure in the way currently drafted will aid in simplifying efforts at a future date.

2.7.4.4.1 Energy Savings

$$kWh_{cooling} = \left[\frac{(Q_{tbc} - Q_{tac})}{EER} - (HP * 0.7457)\right] * t_{open} * CBP$$

$$kWh_{HP\ heating} = \left[\frac{(Q_{tbc} - Q_{tac})}{HSPF} - (HP * 0.7457)\right] * t_{open} * HBP$$

$$kWh_{Gas\ Heating} = -(HP * 0.7457) * t_{open} * HDD$$

Where:

Q_{tbc} = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)

Q_{tac} = rate of total heat transfer through the open entryway, after air curtain (kBtu/hr)

(see calculation in ‘Heat Transfer Through Open Entryway with/without Air Curtain’ sections below)

EER = energy efficiency ratio of the cooling equipment (kBtu/kWh)

HP = Input power for air curtain (hp)

[438] Navigant Consulting Inc, Measures and Assumptions for Demand Side Management (DSM) Planning: Appendix C: Substantiation Sheets, “Air Curtains – Single Door,” Ontario Energy Board, (April 2009): C-137. 2014 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, February 4, 2014.

Table 2-160 Fan Horsepower

Door Size	Fan HP
8’w x 8’h	1
10’w x 10’h	1.5
10’w x 12’h	4
12’w x 14’h	6
16’w x 16’h	12

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

t_{open} = average hours per day the door is open (hr/day)

CB = Cooling Balance Point, total days in year above balance point temperature 65 °F (day) = 239

HSPF = Heating System Performance Factor of heat pump equipment

HB = Heating Balance Point, total days in year above balance point temperature 65 °F (day) = 126

(i) Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

$$Q_{tbc} = 4.5 * CFM_{tot} * \frac{h_{oc} - h_{ic}}{1{,}000 \frac{Btu}{kBtu}}$$

Where:

4.5 = unit conversion factor with density of air: $60 \frac{min}{hr} * 0.075 \frac{lbm}{ft^3}, \left(\frac{lb*min}{ft*hr}\right)$

CFM_{tot} = Total air flow through entryway (cfm), see calculation below

h_{oc} = average enthalpy of outside air during the cooling season (Btu/lb). See table below.[439]

Table 2-161 Average Enthalpy of Outside Air

Location	67 °F	72 °F	77 °F
New Orleans	35.7	36.6	37.7

h_{ic} = average enthalpy of indoor air, cooling season (Btu/lb). See the below table to determine the approximate indoor air enthalpy associated with an indoor temperature setpoint in indoor relative humidity. An estimate 26.6 Btu/lb associated with the 72 °F and 50% indoor relative humidity case can be used as an approximation if no other data is available. For other indoor temperature setpoints and RH, enthalpies may be interpolated.

Table 2-162 Average Humidity

Humidity (%)	67 °F	72 °F	77 °F
60	25.5	28.5	31.8

[439] Enthalpy values were calculated based on TMY3 dry bulb temperatures.

50	23.9	26.6	29.5
40	22.3	24.7	27.3

The total airflow through the entryway, CFM_{tot}, includes both infiltration due to wind as well as thermal forces, as follows below.

$$CFM_{tot} = \sqrt{(CFM_w)^2 + (CFM_t^2)}$$

Where:

CFM_w = Infiltration due to the wind (cfm)

CFM_t = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

$$CFM_w = (v_{wc} * C_{wc}) * C_v * A_d * \left(88 \frac{fpm}{mph}\right)$$

Where:

v_{wc} = average wind speed during the cooling season (mph) = 3.48[440]

C_{wc} = wind speed correction factor due to wind direction in cooling season, (%). Because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the cooling season prevailing winds can be expected to impact the entryway. =0.2395[441]

C_v = effectiveness of openings = 0.3, assumes diagonal wind[442]

A_d = area of the doorway (ft^2) = user defined

The infiltration due to thermal forces is calculated as follows:

$$CFM_t = A_d * C_{dc} * \left(60 \frac{sec}{min}\right) * \sqrt{2 * g * \frac{H}{2} * \frac{T_{oc} - T_{ic}}{459.7 + T_{oc}}}$$

Where:

C_{dc} = the discharge coefficient during the cooling season[483]

$$C_{dc} = 0.4 + 0.0025 * |T_{ic} - T_{oc}|$$

g = acceleration due to gravity = 32.2 ft/sec2

[440] Average wind speeds were calculated based on the TMY3 wind speed data.

[441] Mean of directional correction factors, Illinois TRM

[442] ASHRAE, "Airflow Around Buildings," in 2013 ASHRAE Handbook – Fundamentals (2013): p 24.3

H = the height of the entryway (ft)

T_{ic} = Average indoor air temperature during cooling season = assumed HVAC setpoint of 72°F

T_{oc} = Average outdoor temp during cooling season (°F) = the average outdoor temperature is dependent on the CDD period and zone. See table below.[443]

Table 2-163 Average Outdoor Air During Cooling Season

	T_{OC}				
Climate Zone	62 °F	67 °F	72 °F	77 °F	82 °F
New Orleans	75.8	78.2	80.0	82.8	85.6

459.7 = conversion factor from °F to °R = calculation requires absolute temperature for values not calculated as a difference of temperatures.

Heat Transfer Through Open Entryway with Air Curtain (Cooling Season)

$$Q_{tac} = Q_{tbc} * (1 - E)$$

Where:

E = the effectiveness of the air curtain (%) = 0.60485

2.7.4.4.2 Demand Reductions

$$\Delta kW = (\Delta kWh_{cooling} / (CDD * 24)) * CF$$

Where:

CF = Coincidence Factor for Commercial cooling = 91.30[444]

2.7.4.5 Incremental Cost

The incremental capital cost for overhead air curtains for exterior entryways are as follows, with an added average installation cost approximately equal to the capital cost.[445]

Table 2-164 Incremental Cost by Door Size

Door Size	**Capital Cost**
8’w x 8’h	$3,600
10’w x 10’h	$4,500
10’w x 12’h	$5,400
12’w x 14’h	$8,000
16’w x 16’h	$13,300

[443] Average temperatures were calculated based on TMY3 wet bulb temperatures.

[444] IL TRM V5.0 Vol.2 Sec. 4.4.33 , Page 307

[445] IL TRM V5.0 Vol.2 Sec. 4.4.33 , Page 301

2.7.4.6 Future Studies

There are currently no future studies planned for this measure at this time.

2.7.5 PLUG LOAD OCCUPANCY SENSORS

2.7.5.1 Measure Description

Plug load occupancy sensors are devices that control low wattage devices (<150 watts) using an occupancy sensor. Common applications are computer monitors, desk lamps, printers, and other desktop equipment. Three wattage tiers were analyzed based on available products in the market: 25W, 50W, and 150W.

2.7.5.2 Baseline and Efficiency Standards

Baseline data found in the table below.

Table 2-165 Plug Load Without Occupancy Sensors – Baseline Data

Size (watts)	Annual Energy Consumption[446] (kWh/ unit)	Annual Operating Hours	Demand (kW/unit)
25	110	4,400	0.025
50	220	4,400	0.05
150	555	3,700	0.15

Table 2-166 contains the annual energy consumption and demand for plug load occupancy sensors.

Table 2-166 Plug Load Occupancy Sensors – Minimum Requirements

Size (watts)	Annual Energy Consumption[447] (kWh/ unit)	Annual Operating Hours	Demand (kW/ unit)
25	45	1,452	0.025
50	91	1,452	0.050
150	234	1,250	0.150

2.7.5.3 Estimated Useful Life

According to DEER 2014 the EUL is eight years.

2.7.5.4 Deemed Savings Values

Deemed measure costs and savings for various sized plug load occupancy sensors are provided in Table 2-167.

Table 2-167 Plug Load Occupancy Sensors – Deemed Savings Values

Measure	Demand Reduction (kW/ unit)	Annual Energy Savings (kWh/ unit)
25W sensor	0.000	65
50W sensor	0.000	129
150W sensor	0.000	321

[446] Arkansas TRM

[447] Arkansas TRM

Four resources contained information on plug load occupancy sensors. The energy savings and amount of equipment controlled per sensor varied widely. The values for energy and demand savings are given in Table 2-168.

Table 2-168 Review of Plug Load Occupancy Sensor Measure Information

Available Resource	Type	Size	Annual Energy Saving (kWh/unit)	Demand Savings (kW/unit)
PG&E 2003	Plug load occupancy sensor	150	300	0.124
Quantec 2005	Power strip occupancy sensor	N/A	27	0.012
DEER 2005	Plug load occupancy sensor	50	143	0.051
KEMA 2010	Plug load occupancy sensor	50	221	0.025
NPCC 2005	Cubicle occupancy sensor	25	55	0.025
PacifiCorp 2009	Unitary savings in comprehensive potential study		196	0.00

2.7.5.5 *Incremental Cost*

The incremental cost is $70.[448]

2.7.5.6 *Future Studies*

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. If this measure is added to Energy Smart programs, the evaluation should include a field assessment to inventory the plug loads actually controlled.

[448] Ohio TRM.

2.7.6 ADVANCED POWER STRIPS

2.7.6.1 Measure Description

This measure involves the installation of a multi-plug Advanced Power Strip (APS) that has the ability to automatically disconnect specific loads depending on the power draw of a specified or "master" load. A load sensor in the strip disconnects power from the control outlets when the master power draw is below a certain threshold. The energy savings calculated for this measure are derived by estimating the number of hours that devices in typical office workstations are in "off" or "standby" mode and the number of watts consumed by each device in each mode. When the master device (i.e. computer) is turned off, power supply is cut to other related equipment (i.e. monitors, printers, speakers, etc.), eliminating these loads.

Commercial deemed savings were developed based on reported plug load electricity consumption. The assumed mix of peripheral electronics, and related data, are presented in the following table.

Table 2-169 shows the assumed number of hours each device is typically in "off" mode. Given the assumption that the master device, a desktop computer, will only be in off mode during non-work hours, watts consumed by devices in standby-mode are not counted toward energy savings for a commercial APS. Workday and weekend day watts consumed in off mode are a function of hours multiplied by estimated watt consumption.

There are two deemed savings paths available: Savings can be estimated as follows: 1) per APS for an average complete system or 2) by individual peripheral device.

Table 2-169 Peripheral Watt Consumption Breakdown

Peripheral Device	Workday Daily Off Hours[449]	Weekend Daily Off Hours	Off Power (W)[450,451]	Workday (W-hr) [A]	Weekend (W-hr) [B]
Coffee Maker	16	24	1.14	18.24	27.36
Computer: Desktop	16	24	3.3	52.80	79.20
Computer: Laptop	16	24	4.4	70.40	105.60
Computer Monitor: CRT	16	24	1.5	24.00	36.00
Computer Monitor: LCD	16	24	1.1	17.60	26.40
Computer Speakers	16	24	2.3	36.80	55.20
Copier	16	24	1.5	24.00	36.00
External Hard Drive	16	24	3.0	48.00	72.00

[449] Commercial hours of operation based on typical 8-hour workday schedule.

[450] New York State Energy Research and Development Authority (NYSERDA), "Advanced Power Strip Research Report". August 2011.

[451] Standby Power Summary Table, Lawrence Berkeley National Laboratory. http://standby.lbl.gov/summary-table.html.

Fax Machine: Inkjet	16	24	5.3	84.80	127.20
Fax Machine: Laser	16	24	2.2	35.20	52.80
Media Player: Blu-Ray	16	24	0.1	1.60	2.40
Media Player: DVD	16	24	2.0	32.00	48.00
Media Player: DVD-R	16	24	3.0	48.00	72.00
Media Player: DVD/VCR	16	24	4.0	64.00	96.00
Media Player: VCR	16	24	3.0	48.00	72.00
Microwave	16	24	3.08	49.28	73.92
Modem: Cable	0	24	3.8	0.00	91.20
Modem: DSL	0	24	1.4	0.00	33.60
Multi-Function Printer: Inkjet	16	24	5.26	84.16	126.24
Multi-Function Printer: Laser	16	24	3.12	49.92	74.88
Phone with Voicemail	16	24	2.92	46.72	70.08
Printer: Inkjet	16	24	1.3	20.80	31.20
Printer: Laser	16	24	3.3	52.80	79.20
Router	16	24	1.7	27.20	40.80
Scanner	16	24	2.1	33.60	50.40
Television: CRT	16	24	1.6	25.60	38.40
Television: LCD	16	24	0.5	8.00	12.00
Television: Plasma	16	24	0.6	9.60	14.40
Television: Projection	16	24	7.0	112.00	168.00

2.7.6.2 Baseline and Efficiency Standards

The baseline case is the absence of an APS, where peripherals are plugged into a traditional surge protector or wall outlet. The baseline assumes a typical mix of office equipment, shown in Table 2-169.

2.7.6.3 Estimated Useful Life

The EUL is 10 years according to the New York State Energy Research and Development Authority (NYSERDA) Advanced Power Strip Research Report from August 2011.[452]

2.7.6.4 Deemed Savings Values

Energy savings for a 7-plug APS in use in a commercial setting are calculated using the following algorithm, where kWh saved are calculated and summed for all peripheral devices:

$$\Delta kWh = \frac{\sum(Workdays * A_i) + \sum\big((365 - Workdays) * B_i\big)}{1{,}000}$$

Where:

Workdays = Average number of workdays per year[453] = 240 days

A = Watt-hours/day consumed in the "off" mode per workday

B = Watt-hours/day consumed in the "off" mode per weekend day

1,000 = Constant to convert watts to kilowatts

No demand reductions are awarded for this measure due to the assumption that typical office equipment will be operating throughout the workday.

Energy savings from an APS in an office setting are estimated to be 71.4 kWh using the above equation and assuming six unique peripheral devices. Energy savings per peripheral device are also available in the following table.

Table 2-170 Advanced Power Strips – Deemed Savings Values

Peripheral Device	kWh Savings
Coffee Maker	7.8
Computer: Desktop	22.6
Computer: Laptop	30.1
Computer Monitor: CRT	10.3
Computer Monitor: LCD	7.5
Computer Speakers	15.7
Copier	10.3
External Hard Drive	20.5
Fax Machine: Inkjet	36.3
Fax Machine: Laser	15.0
Media Player: Blu-Ray	0.7
Media Player: DVD	13.7
Media Player: DVD-R	20.5

[452] New York State Energy Research and Development Authority (NYSERDA): Advanced Power Strip Research Report, p. 30. August 2011.

[453] Assuming 50 working weeks, deducting 2 weeks for federal holidays and another 2 weeks for vacation; 48 weeks x 5 days/week = 240 days

Media Player: DVD/VCR	27.4
Media Player: VCR	20.5
Microwave	21.1
Modem: Cable	11.4
Modem: DSL	4.2
Multi-Function Printer: Inkjet	36.0
Multi-Function Printer: Laser	21.3
Phone with Voicemail	20.0
Printer: Inkjet	8.9
Printer: Laser	22.6
Router	11.6
Scanner	14.4
Television: CRT	10.9
Television: LCD	3.4
Television: Plasma	4.1
Television: Projection	47.9
Average APS: Small Business Whole System[454]	61.2

2.7.6.5 *Incremental Cost*

The incremental cost is $16 for a 5-plug strip and $26 for a 7-plug strip[455].

2.7.6.6 *Future Studies*

At the time of authorship of the NO TR V6.1, this measure was not implemented in Energy Smart programs. If this measure is added to Energy Smart programs, the evaluation should include a field assessment to inventory the plug loads actually controlled.

[454] Assuming Computer Monitor: LCD, Computer Speakers, Modem: Average, Printer: Average, and Scanner. Computer not included because it is assumed to be the controlling load. This average value is meant to apply to a typical small business application and should not be applied in other applications. For other applications, calculate the savings for each individual equipment type. kWh savings = 7.5 + 15.7 + [(11.4 + 4.2) ÷ 2] + [(8.9 + 22.6) ÷ 2] + 14.4 = 61.2 kWh.

[455] Price survey performed in NYSERDA Measure Characterization for Advanced Power Strips, p4

2.7.7 COMPUTER POWER MANAGEMENT

2.7.7.1 Measure Description

Computer Power Management (CPM) is the automated control of the power, or "sleep" settings of network desktop and notebook computer equipment. CPM involves using built-in features or add-on software programs to switch off displays and enable computers to enter a low power setting called sleep mode during periods of non-use. This measure applies to both ENERGY STAR® and conventional computer equipment and assumes that the same computer equipment is being used before and after CPM settings are activated. The power draw of a computer is assumed to be roughly equivalent during active and idle periods, so for the purposes of calculating savings, we will combine the terms active and idle as "active/idle" throughout the document.

2.7.7.2 Baseline and Efficiency Standards

The baseline conditions are the estimated number of hours that the computer spends in idle and sleep mode before the power settings are actively managed. The efficient conditions are the estimated number of hours that the computer spends in active/idle and sleep mode after the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used.

2.7.7.3 Deemed Savings Values

Deemed demand and annual savings are based on the ENERGY STAR® Low Carbon IT Savings calculator. The coincidence factor, default equipment wattages in Table 2-171, and the active/idle and sleep hours are taken from assumptions in the ENERGY STAR® calculator with all equipment set to enter sleep mode after 15 minutes of inactivity.

$$kWh_{savings} = \frac{W_{active/idle}\left(hours_{active/idle_{pre}} - hours_{active/idle_{post}}\right) + W_{sleep}\left(hours_{sleep_{pre}} - hours_{sleep_{post}}\right)}{1{,}000}$$

$$kW_{savings} = \frac{(W_{active/idle} - W_{sleep}) * CF}{1{,}000}$$

Where:

$W_{active/idle}$ = total wattage of the equipment, including computer and monitor, in active/idle mode; see Table 2-171.

$Hours_{active\_idle\_pre}$ = annual number of hours the computer is in active/idle mode before computer management software is installed = 6,293

$Hours_{active\_idle\_post}$ = annual number of hours the computer is in active/idle mode after computer management software is installed = 1,173

W_{sleep}= total wattage of the equipment, including computer and monitor, in sleep mode; see Table 2-171

$Hours_{sleep\_pre}$= annual number of hours the computer is in sleep mode before computer management software is installed = 0

$Hours_{sleep\_post}$ = annual number of hours the computer is in sleep mode after computer management software is installed = 5,120

CF= Coincidence Factor[456] = 0.25

1,000 = W/kW conversion

Table 2-171 Computer Power Management - Equipment Wattages

Equipment	W_{sleep}	$W_{active/idle}$
Conventional LCD Monitor	1	32
Conventional Computer	3	69
Conventional Notebook (including display)	2	21

Table 2-172 Computer Power Management - Deemed Savings Values

Equipment	kWh savings	kW savings
Conventional LCD Monitor	158.72	0.008
Conventional Computer	337.92	0.017
Conventional Notebook (including display)	97.28	0.005

2.7.7.4 Estimated Useful Life

The EUL of this measure is based on the useful life of the computer equipment which is being controlled. Computer technology may continue to function long after technological advances have diminished the usefulness of the equipment. The EUL for Computer Power Management is 4 years.[457]

2.7.7.5 Incremental Cost

The incremental cost is $29 per computer, including labor.[458]

2.7.7.6 Future Studies

At the time of authorship of the NO TRM V6.1, this measure was not implemented in Energy Smart programs. If this measure is added to Energy Smart programs, the evaluation should include a field assessment to inventory the plug loads actually controlled.

456 The coincidence factor is the percentage of time the computer is assumed to be not in use during the hours 3pm to 6pm from the ENERGY STAR® calculator modeling study.

457 The Regional Technical Forum, Measure workbook for Commercial: Non-Res Network Computer Power Management. http://rtf.nwcouncil.org/measures/measure.asp?id=95. Accessed August 2013.

458 Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison