Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of ECMs are a result of savings due to the increased efficiency of the fan and the reduction of heat produced from the reduction of fan operation. The energy and demand savings are calculated using the following equations:

Cooler

$$Demand[kW] = N \times \Delta kW_{peak\ per\ unit}$$

Equation 139

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapCool} \times \left(1 + \frac{1}{COP_{cooler}}\right)$$

Equation 140

$$Energy[kWh] = N \times \Delta kWh_{per\ unit}$$

Equation 141

$$\Delta kWh_{per\ unit} = \Delta kW_{peak\ per\ unit} \times Hours \times (1 - \%OFF)$$

Equation 142

Freezer

$$Demand[kW] = N \times \Delta kW_{peak\ per\ unit}$$

Equation 143

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapFreeze} \times \left(1 + \frac{1}{COP_{freezer}}\right)$$

Equation 144

$$Energy[kWh] = N \times \Delta kWh_{per\ unit}$$

Equation 145

$$\Delta kWh_{per\ unit} = \Delta kW_{peak\ per\ unit} \times Hours \times (1 - \%OFF)$$

Equation 146

Where:

N	=	*Number of motors replaced*
W_{base}	=	*Input wattage of existing/baseline evaporator fan motor*
W_{ee}	=	*Input wattage of new energy efficient evaporator fan motor*
LF	=	*Load factor of evaporator fan motor*
$DC_{EvapCool}$	=	*Duty cycle of evaporator fan motor for cooler*

$DC_{EvapFreeze}$ = *Duty cycle of evaporator fan motor for freezer*

COP_{cooler} = $12/EER_{MT}$, *the coefficient of performance of compressor in the cooler*

$COP_{freezer}$ = $12/EER_{LT}$, *the coefficient of performance of compressor in the freezer*

Hours = *The annual operating hours are assumed to be 8,760 for coolers and 8,273*[370] *for walk-ins (see Table 175)*

%OFF = *The percentage of time that the evaporator fan motors are off. If the facility does not have evaporator fan controls %OFF = 0, and if the facility has evaporator fan controls %OFF = 46%.*[371]

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data, as described below.

For medium-temperature refrigerated cases, the saturated condensing temperature (SCT_{MT}) is calculated as the design dry-bulb temperature plus 15 degrees. For low-temperature refrigerated cases, the SCT_{LT} is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant of 1/1.15 or approximately 0.87.[372]

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370 The Pennsylvania TRM, June 2016, utilizes the Efficiency Vermont source reproduced below this footnoted statement for an assumption of 8,273 hours for walk-in freezers. This is, furthermore, equivalent to stating the freezer's duty cycle is approximately 94.4% (8,273 / 8,760 ≈ 0.944), an assumed value which appears in Table 175 for the $DC_{EvapFreeze}$ variable. The Maine TRM, July 2019, details the derivation of 8,273 and thus approximately 94.4%: "A[n] evaporator fan in a cooler runs all the time, but a freezer runs only 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)".

- Pennsylvania TRM, "3.5.3 High-Efficiency Fan Motors for Walk-In Refrigerated Cases". Page 369, Table 3-93. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.
- Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf.
- Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019. Page 83, footnote 401.

371 The Massachusetts Technical Reference Manual, 2012 Program Year – Plan Version, "Refrigeration – Evaporator Fan Controls", October 2011. Page 216, footnote 414 cites the following as the source for this variable:
"The value is an estimate by National Resource Management (NRM) based on extensive analysis of hourly use data. These values are also supported by Select Energy (2004). Cooler Control Measure Impact Spreadsheet User's Manual. Prepared for NSTAR."

372 Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas and Electric Company. May 29,2009. Assumes 15 percent oversizing.

For medium temperature compressors, the following equation is used to determine EER_{MT} [Btu/hr/watts] for each hour of the year:

$$EER_{MT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 147[373]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*
c	=	*29.4589834935596*
d	=	*0.000342066982768282*
e	=	*-11.7705583766926*
f	=	*-0.212941092717051*
g	=	*-1.46606221890819 x* 10^{-6}
h	=	*6.80170133906075*
I	=	*-0.020187240339536*
j	=	*0.000657941213335828*
PLR	=	*1/1.15 = 0.87*
SCT_{MT}	=	$T_{db} + 15$
T_{DB}	=	*Dry-bulb temperature*

For low temperature compressors, the following equation is used to determine EER_{LT} [Btu/hr/watts] for each hour of the year:

$$EER_{LT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 148[374]

373 San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012. https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

374 Ibid.

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	$-7.57495453950879 \times 10^{-6}$
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.87*
SCT_{LT}	=	T_{db} *+10*
T_{DB}	=	*Dry-bulb temperature*

Table 175. Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed values
W_{base}	See Table 176
W_{ee}	See Table 176
LF[375]	0.9
$DC_{EvapCool}$[376]	100%
$DC_{EvapFreeze}$[377]	94.4%
COP_{cooler}	$12/EER_{MT}$
$COP_{freezer}$	$12/EER_{LT}$
Hours[378]	8,760 or 8,273
%OFF	0 or 46%

[375] The Pennsylvania TRM, June 2016, cites the following as the source for determining the load factor of the evaporator fan motor:
"ActOnEnergy; Business Program-Program Year 2, June 2009 through May 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009.
Pennsylvania TRM, "3.5.2 High-Efficiency Fan Motors for Reach-In Refrigerated Cases". page 365, Table 3-89. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.

[376] Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019. Page 83, footnote 401.

[377] See footnotes 370 and 376.

[378] See footnote 370 for the explanation of the assumption of 8,273 for walk-in freezers.

Table 176. Motor Sizes, Efficiencies, and Input Watts[379,380]

Nominal motor size	Motor output (W)	Shaded pole eff	Shaded pole input (W)	PSC eff	PSC input (W)	ECM eff	ECM input (W)
(1-14W)	9	30%	30	60%	15	70%	13
1/40 HP (16-23W)	19.5	30%	65	60%	33	70%	28
1/20 HP (37W)	37	30%	123	60%	62	70%	53
1/15 HP (49W)	49.0	30%	163	60%	82	70%	70
1/4 HP	186.5	30%	622	60%	311	70%	266
1/3 HP	248.7	30%	829	60%	415	70%	355

Table 177. Compressor Coefficient of Performance Based on Climate and Refrigeration Type (COP_{cooler} or $COP_{freezer}$)

Representative climate city	Summer design dry-bulb temperature[381]	EER_{MT}	COP_{cooler}	EER_{LT}	$COP_{freezer}$
Zone 1: Amarillo	98.6	6.18	1.94	4.77	2.51
Zone 2: Dallas	101.4	5.91	2.03	4.56	2.63
Zone 3: Houston	97.5	6.29	1.91	4.86	2.47
Zone 4: Corpus Christi	96.8	6.36	1.89	4.91	2.44
Zone 5: El Paso	101.1	5.94	2.02	4.58	2.62

Deemed Energy and Demand Savings Tables

The energy and demand savings of ECMs are calculated using a deemed algorithm, based on climate zone, refrigeration temperature, and presence of motor controls. Therefore, there are no deemed energy or demand tables. Evaporator fan nameplate data, rated power, and efficiency is also required.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

379 The first three rows in this table are sourced from the Pennsylvania TRM, June 2016. Pennsylvania TRM, "3.5.2 High-Efficiency Fan Motors for Reach-In Refrigerated Cases". page 366, Table 3-90. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.
The last two rows are estimated using logarithmic linear regression of smaller motor efficiencies.

380 Motor efficiencies: "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." Department of Energy. December 2013. Motor efficiencies for the baseline motors are from Table 2.1, which provides peak efficiency ranges for a variety of motors. ECM motor efficiencies is from discussion in Section 2.4.3. https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf.

381 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL IDs GrocDisp-FEEvapFanMtr and GrocWlkIn-WEvapFanMtr.[382]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Climate zone
- Building type
- Motor quantity
- Motor efficiency
- Motor power rating
- Evaporator fan control type
- Refrigeration type (cooler, freezer)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update.~~

[382] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Document Revision History

Table 178. Nonresidential ECM Evaporator Fan Motors Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. Updated the methodology with cooler and freezer values.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added schools as an eligible building type.

2.5.3 Electronic Defrost Controls Measure Overview

TRM Measure ID: NR-RF-DC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, schools[383], grocery stores, hotels, restaurants, and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of electronic defrost controls. The controls sense whether a defrost cycle is required in a refrigerated case and skips it if it is unnecessary.

Eligibility Criteria

Not applicable.

Baseline Condition

The baseline efficiency case is a refrigerated case without defrost controls or with an evaporator fan defrost system that uses a time clock mechanism to initiate electronic resistance defrost.

High-Efficiency Condition

Eligible high-efficiency equipment is an evaporator fan defrost system with electronic defrost controls.

383 Refrigeration and freezer units utilized in a school setting typically function year-round. This operating schedule prevents malfunctioning due to periods of prolonged disuse and allows child nutrition meal programs offered to students and the community to operate during school off-seasons. Schools are therefore an applicable building type for this measure, which utilizes annual operating hours derived from a full-year schedule.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of electronic defrost controls are a result of savings due to the increase in operating efficiency and the reduced heat from a reduction in the number of defrosts. The energy and demand savings are calculated using the equations, with the coefficient of performance variable corresponding to low temperature or medium temperature applications:

$$Energy\ [kWh] = \Delta kWh_{defrost} + \Delta kWh_{heat}$$

Equation 149

$$\Delta kWh_{defrost} = kW_{defrost} \times DRF \times Hours$$

Equation 150

Medium temperature:

$$\Delta kWh_{heat} = \Delta kWh_{defrost} \times 0.28 \times COP_{MT}$$

Equation 151

Low temperature:

$$\Delta kWh_{heat} = \Delta kWh_{defrost} \times 0.28 \times COP_{LT}$$

Equation 152

$$Peak\ Demand\ [kW] = \frac{\Delta kWh}{Hours}$$

Equation 153

Where:

$\Delta kWh_{defrost}$ = *Energy savings resulting from an increase in operating efficiency due to the addition of electronic defrost controls*

ΔkWh_{heat} = *Energy savings due to the reduced heat from reduced number of defrosts*

$kW_{defrost}$ = *Load of electric defrost, default = 0.9 kW*[384]

[384] Efficiency Vermont TRM, 3/16/2015, p. 170. The total defrost element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900W per fan. https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf.

Hours = *Number of hours defrost occurs over a year without defrost controls, 487*[385]

DRF = *Defrost reduction factor—percent reduction in defrosts required per year, see Table 179*

0.28 = *Conversion of kW to tons; 3,412 Btuh/kW divided by 12,000 Btuh/ton*

COP_{MT} = $12/EER_{MT}$, *the coefficient of performance of compressor in the cooler*

COP_{LT} = $12/EER_{LT}$, *the coefficient of performance of compressor in the freezer*

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data.

For medium-temperature refrigerated cases, the saturated condensing temperature (SCT_{MT}) is calculated as the design dry-bulb temperature plus 15 degrees. For low-temperature refrigerated cases, the SCT_{LT} is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant of 1/1.15 or approximately 0.87.[386]

For medium-temperature compressors, the following equation is used to determine EER_{MT} [Btu/hr/watts] for each hour of the year.

$$EER_{MT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 154[387]

Where:

a = *3.75346018700468*

b = *-0.049642253137389*

[385] Demand Defrost Strategies in Supermarket Refrigeration Systems, Oak Ridge National Laboratory, 2011. The refrigeration system is assumed to be in operation every day of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be (4) 20-minute cycles per day, for a total of 487 hours. https://info.ornl.gov/sites/publications/files/pub31296.pdf.

[386] Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas and Electric Company. May 29,2009. Assumes 15 percent oversizing.

[387] San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012. https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

c	=	*29.4589834935596*
d	=	*0.000342066982768282*
e	=	*-11.7705583766926*
f	=	*-0.212941092717051*
g	=	$-1.46606221890819 \times 10^{-6}$
h	=	*6.80170133906075*
I	=	*-0.020187240339536*
j	=	*0.000657941213335828*
PLR	=	*1/1.15 = 0.87*
SCT_{MT}	=	$T_{db} + 15$
T_{DB}	=	*Dry-bulb temperature*

For low-temperature compressors, the following equation is used to determine EER_{LT} [Btu/hr/watts] for each hour of the year:

$$EER_{LT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 155[388]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	$-7.57495453950879 \times 10^{-6}$
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.87*

[388] Ibid.

SCT_{LT} = T_{db} +10

T_{DB} = *Dry-bulb temperature*

Table 179. Deemed Variables for Energy and Demand Savings Calculations

Climate zone	DRF[389]	COP_{MT}[390]	COP_{LT}[391]
Zone 1: Amarillo	35%	1.94	2.51
Zone 2: Dallas		2.03	2.63
Zone 3: Houston		1.91	2.47
Zone 4: Corpus Christi		1.89	2.44
Zone 5: El Paso		2.02	2.62

Deemed Energy and Demand Savings Tables

The energy and demand savings of Defrost Controls are calculated using a deemed algorithm based on climate zone and refrigeration temperature and are therefore not associated with deemed energy nor demand tables.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) has been defined for this measure as 10 years.[392]

389 Smart defrost kits claim 30-40% savings, of which this value is the midpoint (with up to 44% savings by third party testing by Intertek Testing Service - Smart HVAC: Refrigeration Defrost Kit Aids Troubleshooting (achrnews.com)). https://www.heatcraftrpd.com/contentAsset/raw-data/aee972cd-cbe8-4912-879e-b69aba4d25e9/fileAsset?byInode=true

390 Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPSCNRRN009 (rev.o.2007).

391 Ibid.

392 GDS Associates, Inc. (June 2007). *Measure Life Report.* Prepared for The New England State Program Working Group (SPWG). https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf
Additionally, the Pennsylvania TRM Volume 3 Page 162 cites the Vermont TRM, March 16, 2015. Pg. 171: "This is a conservative estimate is based on a discussion with Heatcraft based on the components expected life. https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf"

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Climate zone
- Hours that defrost occurs over a year without defrost controls
- Load of electric defrost
- Refrigeration temperature (low temperature or medium temperature)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket No. 40669 provides energy and demand savings and measure specifications

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

~~Not applicable.~~

Document Revision History

Table 180. Nonresidential Electronic Defrost Controls Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper.
v10.0	10/2022	TRM v10.0 update. Added schools as an eligible building type.

2.5.4 Evaporator Fan Controls Measure Overview

TRM Measure ID: NR-RF-FC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, schools[393], grocery stores, hotels, restaurants, and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for 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.

Eligibility Criteria

Not applicable.

Baseline Condition

The baseline efficiency case is an existing shaded pole evaporator fan motor with no temperature controls, running 8,760 annual hours.

High-Efficiency Condition

Eligible high-efficiency equipment will be regarded as an energy management system (EMS) or other electronic controls to modulate evaporator fan operation based on the temperature of the refrigerated space.

[393] Refrigeration and freezer units utilized in a school setting typically function year-round. This operating schedule prevents malfunctioning due to periods of prolonged disuse and allows child nutrition meal programs offered to students and the community to operate during school off-seasons. Schools are therefore an applicable building type for this measure, which utilizes annual operating hours derived from a full-year schedule.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of evaporator fan controls are a result of savings due to the reduction in the operation of the fan. The energy and demand savings are calculated using the equations:

$$Energy\ [kWh] = \Delta kW \times 8{,}760$$

Equation 156

$$Peak\ Demand\ [kW] = \left(\left(kW_{evap} \times n_{fans}\right) - kW_{circ}\right) \times \left(1 - DC_{comp}\right) \times DC_{evap} \times BF$$

Equation 157

Where:

kW_{evap}	=	*Connected load kW of each evaporator fan, see Table 181*
kW_{circ}	=	*Connected load kW of the circulating fan, see Table 181*
n_{fans}	=	*Number of evaporator fans*
DC_{comp}	=	*Duty cycle of the compressor, see Table 181*
DC_{evap}	=	*Duty cycle of the evaporator fan, see Table 181*
BF	=	*Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running, see Table 181*
8,760	=	*Annual hours per year*

Table 181. Deemed Variables for Energy and Demand Savings Calculations [394]

Variable	Deemed values
kW_{evap}	0.123 kW
kW_{circ}	0.035 kW
DC_{comp}	50%
DC_{evap}	Cooler: 100% Freezer: 94.4%
BF	Low Temp: 1.5 Medium Temp: 1.3 High Temp: 1.2

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-WEvapFMtrCtrl.[395]

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[394] The Maine Technical Reference Manual was utilized to determine these assumed values. Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019.

- kW_{evap}: Page 78, footnote 366 states this value is determined "based on a weighted average of 80% shaded-pole motors at 132 watts and 20% PSC motors at 88 watts. This weighted average is based on discussions with refrigeration contractors and is considered conservative (market penetration estimated at approximately 10%)."
- kW_{circ}: Page 78, footnote 367 states this value is the "wattage of fan used by Freeaire and Cooltrol"
- DC_{comp}: Page 78, footnote 368 states the reasoning for this value as follows: "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 and Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor."
- DC_{evap}: 94.4% is equivalent to 8,273 / 8,760 annual operating hours. The assumption of 8,273 is the annual total of the assumption that "a[n] evaporator fan in a cooler runs all the time, but a freezer only runs 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)", an explanation given on page 82, footnote 401.
- BF: Page 183, Table 45, footnote A summarizes the Bonus Factor (-1 + 1/COP) as "assum[ing] 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."

[395] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Number of evaporator fans controlled
- Refrigeration type (cooler, freezer)
- Refrigeration temperature (low, medium, high)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket No. 40669 provides energy and demand savings and measure specifications
- PUCT Docket No. 36779 provides approved EUL for Evaporator Fan Controls

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update~~

Document Revision History

Table 182. Nonresidential Evaporator Fan Controls Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
~~V~~v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added schools as an eligible building type.

2.5.5 Night Covers for Open Refrigerated Display Cases Measure Overview

TRM Measure ID: NR-RF-NC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of night covers on the otherwise *open vertical* (multi-deck) and *horizontal* (or coffin-type) low-temperature and medium-temperature display cases. Night covers reduce the cooling load borne by the refrigerated display case's compressor due to a combination of factors: (1) a decrease in convective heat transfer from reduced air infiltration, (2) increased insulation reducing conductive heat transfer, and (3) decreased radiation through the blocking of radiated heat. Additionally, it is acceptable for these film-type covers to have small, perforated holes to decrease any potential build-up of moisture.

Eligibility Criteria

Any suitable low-emissivity material sold as a night cover.

Baseline Condition

The baseline efficiency case is an open low-temperature or medium-temperature refrigerated display case (vertical or horizontal) that is not equipped with a night cover.

High-Efficiency Condition

Eligible high-efficiency equipment is considered any suitable low-emissivity material sold as a night cover. The night cover must be applied for a period of at least six hours[396] per day (i.e., average continuous overnight use).

[396] Faramarzi, R. "Practical Guide: Efficient Display Case Refrigeration", 1999 ASHRAE Journal, Vol. 41, November 1999.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The following outlines the assumptions and approach used for estimating demand and energy savings resulting from the installation of night covers on open low- and medium-temperature, vertical and horizontal refrigerated display cases. Heat transfer components of the display case include infiltration (convection), transmission (conduction), and radiation.

$$\Delta kWh = L \times kWh_{baseline} \times 9\%$$

Equation 158

Where:

ΔkWh	=	*Energy savings*
L	=	*Horizontal linear feet of the low- or medium-temperature refrigerated display case*
$kWh_{baseline}$	=	*Average annual unit energy consumption in terms of kWh/horizontal linear foot/year*
9%	=	*The reduction in compressor's electricity usage due to the night cover's decreasing of convection, conduction, and radiation heat transfer*[397]

Deemed Energy and Demand Savings Tables

The per-linear-foot energy savings of night covers are deemed as nine percent (the compressor load reduction from night covers defined in the previous section) of the "base-case scenario" efficiency level's average-annual-unit energy consumption per horizontal linear foot per display case type from the US Department of Energy's (DOE) Technical Support Document for Commercial Refrigeration Equipment.[398] Vertical and horizontal *open* equipment types were selected for inclusion given the nature of this measure.

[397] Ibid. "Table 1 - Effects of utilizing Heat Reflecting Shields on Refrigeration System Parameters Non-24-hour Supermarket with Shields and Holiday Case versus Base Case"

[398] In 2013, the U.S. DOE conducted an extensive life-cycle cost (LCC) analysis of the commercial refrigeration equipment classes listed in the current federal standard 10 CFR 431.66 to determine average annual unit energy consumption per equipment class. In this analysis, 10,000 separate simulations yielded probability distributions for various parameters associated with each equipment class, among them: the efficiency level in kWh/yr. These efficiency levels were then subject to roll-up calculations to determine market shares of each efficiency level, which were then utilized to compute the average consumption for said efficiency level listed in Table 183.
Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. LCC Summary Statistics: Section 8B2; Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf.

Table 183. Modeled Deemed Savings for Night Covers for Texas (per Linear Foot)

Temperature[399]	Condensing unit configuration	Equipment family	Average annual energy consumption per linear foot ($kWh_{baseline}$)	ΔkWh	Annual demand savings[400]
Medium (≥32 ± 2°F)	Remote condensing	Vertical open	1,453	130.77	0
		Horizontal open	439	39.51	0
	Self-contained	Vertical open	2,800	252.00	0
		Horizontal open	1,350	121.50	0
Low (<32 ± 2°F)	Remote condensing	Vertical open	3,292	296.28	0
		Horizontal open	1,007	90.63	0
	Self-contained	Horizontal open	2,748	247.32	0

Claimed Peak Demand Savings

This measure does not have peak demand savings because the night covers are applied at night, from approximately midnight to 6:00 a.m.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-DispCvrs.[401]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly:

- Display case equipment type:
    - Condensing unit configuration (remote condensing or self-contained)
    - Equipment family (vertical or horizontal)

[399] Temperature ranges per commercial refrigeration equipment type are detailed in the current federal standard 10 CFR 431.66. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

[400] The demand savings for this measure are 0 because energy savings exist at night only.

[401] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Operating temperature (low or medium as defined in Table 183)
- Horizontal linear feet length of refrigerated case

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications : https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update~~

Document Revision History

Table 184. Nonresidential Night Covers for Open Refrigerated Display Cases Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Removed all references to Peak Demand Savings as this measure is implemented outside of the peak demand period. Also, rounded off savings to a reasonable number of significant digits.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. Added more significant digits to the input variables a-j
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated reference city for climate zone 4. Added “linear feet” for tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.5.6 Solid and Glass Door Reach-Ins Measure Overview

TRM Measure ID: NR-RF-RI

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of ENERGY STAR® or CEE certified solid and glass door reach-in refrigerators and freezers, which are significantly more efficient than units that are not certified. The high-efficiency criteria, developed by ENERGY STAR®, relate the volume of the appliance in cubic feet to its daily energy consumption.

Eligibility Criteria

Solid- or glass-door reach-in vertical refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements (See Table 186).

The following products are excluded from the ENERGY STAR® eligibility criteria:

- Residential refrigerators and freezers
- Chef base or griddle stands, prep tables, service over counter equipment, horizontal open equipment, vertical open equipment, semi-vertical open equipment, remote condensing equipment, convertible temperature equipment, and ice cream freezers

Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 185.

Table 185. Baseline Energy Consumption[402,403]

Baseline standards	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Solid door	0.10V + 2.04	0.40V + 1.38
Glass door	0.12V + 3.34	075V + 4.10

High-Efficiency Condition

Eligible high-efficiency equipment for solid- or glass-door reach-in refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements, as shown in Table 186.

Table 186. Efficient Energy Consumption Requirements[404]

Door type	Product volume (cubic feet)	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Vertical solid door	0 < V < 15	0.022V + 0.97	0.21V + 0.9
	15 ≤ V < 30	0.066V + 0.31	0.12V + 2.248
	30 ≤ V < 50	0.04V + 1.09	0.285V - 2.703
	V ≥ 50	0.024V + 1.89	0.142V + 4.445
Vertical glass door	0 < V < 15	0.095V + 0.445	0.232V + 2.36
	15 ≤ V < 30	0.05V + 1.12	
	30 ≤ V < 50	0.076V + 0.34	
	V ≥ 50	0.105V - 1.111	

402 https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8.

403 V = Interior volume [ft^3] of a refrigerator or freezer (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).

404 ENERGY STAR® Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 2.0, U.S. Environmental Protection Agency. https://www.energystar.gov/sites/default/files/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy and demand savings of solid and glass door reach-in refrigerators and freezers are calculated using values in Table 185 and Table 186, based on the volume of the units.

The savings calculations are specified as:

$$Energy\ [kWh] = (kWh_{base} - kWh_{ee}) \times 365$$

Equation 159

$$Peak\ Demand\ [kW] = \frac{\Delta kWh}{8{,}760} \times CF$$

Equation 160

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 185.*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 186.*
V	=	*Chilled or frozen compartment volume [ft^3] (as defined in the Association of Home Appliance Manufacturers Standard HRF-1-1979)*
365	=	*Days per year*
8,760	=	*Hours per year*
CF	=	*Summer peak coincidence factor (1.0)*[405]

[405] The summer peak coincidence factor is assumed equal to 1.0, since the annual kWh savings is divided by the total annual hours (8760), effectively resulting in the average kW reduction during the peak period.

Deemed Energy and Demand Savings Tables

Table 187. Deemed Energy and Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume[406]	Energy savings (kWh)	Demand savings (kW)
Refrigerator	Vertical Solid Door	0 < V < 15	8.54	16	0.002
		15 ≤ V < 30	21.00	892	0.102
		30 ≤ V < 50	41.53	1,256	0.143
		V ≥ 50	67.19	1,919	0.219
	Vertical Glass Door	0 < V < 15	8.84	1,137	0.130
		15 ≤ V < 30	21.30	1,355	0.155
		30 ≤ V < 50	42.76	1,782	0.203
		V ≥ 50	68.93	2,002	0.229
Freezer	Vertical Solid Door	0 < V < 15	7.76	713	0.081
		15 ≤ V < 30	19.99	1,726	0.197
		30 ≤ V < 50	43.13	3,301	0.377
		V ≥ 50	66.86	5,177	0.591
	Vertical Glass Door	0 < V < 15	5.98	1,766	0.202
		15 ≤ V < 30	19.49	4,321	0.493
		30 ≤ V < 50	42.29	8,630	0.985
		V ≥ 50	65.89	13,093	1.495

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.[407]

[406] Simple average product volume for volume ranges of vertical solid and glass door refrigerators and freezers. ENERGY STAR® Certified Commercial Refrigerators and Freezers qualified product listing (August 2020). https://www.energystar.gov/productfinder/product/certified-commercial-refrigerators-and-freezers/results.

[407] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Baseline unit volume
- Baseline unit door type (solid or glass)
- Baseline unit temperature (refrigerator or freezer)
- Post-retrofit unit volume
- Post-retrofit unit door type (solid or glass)
- Post-retrofit unit temperature (refrigerator or freezer)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications
- PUCT Docket 36779 provides EUL estimates for commercial refrigerators and freezers.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~ENERGY STAR® Commercial Refrigerators and Freezers. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CRF.~~
- ~~Association of Home Appliance Manufacturers. HRF-1: Household Refrigerators, Combination Refrigerator-Freezers, and Household Freezers.~~

Document Revision History

Table 188. Nonresidential Solid and Glass Door Reach-Ins Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Updated methodology for ENERGY STAR® Version 4.0.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Citation added for average product volumes.

2.5.7 Strip Curtains for Walk-In Refrigerated Storage Measure Overview

TRM Measure ID: NR-RF-SC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V analysis

Measure Description

This measure refers to the installation of infiltration barriers (strip curtains or plastic swinging doors) on walk-in coolers or freezers. These units impede heat transfer from adjacent warm and humid spaces into walk-ins when there is an opening or a door is open, reducing the cooling load. This results in a reduced compressor run-time and energy consumption. The measure assumes varying durations for the amount of time the walk-in door is open based on facility type and that the strip curtains cover the entire doorframe.

Eligibility Criteria

Strip curtains or plastic swinging doors installed on walk-in coolers or freezers.

Baseline Condition

The baseline efficiency case is a refrigerated walk-in space with nothing to impede airflow from the refrigerated space to adjacent warm and humid space when the door is opened.

High-Efficiency Condition

Eligible high-efficiency equipment is a polyethylene strip curtain that is at least 0.06 inches thick, or equivalent. Low-temperature strip curtains must be used on low-temperature applications (e.g., freezers). The strip curtain must cover the entire area of opening and may not leave gaps between strips or along the doorframe.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The algorithms and assumptions detailed in this section are based on the Regional Technical Forum's methodology[408], which utilizes calculations that determine refrigeration load due to infiltration by air exchange from ASHRAE's Refrigeration Handbook.

Saturation pressure over liquid water, for both the temperature of the refrigerated space which will be treated with strip curtains and the adjacent space, is calculated as follows:

$$\ln(P_{ws,Adj}) = \frac{C_1}{°R_{Adj}} + C_2 + (C_3 * °R_{Adj}) + (C_4 * °R_{Adj}^2) + (C_5 * °R_{Adj}^3) + (C_6 * °R_{Adj}^4) + (C_7 * \ln(°R_{Adj}))$$

Equation 161

$$\ln(P_{ws,Refrig}) = \frac{C_1}{°R_{Refrig}} + C_2 + (C_3 * °R_{Refrig}) + (C_4 * °R_{Refrig}^2) + (C_5 * °R_{Refrig}^3) + (C_6 * °R_{Refrig}^4) + (C_7 * \ln(°R_{Refrig}))$$

Equation 162

Where:

$P_{ws,Adj}$	=	*Saturation pressure over liquid water for the adjacent space*
$P_{ws,Refrig}$	=	*Saturation pressure over liquid water for the refrigerated space*
C_1	=	*-1.0214165E+04*
C_2	=	*-4.8932428E+00*
C_3	=	*-5.3765794E-03*
C_4	=	*1.9202377E-07*
C_5	=	*3.5575832E-10*
C_6	=	*-9.0344688E-14*
C_7	=	*4.1635019E+00*
C_8	=	*-1.0440397E+04*
C_9	=	*-1.1294650E+01*
C_{10}	=	*-2.7022355E-02*
C_{11}	=	*1.2890360E-05*
C_{12}	=	*-2.4780681E-09*

[408] Regional Technical Forum Strip Curtains UES Measure Workbook (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

C_{13}	=	*6.5459673E+00*
$°R_{Adj}$	=	*Adjacent absolute temperature,* $t_{DB,Adj} + 459.67$ *(see Table 189)*
$°R_{Refrig}$	=	*Refrigeration box absolute temperature,* $t_{DB,Refrig} + 459.67$ *(see Table 189)*

Saturation pressure over liquid water is then utilized to calculate the humidity ratio of both the refrigerated and adjacent space:

$$W_{Adj} = 0.62198 * \frac{Rh_{Adj} * P_{ws,Adj}}{14.696 - (Rh_{Adj} * P_{ws,Adj})}$$

Equation 163

$$W_{Refrig} = 0.62198 * \frac{Rh_{Refrig} * P_{ws,Refrig}}{14.696 - (Rh_{Refrig} * P_{ws,Refrig})}$$

Equation 164

Where:

W_{Adj}	=	*Humidity ratio of the adjacent space*
W_{Refrig}	=	*Humidity ratio of the refrigerated space*
Rh_{Adj}	=	*Relative humidity of the adjacent space (see Table 189)*
Rh_{Refrig}	=	*Relative humidity of the refrigerated space (see Table 189)*

The humidity ratio is utilized to compute the air enthalpies for the adjacent and refrigerated space:

$$h_{Adj} = 0.24 * t_{DB,Adj} + \left(W_{Adj} * \left(1061 + (0.444 * t_{DB,Adj})\right)\right)$$

Equation 165

$$h_{Refrig} = 0.24 * t_{DB,Refrig} + \left(W_{Refrig} * \left(1061 + (0.444 * t_{DB,Refrig})\right)\right)$$

Equation 166

Where:

h_{Adj}	=	*Air enthalpy of the adjacent space*
h_{Refrig}	=	*Air enthalpy of the refrigerated space*
$t_{DB,Adj}$	=	*Dry-bulb temperature of the adjacent space (see Table 189)*
$t_{DB,Refrig}$	=	*Dry-bulb temperature of the refrigerated space (see Table 189)*

This pair of air enthalpies is then utilized alongside the density factor and the adjacent and refrigerated spaces' air temperature densities and specific volumes to compute the refrigeration load for the fully established flow:

$$v_{Adj} = 0.025210942 * {}^{\circ}R_{Adj} * \left(1 + \left(1.6078 * W_{Adj}\right)\right)$$

Equation 167

$$v_{Refrig} = 0.025210942 * {}^{\circ}R_{Refrig} * \left(1 + \left(1.6078 * W_{Refrig}\right)\right)$$

Equation 168

$$r_{Adj} = \frac{1}{v_{Adj}}$$

Equation 169

$$r_{Refrig} = \frac{1}{v_{Refrig}}$$

Equation 170

$$F_m = \frac{2}{1 + \frac{r_{Refrig}}{r_{Adj}}^{\frac{1}{3}}}^{\frac{3}{2}}$$

Equation 171

$$q = 795.6 * Height * Width * \left(h_{Adj} - h_{Refrig}\right) * r_{Refrig} * \left(1 - \frac{r_{Adj}}{r_{Refrig}}\right)^{\frac{1}{2}} * (32.174 * Height)^{\frac{1}{2}} * F_m$$

Equation 172

Where:

v_{Adj}	=	*Specific volume of the adjacent space*
v_{Refrig}	=	*Specific volume of the refrigerated space*
r_{Adj}	=	*Air temperature density of the adjacent space*
r_{Refrig}	=	*Air temperature density of the refrigerated space*
F_m	=	*Density factor*
q	=	*Refrigeration load for fully established flow*
$Height$	=	*Doorway height (see Table 189)*
$Width$	=	*Doorway width (see Table 189)*

The infiltration between the adjacent and refrigerated space before and after the installation of the strip curtains is a product of the refrigeration load between the two spaces, the time the doorway is assumed to be open per day, the assumed doorway flow factor, and the assumed effectiveness against infiltration post-retrofit:

$$Q_{baseline} = q * \frac{m}{60 * 24} * D_F * (1 - E_{baseline})$$

Equation 173

$$Q_{retrofit} = q * \frac{m}{60 * 24} * D_F * (1 - E_{retrofit})$$

Equation 174

Where:

$Q_{baseline}$	=	*Baseline total infiltration load*
$Q_{retrofit}$	=	*Total infiltration load, post-retrofit*
m	=	*Time the door is open per day (see Table 189)*
D_F	=	*Doorway flow factor (see Table 189)*
$E_{baseline}$	=	*Baseline assumed effectiveness against infiltration, 0*
$E_{retrofit}$	=	*Assumed effectiveness against infiltration post-retrofit (see Table 189)*

The demand and energy consumption of the compressor associated with each infiltration case are calculated as follows:

$$kW_{baseline} = \frac{Q_{baseline}}{EER * 1000}$$

Equation 175

$$kW_{retrofit} = \frac{Q_{retrofit}}{EER * 1000}$$

Equation 176

$$kWh_{baseline} = kW_{baseline} * EFLH$$

Equation 177

$$kWh_{retrofit} = kW_{retrofit} * EFLH$$

Equation 178

Where:

$kW_{baseline}$	=	*Baseline demand consumption of the compressor*
$kW_{retrofit}$	=	*Demand consumption of the compressor, post-retrofit*
$kWh_{baseline}$	=	*Baseline energy consumption of the compressor*
$kWh_{retrofit}$	=	*Energy consumption of the compressor, post-retrofit*
EER	=	*EER per facility type (see Table 189), which are averaged or weighted across suction-group types (see Table 190)*
FLH	=	*Assumed full-load hours per facility type (see Table 189)*

The difference between the baseline and retrofit demand/energy calculations yields whole-door energy savings, which are divided by the area of the doorway to yield per-square foot savings:

$$\Delta kW = kW_{baseline} - kW_{retrofit}$$

Equation 179

$$\Delta kWh = kWh_{baseline} - kWh_{retrofit}$$

Equation 180

$$kW_{Savings} = \frac{\Delta kW}{Height * Width}$$

Equation 181

$$kWh_{Savings} = \frac{\Delta kWh}{Height * Width}$$

Equation 182

Where:

ΔkW = *Whole-door demand savings*

ΔkWh = *Whole-door energy savings*

$kW_{Savings}$ = *Per-square foot demand savings*

$kWh_{Savings}$ = *Per-square-foot energy savings*

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 189. EER variables are calculated as either the simple or weighted average of representative EERs for refrigeration suction groups that correspond to medium temperature (cooler) or low temperature (freezer) multiplex or standalone units; these are detailed in Table 190:

Table 189. Assumed Independent Variables[409]

Variable	Notation	Restaurant		Convenience store		Grocery		Refrigerated warehouse	
		Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door
Adjacent temperature	t_{DB}	70	67	68	64	71	67	59	N/A
Refrigeration box temperature		39	8	39	5	37	5	28	N/A
Relative humidity of adjacent surroundings	Rh	0.55	0.55	0.55	0.55	0.55	0.55	0.3	N/A
Relative humidity of refrigeration box		0.65	0.4	0.4	0.6	0.5	0.45	0.86	N/A
Height	$Height$	7	7	7	7	7	7	12	N/A
Width	$Weight$	3	3	3	3	3	3	10	N/A
Doorway flow factor	D_F	0.51	0.51	0.51	0.51	0.625	0.625	0.8	N/A
Effectiveness against infiltration – post-retrofit	$E_{retrofit}$	0.8	0.81	0.79	0.83	0.88	0.88	0.89	N/A
Time door is open per day	m	45	38	38	9	132	102	494	N/A
Full-load-hours (FLH) of operation	FLH	5,509	5,509	6,887	6,887	6,482	6,482	2,525	N/A
EER[410]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	N/A

[409] Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

[410] EER is not an independent variable but is rather dependent on Table 190. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 190. Default EER by System Configuration[411]

System configurations	Representative suction group	Annual average EER value (Btu/hr-W)	Average EER of system configuration (Btu/hr-W)	Straight average EER of temperature (Btu/hr-W)	Grocery store weighted average EER for temperature (Btu/hr-W)
Medium-temperature multiplex	Suction group 2075	12.0	11.0	9.8	11.0
	Suction group 2014	12.0			
	Suction group 2185	12.0			
	Suction group 2668	9.2			
Medium-temperature standalone	Suction group 2754	7.8	8.4		
	Suction group 894	8.7			
	Suction group 512	8.8			
	Suction group 2043	8.3			
Low-temperature multiplex	Suction group 1509	3.7	4.2	4.0	4.1
	Suction group 898	4.1			
	Suction group 2152	4.7			
	Suction group 1753	4.4			
Low-temperature standalone	Suction group 996	3.3	3.7		
	Suction group 2518	3.4			
	Suction group 1950	4.6			
	Suction group 2548	3.7			

Table 191. Energy Consumption and Demand for Coolers and Freezers for Deemed Openings

Variable	Notation	Restaurant		Convenience store		Grocery		Refrigerated warehouse	
		Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door
Compressor power (kW)	$kW_{baseline}$	0.11	0.54	0.09	0.12	0.44	1.82	8.19	N/A
	$kW_{retrofit}$	0.02	0.10	0.02	0.02	0.05	0.22	0.90	N/A
Deemed annual energy usage	$kWh_{baseline}$	590.72	2,956	626.86	838.78	2,861	11,796	20,678	N/A
	$kWh_{retrofit}$	118.14	561.60	131.64	142.59	343.30	1,416	2,275	N/A

411 Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are shown below in Table 192.

A standard doorway opening of 7' x 3' = 21 square feet may be assumed in lieu of collecting individual door dimensions.

Table 192. Deemed Energy and Demand Savings for Freezers and Coolers

Savings	Restaurant		Convenience store		Grocery		Refrigerated warehouse	
	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door
$kW_{savings}$ $per\ sq. ft.$	0.004	0.021	0.003	0.005	0.018	0.076	0.061	N/A
$kWh_{savings}$ $per\ sq. ft.$	22.50	114.01	23.58	33.15	119.88	494.32	153.36	N/A

Claimed Peak Demand Savings

Because the utilization of the strip curtains coincident with the peak demand period is uncertain, an average of the total savings over the operating hours per facility type is used.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-StripCrtn.[412]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Unit temperature (refrigerator or freezer)
- Facility type (restaurant, convenience store, grocery store, or refrigerated warehouse)
- Number of openings treated
- Area of each opening

[412] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications
- PUCT Docket 36779 provides EUL estimates for commercial refrigerators and freezers

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update~~

Document Revision History

Table 193. Nonresidential Strip Curtains for Walk-In Refrigerated Storage Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Added documentation for calculation methodology. Updated tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.5.8 Zero-Energy Doors for Refrigerated Cases Measure Overview

TRM Measure ID: NR-RF-ZE

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants and convenience stores

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of zero-energy doors for refrigerated cases. These new zero-energy door designs 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.

Eligibility Criteria

The efficient equipment must be a standard refrigerated case door with design to eliminate the anti-sweat heaters. This measure cannot be used in conjunction with anti-sweat heat (ASH) controls.

Baseline Condition

The baseline efficiency case is a standard vertical reach-in refrigerated case with anti-sweat heaters on the glass surface of the doors[413].

High-Efficiency Condition

Eligible high-efficiency equipment is the installation of special doors that eliminate the need for anti-sweat heaters, for low-temperature cases only (below 0 ºF). Doors must have either heat-reflective treated glass, be gas-filled, or both.

[413] An open refrigerated case is not a baseline for these existing deemed savings. Contact the evaluation team for preliminary approval of the savings methodology for the application of a zero-energy door to an open refrigerated case.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of zero energy doors are a result of eliminating the heater (kWh_{ASH}) and the reduction in load on the refrigeration (kWh_{refrig}). These savings are calculated using the following procedures.

The baseline assumes door heaters are running on an 8,760-hour operating schedule. In the post-retrofit case, it is assumed that the door heaters will be all off (duty cycle of 0 percent).

The instantaneous door heater power (kW_{ASH}) as a resistive load remains constant is per linear horizontal foot of door heater at an assumed 2.5 linear horizontal feet of door:

For medium temperature:

kW_{ASH} = *0.109 per door*[414]

For low temperature:

kW_{ASH} = *0.191 per door*[415]

Door heater energy consumption for each hour of the year is a product of power and run-time:

$$kWh_{ASH-Hourly} = kW_{ASH} \times Door\ Heater\ ON\% \ \times 1 Hour$$

Equation 183

$$kWh_{ASH} = \sum kWh_{ASH-Hourly}$$

Equation 184

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system,[416] the cooling load contribution from door heaters can be given by:

$$Q_{ASH}(ton-hrs) = 0.35 \times kW_{ASH} \times \frac{3{,}412 \frac{Btu}{hr}}{12{,}000 \frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 185

[414] Here, “medium temperature” is equivalent to the categorization “coolers”.
Pennsylvania TRM, “3.5.6 Controls: Anti-Sweat Heater Controls”. page 383, June 2016.
https://www.puc.pa.gov/Electric/pdf/Act129/Act129_TRM-2016_Redlined-Final.pdf.

[415] Ibid. Here, “low temperature” is equivalent to the categorization “freezers”.

[416] *A Study of Energy Efficient Solutions for Anti-Sweat Heaters*. Southern California Edison RTTC. December 1999.

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from 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.

For medium temperature refrigerated cases, the saturated condensing temperature (SCT) is calculated as the design dry-bulb temperature plus 15 degrees. For low temperature refrigerated cases, the SCT is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant or 1/1.15 or approximately 0.87.[417]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 194.

$$EER_{MT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 186[418]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*
c	=	*29.4589834935596*
d	=	*0.000342066982768282*
e	=	*-11.7705583766926*
f	=	*-0.212941092717051*
g	=	*-1.46606221890819 x 10^{-6}*
h	=	*6.80170133906075*
I	=	*-0.020187240339536*
j	=	*0.000657941213335828*
PLR	=	*0.87*
SCT	=	*T_{DB} + 15*

[417] *Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls.* Pacific Gas and Electric Company. May 29, 2009. Assumes 15% oversizing.

[418] San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012. https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

For low temperature compressors, the following equation is used to determine the EER_{LT} [Btu/hr/watts]:

$$EER_{LT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 187[419]

Where:

a = *9.86650982829017*

b = *-0.230356886617629*

c = *22.905553824974*

d = *0.00218892905109218*

e = *-2.4886737934442*

f = *-0.248051519588758*

g = $-7.57495453950879 \times 10^{-6}$

h = *2.03606248623924*

i = *-0.0214774331896676*

j = *0.000938305518020252*

PLR = *0.87*

SCT = $T_{DB} + 10$

Table 194. Coefficients by Climate Zone

Climate zone	T_{DB}[420]	SCT_{MT}	SCT_{LT}	EER_{MT}	EER_{LT}
Zone 1: Amarillo	98.6	113.6	108.6	6.18	4.74
Zone 2: Dallas	101.4	116.4	111.4	5.91	4.56
Zone 3: Houston	97.5	112.5	107.5	6.29	4.86
Zone 4: Corpus Christi	96.8	111.8	106.8	6.36	4.91
Zone 5: El Paso	101.1	116.1	111.1	5.94	4.58

Where:

T_{DB} = *Dry-bulb temperature*

419 Ibid.

420 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

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:

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER}$$

Equation 188

$$kWh_{refrig} = \sum kWh_{refrig-Hourly}$$

Equation 189

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of all hourly reading values:

$$kWh_{total} = kWh_{refrig} + kWh_{ASH}$$

Equation 190

Total energy savings is a result of the baseline and post-Retrofit case:

$$Annual\ Energy\ Savings\ [kWh] = kWh_{total-baseline} - kWh_{total-post}$$

Equation 191

While there might be instantaneous demand savings because of the cycling of the door heaters, peak demand savings will only be due to the reduced refrigeration load. Peak demand savings is calculated by the following equation:

$$Peak\ Demand\ Savings = \frac{kWh_{refrig-baseline} - kWh_{refrig-post}}{8{,}760}$$

Equation 192

Table 195. Deemed Energy and Demand Savings Values by Climate Zone and Refrigeration Temperature

Climate zone	Medium temperature		Low temperature	
	Annual energy savings (kWh/door)	Peak demand savings (kW/door)	Annual energy savings (kWh/door)	Peak demand savings (kW/door)
Zone 1: Amarillo	1,139	0.130	2,092	0.239
Zone 2: Dallas	1,148	0.131	2,111	0.241
Zone 3: Houston	1,136	0.130	2,084	0.238
Zone 4: Corpus Christi	1,134	0.129	2,080	0.237
Zone 5: El Paso	1,147	0.131	2,109	0.241

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ZeroHtDrs.[421]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Refrigeration temperature range

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications
- PUCT Docket 36779 provides EUL values for Zero Energy Doors

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update~~

Document Revision History

Table 196. Nonresidential Zero-Energy Doors for Refrigerated Cases Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. Updated savings methodology to be consistent with the door heater controls measure.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Clarified energy and demand savings are in kilowatt/door rather than kilowatt/feet. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added clarification for baseline condition.

[421] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

2.5.9 Door Gaskets for Walk-In and Reach-In Coolers and Freezers Measure Overview

TRM Measure ID: NR-RF-DG

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, convenience stores, restaurants, and refrigerated warehouses

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V, engineering algorithms, and estimates

Measure Description

This measure applies to the installation of door gaskets on walk-in and reach-in coolers and freezers to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated space. Additionally, the reduction in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time, reducing energy consumption and improving the overall effectiveness of heat removal from a refrigerated cabinet.

Eligibility Criteria

Door gaskets must be installed on walk-in and reach-in coolers or freezers. The most common applications for this measure are refrigerated coolers or freezers in supermarkets, convenience stores, restaurants, and refrigerated warehouses.

Baseline Condition

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets with at least six inches of damage for reach-in units and at least two feet of damage for walk-in units.[422] An average baseline gasket efficacy[423] of 90 percent is assumed for this measure.

[422] Musgrave, Dwight. Emerson Design Services Network. "Study of Typical Gasket Deterioration", Feb 27, 2008, Slide 24. https://slideplayer.com/slide/4525301/.

[423] Gasket efficacy is defined as the ratio of the gasket length that was removed by the installers to the gasket length that was replaced. A 90 percent gasket efficacy translates to an average of 10 percent of missing, badly damaged or ineffective gasket by length replaced.

High-Efficiency Condition

The efficient condition for this measure is a new, better-fitting gasket. Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, reducing the cooling load. A decrease in moisture entering the refrigerated space also prevents frost on cooling coils.

Energy and Demand Savings Methodology

The energy savings assumptions are based on DEER 2005 analysis performed by Southern California Edison (SCE) and an evaluation of a Pacific Gas and Electric (PG&E) direct install refrigeration measures for program year 2006-2008.[424,425] The results from the PG&E evaluation were used as the foundation for establishing the energy savings for the refrigeration gasket measures. The energy savings achievable for new gaskets replacing baseline gaskets were found during this study to be dependent almost entirely on the leakage through the baseline gaskets. Therefore, the energy savings attributable to door gaskets were derived for various scenarios regarding baseline gasket efficacies and are shown in Table 197 below.

Table 197. Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)[426]

Refrigerator type	Baseline 0% efficacy (kWh/ft)	Baseline 50% efficacy (kWh/ft)	Baseline 90% efficacy (kWh/ft)	Baseline 100% efficacy (kWh/ft)
Cooler	30	15	3	0
Freezer	228	114	23	0

As the PG&E analysis was performed in California with different climate zones as compared to those in Texas, an analysis was conducted to develop an adjustment factor to associate the savings in the table above to Texas anticipated results. The PG&E study could not be used to determine these effects, as insufficient climate zones were researched. Therefore, the SCE study was utilized as savings in this study were determined for each of the 16 climate zones in California and were similar[427] to those assessed within the PG&E results at 90 percent efficacy. A comparison was completed between the SCE energy savings and the typical meteorological year 3 (TMY3) data[428] to establish a cooling degree day (CDD) correlation across the 16 California climate zones. Figure 3 provides a summary comparison for coolers and Figure 4 for freezers.

[424] Southern California Edison (SCE). WPSCNRRN0013—Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases and Solid Doors of Reach-in Coolers and Freezers. 2007.

[425] Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.

[426] Ibid., Table 5-3.

[427] The SCE ex-ante savings as reported in the PG&E report were 10.2 and 21.7 kWh/linear foot for coolers and freezers respectively.
Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. Table 5-3.
http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.
Modeled savings as reported in the SEC report for climate zone 4 were approximately 6 and 15 kWh/linear foot for coolers and freezers respectively.

[428] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings

The resulting correlations are strong, with an R^2 of 0.85 for coolers and an R^2 of 0.88 for freezers, respectively.

Figure 3. Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Coolers)

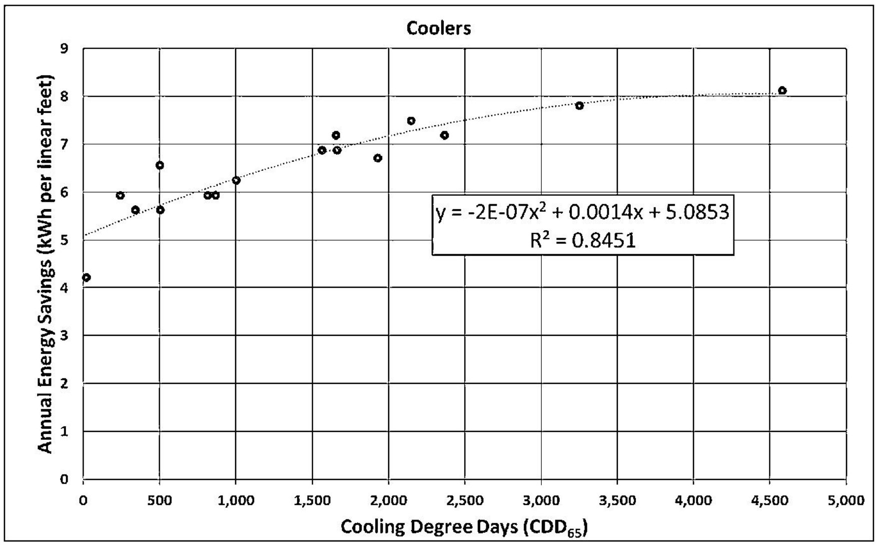
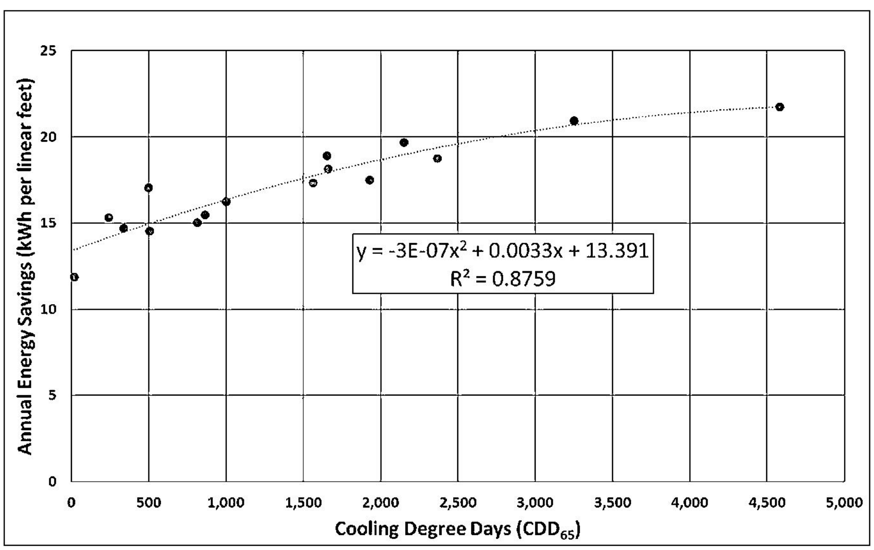


Figure 4. Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Freezers)



These correlations were used to adjust the energy savings and TMY3 CDDs in California to TMY3 CDDs in Texas to determine an average energy savings of 7.4 and 20.0 kWh/linear feet for coolers and freezers in Texas. Comparing the average energy savings between California and Texas, the CDD adjustment results in a 113 percent adjustment factor for coolers and a 117 percent adjustment factor for freezers. For simplicity, an average adjustment factor of 115 percent (the midpoint of 113% and 117% TX vs. CA Energy Savings values) was applied to the PG&E results at 90 percent efficacy (as shown in Table 197 above), resulting in Texas-based annual energy savings values for coolers of 3.5 kWh/linear feet and freezers of 26.5 kWh/linear feet. These results are summarized in Table 198 below.

Table 198. Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)

Refrigerator type	CA CZ1-CZ16 average savings (kWh/ft)	CA average savings normalized to TX by CDD (kWh/ft)	TX vs. CA energy savings	Average CDD adjustment factor	PG&E baseline 90% efficacy (kWh/ft)	TX baseline 90% efficacy (kWh/ft)
Cooler	6.5	7.4	113%	115%	3	3.5
Freezer	17.1	20.0	117%		23	26.5

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8,760 hours).

Savings Algorithms and Input Variables

The energy and demand algorithms and associated input variables are listed below:

$$Energy\ Savings\ [kWh] = \frac{\Delta kWh}{ft} \times L$$

Equation 193

$$Demand\ Savings\ [kW] = \frac{kWh_{Savings}}{8760} \times L$$

Equation 194

Where:

ΔkWh/ft = *Annual energy savings per linear foot of gasket (see Table 199)*

L = *Total gasket length (ft.)*

Deemed Energy and Demand Savings Tables

Table 199. Deemed Energy and Demand Savings per Linear Foot of Installed Door Gasket

Refrigerator type	ΔkW/ft	ΔkWh/ft
Walk-in or reach-in cooler	0.0004	3.5
Walk-in or reach-in freezer	0.0030	26.5

Claimed Peak Demand Savings

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8,760 hours).

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 3 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDrGask.[429]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Building type (convenience store, supermarket, restaurant, refrigerated warehouse)
- Refrigerator type (walk-in or reach-in cooler or freezer)
- Length of ineffective gasket (ft.)
- Primary reason for ineffectiveness (missing, torn through both sides, rotted/dry, poor fit/shrink, or other)
- Total length of installed gasket (ft.)
- Presence of existing gasket (yes/no)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 48265. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. *Petition to Approve Deemed Savings for New Nonresidential Door Air Infiltration, Nonresidential Door Gaskets, And Residential ENERGY STAR® Connected Thermostats.* Public Utility Commission of Texas.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~TMY3 Hourly Weather Data by Climate Zone~~[430]

[429] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
~~[430] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings~~

Document Revision History

Table 200. Nonresidential Door Gaskets for Walk-In and Reach-In Coolers and Freezers Revision History

TRM version	Date	Description of change
v6.0	10/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.5.10 High-Speed Doors for Cold Storage Measure Overview

TRM Measure ID: NR-RF-HS

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithms

Savings Methodology: Algorithms

Measure Description

This measure presents deemed savings for installation of high-speed doors for cold storage facilities. High speed automatic doors differ from regular automatic doors by increasing their closing speed. High speed doors can save energy over regular automatic and manual doors by shortening the duration that the door to the cold storage area is open.

Eligibility Criteria

Eligible equipment includes high-speed doors with a minimum opening rate of 32 inches per second, a minimum closing rate of 24 inches per second, and a means to automatically reclose the door, as defined by the Door and Access Systems Manufacturers' Association, International (DASMA).[431] The high-speed doors must be installed for access to a cold storage area either from exterior conditions, such as a loading dock, or from a conditioned area, such as a non-refrigerated warehouse.

Baseline Condition

The baseline condition is a manual or non-high-speed automatic door installed for access to a cold storage area.

High-Efficiency Condition

The efficient condition is a high-speed door installed for access to a cold storage area.

[431] DASMA Standard Specification for High Speed Doors and Grilles, definition 2.6 for High Speed Door. https://www.dasma.com/wp-content/uploads/pubs/Standards/DASMA403.pdf.

Energy and Demand Savings Methodology

Savings are calculated based on a reduction in heat gain from airflow across the door opening area. The algorithms below are modeled after equations 14 and 16 in Chapter 24: Refrigerated-Facility Loads of the 2018 ASHRAE Handbook—Refrigeration to calculate heat load associated with infiltration air exchange. This measure does not account for associated motor load or efficiencies; if the new high-speed door includes an efficient motor, reference the motor measure for savings.

Savings Algorithms and Input Variables

$$\text{kWh savings} = \frac{w \times h^{1.5} \times energy\ factor}{COP\ \times 3{,}412}$$

Equation 195

$$\text{energy factor} = hours\ \times 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E$$

Equation 196

$$\text{kW savings} = \frac{w \times h^{1.5} \times demand\ factor}{COP\ \times 3{,}412}$$

Equation 197

$$\text{demand factor} = 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E$$

Equation 198

Where:

w	=	*Width of the door opening (ft.)*
h	=	*Height of the door opening (ft.)*
$energy\ factor$	=	*The outcome of Equation 196 based on climate zone and cold storage application, see Table 201 and Table 202*
$demand\ factor$	=	*The outcome of Equation 198 based on climate zone and cold storage application, see Table 203, Table 204, and Table 205*
$hours$	=	*Operating hours, 3,798*[432]
$3{,}790$	=	*Constant*[433]

[432] Operating hours taken from TRM Volume 3, Table 8, hours for refrigerated warehouse.

[433] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

$\frac{q_s}{A}$	=	*Sensible heat load of infiltration air per square foot of door opening, ton/ft², see Table 206*
R_s	=	*Sensible heat ratio of the infiltration air heat gain, see Table 207*
ΔD_t	=	*Change in percent of time the doorway is open, 0.33*[434]
D_f	=	*Doorway flow factor, varies based on temperature delta between cold room and infiltration air, 0.8 for delta T ≥ 20°F, 1.1 for delta T < 20°F*[435]
ΔE	=	*Change in door effectiveness, 0.2*[436]
COP	=	*Coefficient of performance, assume 2.8 COP*[437]
$3{,}412$	=	*Conversion factors*

Table 201. High-Speed Doors—Energy Factors for Door to Unconditioned Area

Cold room temperature	-20°F	0°F	20°F	40°F
Zone 1: Amarillo	849,911	76,602	324,007	122,795
Zone 2: Dallas	1,025,489	719,712	432,092	209,695
Zone 3: Houston	1,179,743	837,151	562,418	420,336
Zone 4: Corpus Christi	1,240,984	887,904	603,598	464,913
Zone 5: El Paso	902,050	614,930	343,300	142,285

[434] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes; assume baseline door open-close time is 15 seconds, and high-speed door open-close time is 10 seconds, for a difference in percent of time the door is open of (15-10)/15 = 0.33.

[435] ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 17 notes.

[436] ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes. ASHRAE provides a range of doorway effectiveness, stating 0.95 for newly installed doors though that may quickly decrease to 0.8 or 0.85 depending on door use frequency and maintenance. Air curtain effectiveness ranges from very poor to more than 0.7. The input assumptions for this measure are conservatively estimated for baseline door effectiveness of 0.7 and high-speed door effectiveness of 0.9.

[437] Air cooled chiller efficiency from IECC 2009.

Table 202. High-Speed Doors—Energy Factors for Door to Conditioned Area

Cold room temperature	-20°F	0°F	20°F	40°F
All climate zones	783,056	518,199	322,435	230,311

Table 203. High-Speed Doors—Summer and Winter Demand Factors for Door to Conditioned Area

Cold room temperature	All temperatures
All climate zones	1.0

Table 204. High-Speed Doors—Summer Demand Factors for Door to Unconditioned Area

Cold room temperature	-20°F	0°F	20°F	40°F
Zone 1: Amarillo	278.94	208.20	141.49	90.96
Zone 2: Dallas	293.09	218.30	153.62	101.07
Zone 3: Houston	293.09	218.30	153.62	101.07
Zone 4: Corpus Christi	264.79	192.03	131.39	76.81
Zone 5: El Paso	278.94	208.20	141.49	90.96

Table 205. High-Speed Doors—Winter Demand Factors for Door to Unconditioned Area

Cold room temperature	-20°F	0°F	20°F	40°F
Zone 1: Amarillo	40.43	-	-	-
Zone 2: Dallas	40.43	-	-	-
Zone 3: Houston	80.85	36.38	22.23	-
Zone 4: Corpus Christi	80.85	36.38	22.23	-
Zone 5: El Paso	80.85	36.38	-	-

Table 206. High-Speed Doors—$\frac{q_s}{A}$, Sensible Heat Load of Infiltration Air[438]

Cold room temperature	Applicable climate zones							
	Z1-2, winter peak	Z3-5, winter peak	Z1, annual	Z2, Z5, annual	Z3-4, annual	Z4, summer peak	Z1, Z5, summer peak	Z2-3, summer peak
	Infiltration air temperature							
	15°F	30°F	63°F	70°F	75°F	96°F	99°F	103°F
-20°F	0.2	0.40	0.85	0.94	1.02	1.31	1.38	1.45

[438] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, figure 9. Values in table are summarized to reflect average annual and summer and winter peak infiltration air Temperatures. Where infiltration air Temperatures are not shown on ASHRAE figure 9, $\frac{q_s}{A}$ is estimated by extrapolation. Values for infiltration air temperature of 75°F are used to calculate energy and demand factors for doorways between cold room and conditioned space.

0°F	-	0.18	0.55	0.62	0.68	0.95	1.03	1.08
20°F	-	0.08	0.30	0.35	0.42	0.65	0.70	0.76
40°F	-	-	0.13	0.17	0.30	0.38	0.45	0.50

Table 207. High-Speed Doors—R_s, Sensible Heat Ratio of Infiltration Air[439]

Applicable climate zones	For energy factor, unconditioned space				For energy factor, conditioned space	For demand factor, conditioned and unconditioned space	
	Cold room temperature						
	-20°F	0°F	20°F	40°F	All temps	Summer, all temps	Winter, all temps
Zone 1: Amarillo	0.77	0.73	0.71	0.81	1.0	1.0	1.0
Zone 2: Dallas	0.70	0.66	0.62	0.62			
Zone 3: Houston	0.66	0.62	0.57	0.55			
Zone 4: Corpus Christi	0.63	0.58	0.53	0.50			
Zone 5: El Paso	0.80	0.77	0.78	0.92			

Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure. Please refer to the savings algorithms above.

Claimed Peak Demand Savings

The utilization of the high-speed doors coincident with the peak demand period is uncertain, an average of the total savings over the operating hours per facility type is used (the absence of $hours$ in Equation 198 implies Equation 195 can be divided by $hours$ to yield $kW\ savings$.

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

[439] Sensible heat ratio determined from psychrometric chart, using values for the air properties of dry bulb Temperature and relative humidity. Relative humidity of the cold room is estimated at 90 percent based on ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, Table 9. Energy factor values for unconditioned space are the average annual values between the expected operating hours of 8 a.m. to 6 p.m. using TMY3 data. Demand factor values for unconditioned space are taken using the highest probability temperatures from TRM Volume 1 and their associated relative humidity from TMY3 data. Energy and demand factor values for conditioned space assume conditioned air temperature of 75°F and 45 percent RH.

The estimated useful life (EUL) for this measure is 5 years based on published manufacturer warranty duration.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Cold room temperature
- Doorway opening location (conditioned or unconditioned)
- Door quantity
- Width and height of door(s)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

~~Not applicable.~~

Document Revision History

Table 208. Nonresidential High-Speed Doors for Cold Storage Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/20221	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.6 NONRESIDENTIAL: WATER HEATING

2.6.1 Central Domestic Hot Water Controls Measure Overview

TRM Measure ID: NR-WH-DC

Market Sector: Commercial

Measure Category: Water Heating

Applicable Building Types: Multifamily, lodging, nursing homes, dormitories, prisons, offices, and education

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Central domestic hot water (DHW) systems with recirculation pumps distribute hot water continuously throughout the building to the end-users. DHW pump controls save energy by reducing the operating hours of the circulation pumps and reducing thermal losses throughout the distribution system.

Eligibility Criteria

This measure applies to commercial and lodging applications with a central DHW system that includes a pump to circulate hot water through the distribution loop. To be eligible for these deemed savings, the control strategy must include operating the pump only when the hot water circulation loop temperature drops below a specific value, and there is hot water demand called by an end-user.

Baseline Condition

The baseline condition is a new or existing central DHW system with a circulation pump that operates continuously.

High-Efficiency Condition

The measure requires the installation of a pump controller with a combination temperature and demand control method.

Energy and Demand Savings Methodology

Savings for central DHW controls come from circulation pump controller runtime reduction and thermal distribution loss reduction. Pump runtime savings apply to all projects, while thermal distribution loss reduction applies only to lodging sites with an electrically fueled water heater.

Savings Algorithms and Input Variables

Circulation Pump Savings Algorithm

$$Annual\ Pump\ Energy\ Savings\ [kWh] = kW_{pump} \times \left(Pump_{\%On\_base} - Pump_{\%On\_eff}\right) \times Hours$$

Equation 199

$$Pump\ Demand\ Savings\ [kW] = Annual\ Pump\ Energy\ Savings\ \times PLS$$

Equation 200

Where:

kW_{pump}	=	*The demand used by the circulation pump, obtained from the project site; if unknown, assume 0.075 kW*
$Pump_{\%On\_base}$	=	*Baseline pump operation as percentage of time, 100%*
$Pump_{\%On\_eff}$	=	*Efficient pump operation as percentage of time, 7%*[440]
Hours	=	*Hours per year = 8,760*
PLS	=	*Probability-weighted peak load share, Table 209*

Table 209. Central DHW Controls—Probability Weighted Peak Load Share[441]

Building type	Commercial		Lodging[442]	
Climate zone	Summer peak	Winter peak	Summer peak	Winter peak
Zone 1	0.00016	0.00011	0.00012	0.00015
Zone 2	0.00017	0.00011	0.00012	0.00014
Zone 3	0.00016	0.00011	0.00012	0.00015

[440] A 93 percent pump runtime reduction is assumed based on the average runtime reduction of field studies conducted at multiple sites: "Evaluation of New DHW System Controls in Hospitality and Commercial Buildings," Minnesota Department of Commerce, average reduction of 87 percent; and "Energy-Efficiency Controls for Multifamily Domestic Hot Water Systems," New York State Energy Research and Development Authority, average reduction of 99 percent.

[441] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. http://loadshape.epri.com/enduse.

[442] For the purposes of this measure, the lodging building type applies to all buildings where lodging takes place, including multifamily, hotels, nursing homes, dormitories, prisons, and similar.

Building type	Commercial		Lodging[442]	
Climate zone	Summer peak	Winter peak	Summer peak	Winter peak
Zone 4	0.00016	0.00011	0.00012	0.00015
Zone 5	0.00018	0.00011	0.00012	0.00014

Thermal Distribution Savings Algorithm

$$Annual\ Thermal\ Energy\ Savings\ [kWh] = \#\ Units\ \times kWh_{reference}\ \times HDD\ Adjustment$$

Equation 201

$$Thermal\ Demand\ Savings\ [kW] = Annual\ Thermal\ Energy\ Savings\ \times PLS$$

Equation 202

Where:

 # Units = *The number of dwelling units at the project site*

$kWh_{reference}$ = *Annual kWh energy savings from reference study, see Table 210.*

HDD Adjustment = *Climate adjustment for Texas heating degree days, see Table 211.*

PLS = *Probability-weighted peak load share, see Table 209*

Table 210. Central DHW Controls—Reference kWh by Water Heater and Building Type[443]

Water heater type	Electric resistance		Heat pump	
Building type	Low rise	High rise	Low rise	High rise
kWh reference	539	332	211	130

Table 211. Central DHW Controls—HDD Adjustment Factors[444]

Climate zone	HDD adjustment
Zone 1	1.9
Zone 2	1.1
Zone 3	0.7
Zone 4	0.5
Zone 5	1.1

443 Reference kWh are the annual energy savings per dwelling unit from the Southern California Edison Company Work Paper SCE13WP002, Demand Control for Centralized Water Heater Recirculation Pump for California Climate Zone 13.

444 HDD Adjustment factors for DHW controls are derived by dividing the HDD for each Texas climate zone by the HDD from the reference climate zone (California Climate Zone 13).

Deemed Energy Savings Tables

Table 212 presents the energy savings (kWh) for a range of pump sizes for all climate zones. The deemed savings are provided for convenience, but the algorithm may be used for pump sizes that differ from the assumed wattage listed in the tables.

Table 212. Central DHW Controls—Annual kWh Circulation Pump Savings

Pump size (watts)	Assumed wattage	Annual pump kWh savings
≤ 50	50	407
50 < watts < 100	75	611
100 ≤ watts < 150	125	1,018
≥ 150	150	1,222

Table 213 presents the thermal energy savings (kWh) per dwelling unit for all climate zones. Thermal energy savings only apply to lodging building types where lodging takes place (multifamily, hotels, nursing homes, dormitories, prisons, and similar). For commercial applications, please follow a custom approach.

Table 213. Central DHW Controls—Annual kWh Thermal Distribution Savings per Dwelling Unit

Climate zone	Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise
Zone 1	1,007	620	395	243
Zone 2	566	349	222	137
Zone 3	372	229	146	90
Zone 4	249	153	98	60
Zone 5	590	364	231	143

Deemed Summer and Winter Demand Savings Tables

The following tables present the peak demand impacts for all climate zones.

Table 214. Central DHW Controls—Peak Demand kW Circulation Pump Savings

Pump size	Climate zone	Commercial		Lodging	
		Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
≤ 50	Zone 1	0.065	0.045	0.049	0.061
	Zone 2	0.069	0.045	0.049	0.057
	Zone 3	0.065	0.045	0.049	0.061
	Zone 4	0.065	0.045	0.049	0.061
	Zone 5	0.073	0.045	0.049	0.057

Pump size	Climate zone	Commercial		Lodging	
		Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
50 < watts < 100	Zone 1	0.098	0.067	0.073	0.092
	Zone 2	0.104	0.067	0.073	0.086
	Zone 3	0.098	0.067	0.073	0.092
	Zone 4	0.098	0.067	0.073	0.092
	Zone 5	0.110	0.067	0.073	0.086
100 ≤ watts < 150	Zone 1	0.163	0.112	0.122	0.153
	Zone 2	0.173	0.112	0.122	0.143
	Zone 3	0.163	0.112	0.122	0.153
	Zone 4	0.163	0.112	0.122	0.153
	Zone 5	0.183	0.112	0.122	0.143
≥ 150	Zone 1	0.196	0.134	0.147	0.183
	Zone 2	0.208	0.134	0.147	0.171
	Zone 3	0.196	0.134	0.147	0.183
	Zone 4	0.196	0.134	0.147	0.183
	Zone 5	0.220	0.134	0.147	0.171

Table 215. Central DHW Controls—Peak Demand kW Thermal Savings per Dwelling Unit

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Zone 1	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Zone 2	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Zone 3	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Zone 4	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Zone 5	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Time_clock.[445]

Program Tracking Data and Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Circulation pump wattage
- Building type: commercial or lodging
- Building size: Low rise or high rise
- Water heater type: electric resistance or heat pump
- If lodging, number of lodging units at project site

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~DEER 2014 EUL update.~~

Document Revision History

Table 216. Nonresidential Central DHW Controls Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

[445] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

2.6.2 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: NR-WH-SV

Market Sector: Commercial

Measure Category: Water Heating

Applicable Building Types: Lodging

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)[446] between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95˚F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

Eligibility Criteria

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in commercial lodging applications. Buildings must have electrically-fueled hot water to be eligible for this measure.

Baseline Condition

The baseline condition is the commercial lodging shower arm and standard (2.5 gpm) showerhead without a temperature sensitive restrictor valve installed.

High-Efficiency Condition

The high-efficiency condition is a temperature sensitive restrictor valve installed on a commercial lodging shower arm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead.

[446] A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

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:

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{OCC}{n_{SH}}$$

Equation 203

Where:

SHFR	=	*Showerhead flow rate, gallons per minute (gpm) (see Table 217)*
BW	=	*Behavioral waste, minutes per shower (see Table 217)*
n_S	=	*Number of showers per occupied room per day (see Table 217)*
365	=	*Constant to convert days to years (see Table 217)*
OCC	=	*Occupancy rate (see Table 217)*
n_{SH}	=	*Number of showerheads per room (see Table 217)*

Applying the formula to the values used for Texas from Table 217 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM): 2.5 \times\ 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}838\ gal$$

$$Showerhead\ (2.0\ GPM): 2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}471\ gal$$

$$Showerhead\ (1.75\ GPM): 1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}287\ gal$$

$$Showerhead\ (1.5\ GPM): 1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}103\ gal$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 217.

$$Gallons\ of\ hot\ water\ saved\ per\ year = Annual\ Behavioral\ Waste \times HW\%$$

Equation 204

Where:

HW% = *Hot water percentage (see Table 217)*

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 1{,}838 \times 0.825 = 1{,}516\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 1{,}471 \times 0.825 = 1{,}213\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 1{,}287 \times 0.825 = 1{,}062\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 1{,}103 \times 0.825 = 910\ gal$$

Table 217. Showerhead TSRVs—Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower)[447]	1.742			
Showers/occupied room/day[448]	1.756			
Occupancy rate[449]	65.9%			
Showerheads/room[450]	1.0			
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water[451]	80-85%, or 82.5% on average			
Hot water saved/year (gal)	1,516	1,213	1,062	910

[447] Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

[448] Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

[449] 2001-~~2019~~ 2021 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 5 pre-COVID years (2015-2019).

[450] Assuming industry standard for standard one-bathroom rooms.

[451] Average percent hot water from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times 3{,}412}$$

Equation 205

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

V = *Gallons of hot water saved per year per showerhead (see Table 217)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [452]

T_{Supply} = *Average supply water temperature (see Table 218)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric-resistance water heaters, or 2.2 for heat-pump water heaters.*[453]

3,412 = *Constant to convert from Btu to kWh*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3{,}412 \times 365} \times CF$$

Equation 206

[452] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99. Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[453] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 218)*

CF = *Peak coincidence factor (see Table 219)*

Table 218. Showerhead TSRVs—Water Mains Temperatures

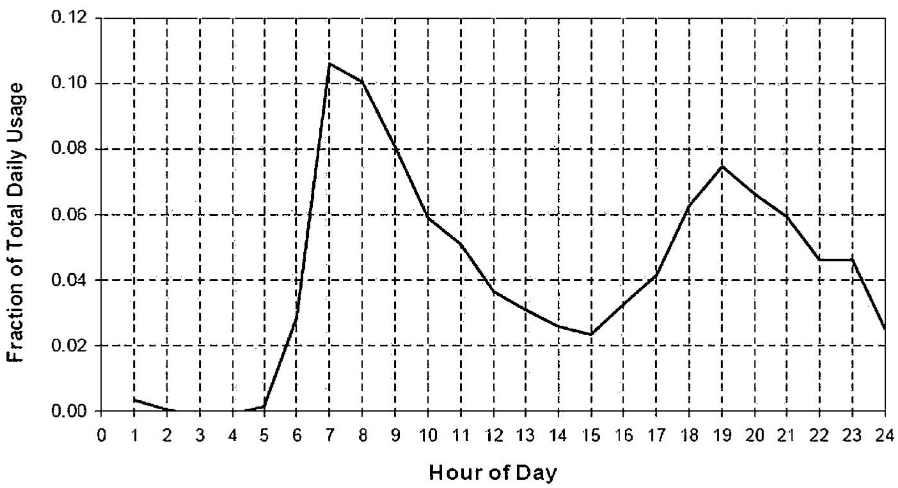
Climate zone	Water mains temperature (°F)[454]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 219. Showerhead TSRVs—Peak Coincidence Factors

Climate zones	Summer	Winter
Climate Zone 1: Amarillo	0.039	0.073
Climate Zone 2: Dallas	0.035	0.075
Climate Zone 3: Houston	0.038	0.080
Climate Zone 4: Corpus Christi	0.038	0.068
Climate Zone 5: El Paso	0.028	0.069

[454] Based on typical meteorological year (TMY) dataset for TMY3: https://sam.nrel.gov/weather-data.html.

Figure 5. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[455]



Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Winter Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

[455] Building America Performance Analysis Procedures for Existing Homes.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[456] This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[457]

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone
- Flow rate in gallons per minute (gpm) of showerhead installed
- Water heater type (heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 220. Nonresidential Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

456 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
457 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.

2.6.3 Tub Spout and Showerhead Temperature-Sensitive Restrictor Valves Measure Overview

TRM Measure ID: NR-WH-TV

Market Sector: Commercial

Measure Category: Water Heating

Applicable Building Types: Lodging

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of replacing existing tub spouts and showerheads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV)[458] between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95˚F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

Eligibility Criteria

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in commercial lodging applications. Buildings must have electrically-fueled hot water to be eligible for this measure.

Baseline Condition

The baseline condition is the commercial lodging tub spout with a standard diverter and a standard (2.5 gpm) showerhead.

[458] A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a commercial lodging shower arm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

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.

Part 1: To determine baseline gallons of behavioral waste per year, the following formula was used:

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

Equation 207

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

Equation 208

Where:

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 221)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 221)*

SHFR = *Showerhead flow rate, gallons per minute (gpm) (see Table 221)*

TSFR = *Tub spout flow rate, gallons per minute (gpm) (see Table 221)*

BW = *Behavioral waste, minutes per shower (see Table 221)*

n_S = *Number of showers per occupied room per day (see Table 221)*

365 = *Constant to convert days to years (see Table 221)*

OCC = *Occupancy rate (see Table 221)*

n_{SH} = *Number of showerheads per room (see Table 221)*

Applying the formula to the values from Table 221 returns the following values:

$$Showerhead\ (1.5\ GPM): 0.6 \times \left(1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 662$$

$$Showerhead\ (1.75\ GPM): 0.6 \times \left(1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 772$$

$$Showerhead\ (2.0\ GPM): 0.6 \times \left(2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 882$$

$$Showerhead\ (2.5\ GPM): 0.6 \times \left(2.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 1{,}103$$

$$Tub\ Spout\ (5.0\ GPM): 0.4 \times \left(5.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 1{,}471$$

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

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{OCC}{n_{SH}}$$

Equation 209

Where:

DLR = *Diverter leakage rate (gpm) (see Table 221)*

t_S = *Shower time (min/shower) (see Table 221)*

Applying the formula to the values used for Texas from Table 221 returns the following values:

$$Diverter\ (0.8\ GPM): 0.8 \times 7.8 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 2{,}634$$

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percentage of hot water from Table 221.

$$Gallons\ of\ hot\ water\ saved = (SHBW + TSBW) \times HW\%_{SH,TS} + DW \times HW\%_D$$

Equation 210

Where:

SHBW = *Showerhead behavioral waste (gal)*

TSBW = *Tub-spout behavioral waste (gal)*

DW = *Diverter waste (gal)*

$HW\%_{SH,TS}$	=	*Showerheads and tub-spout hot water percentage (see Table 221)*
$HW\%_{D}$	=	*Diverter hot-water percentage (see Table 221)*

Applying the formula to the values from Table 221 returns the following values:

$$Total\ Annual\ Waste\ (1.5\ gpm): (662 + 1{,}471) \times 0.825 + 2{,}634 \times 0.737 = 3{,}700$$

$$Total\ Annual\ Waste\ (1.75\ gpm): (772 + 1{,}471) \times 0.825 + 2{,}634 \times 0.737 = 3{,}791$$

$$Total\ Annual\ Waste\ (2.0\ gpm): (882 + 1{,}471) \times 0.825 + 2{,}634 \times 0.737 = 3{,}882$$

$$Total\ Annual\ Waste\ (2.5\ gpm): (1{,}103 + 1{,}471) \times 0.825 + 2{,}634 \times 0.737 = 4{,}064$$

Table 221. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			N/A
Tub-spout flow rate (gpm)[459]	N/A	5.0		N/A
Percentage of warm-up events[460]	60%	40%		N/A
Average behavioral waste (minutes per shower)[461]		1.742		N/A
Average diverter leakage-rate (gpm)[462]		N/A	0.80	N/A
Average shower time (minutes)[463]		N/A	7.8	N/A
Showers/occupied room/day[464]				1.756
Occupancy rate[465]				65.9%

[459] Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[460] Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

[461] Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

[462] Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.

[463] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.

[464] Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

[465] 2001-2019 2021 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 5 pre-COVID years (2015-2019).

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Showerheads/room[466]	1.0			
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	662	1,471	2,634	4,766
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	772			4,877
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	882			4,987
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	1,103			5,207
Percentage hot water[467]	80-85%, or 82.5% average		73.7%	N/A
Gallons of hot water saved per year (1.5 gpm)	N/A			3,700
Gallons of hot water saved per year (1.75 gpm)	N/A			3,791
Gallons of hot water saved per year (2.0 gpm)	N/A			3,882
Gallons of hot water saved per year (2.5 gpm)	N/A			4,064

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times 3{,}412}$$

Equation 211

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

V = *Gallons of hot water saved per year per showerhead (see Table 221)*

[466] Assuming industry standard for standard one-bathroom rooms.

[467] Average percentage of hot water for warm-up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

$T_{SetPoint}$	=	*Water heater setpoint: 120°F* [468]
T_{Supply}	=	*Average supply water temperature (see Table 222)*
RE	=	*Recovery efficiency (or in the case of heat-pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, or 2.2 for heat-pump water heaters*[469]
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3{,}412 \times 365} \times CF$$

Equation 212

Where:

$T_{SupplySeasonal}$	=	*Seasonal-supply water temperature (see Table 222)*
CF	=	*Peak coincidence factor (see Table 223)*

Table 222. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature (°F)[470]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5

468 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

469 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

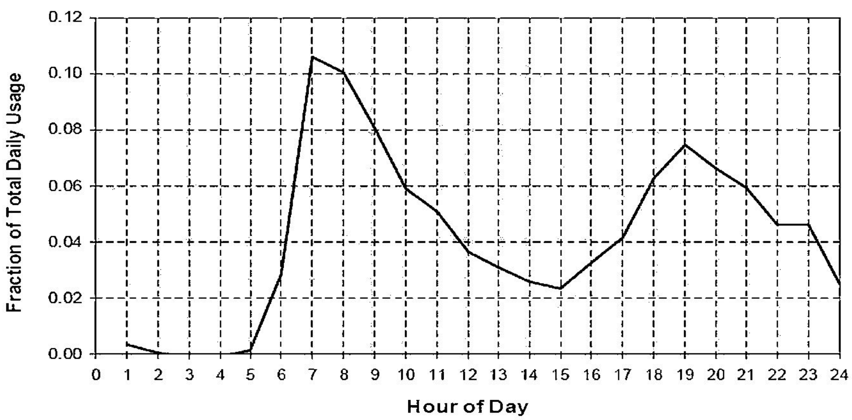
470 Based on typical meteorological year (TMY) dataset for TMY3: https://sam.nrel.gov/weather-data.html.

Zone 5: El Paso	70.4	81.5	60.4

Table 223. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors

Climate zones	Summer	Winter
Zone 1: Amarillo	0.039	0.073
Zone 2: Dallas	0.035	0.075
Zone 3: Houston	0.038	0.080
Zone 4: Corpus Christi	0.038	0.068
Zone 5: El Paso	0.028	0.069

Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[471]



Deemed Energy and Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

[471] Building America Performance Analysis Procedures for Existing Homes.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[472]

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 224. Nonresidential Tub Sprout and Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revisions.

472 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

2.7 NONRESIDENTIAL: MISCELLANEOUS

2.7.1 Vending Machine Controls Measure Overview

TRM Measure ID: NR-MS-VC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All building types applicable

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

This measure is for the installation of vending machine controls to reduce energy usage during periods of inactivity. These controls reduce energy usage by powering down the refrigeration and lighting systems when the control device signals that there is no human activity near the machine. If no activity or sale is detected over the manufacturer's programmed time duration, the device safely de-energizes the compressor, condenser fan, evaporator fan, and any lighting. For refrigerated machines, it will power up occasionally to maintain cooling to meet the machine's thermostat set point. When activity is detected, the system returns to full power. The energy and demand savings are determined on a per-vending machine basis.

Eligibility Criteria

This measure applies to refrigerated beverage vending machines manufactured and purchased prior to August 31, 2012. Refrigerated beverage vending machines manufactured after this date must already comply with current federal-standard maximum daily-energy consumption requirements.

All non-refrigerated snack machines are eligible if controls are installed on equipment consistent with the baseline condition below. Display lighting must not have been permanently installed.

Baseline Condition

The baseline condition is a 120-volt single phase refrigerated beverage or non-refrigerated snack vending machine without any controls.

High-Efficiency Condition

The high-efficiency condition is a 120-volt single-phase refrigerated beverage or non-refrigerated-snack vending machine with occupancy controls and compliant with the current federal standard, effective January 8, 2019.[473]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy savings are deemed based on a metering study completed by Pacific Gas & Electric (PG&E). Delta load shapes for this measure are taken from a Sacramento Municipal Utility District (SMUD) metering study. Demand savings for refrigerated cold drink units are calculated based on a probability-weighted analysis of hourly consumption impacts, and demand savings for other unit types are adjusted proportionally based on differences in rated product wattage.

Deemed Energy and Demand Savings Tables

Energy and demand savings are specified by unit type and climate zone in the following tables:

Table 225. Vending Machine Controls—Refrigerated Cold Drink Unit Deemed Savings[474]

Climate zone	kWh savings	Summer kW savings[475]	Winter kW savings
Zone 1: Amarillo	1,612	0.023	0.060
Zone 2: Dallas		0.021	0.063
Zone 3: Houston		0.022	0.060
Zone 4: Corpus Christi		0.022	0.064
Zone 5: El Paso		0.015	0.068

473 Appliance Standards for Refrigerated Beverage Vending Machines. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

474 Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

475 Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56. https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper.pdf.

Table 226. Vending Machine Controls—Refrigerated Reach-In Unit Deemed Savings[476]

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Zone 1: Amarillo	1,086	0.026	0.069
Zone 2: Dallas		0.024	0.073
Zone 3: Houston		0.026	0.068
Zone 4: Corpus Christi		0.026	0.074
Zone 5: El Paso		0.017	0.078

Table 227. Vending Machine Controls—Non-Refrigerated Snack Unit Deemed Savings[477]

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Zone 1: Amarillo	387	0.005	0.013
Zone 2: Dallas		0.004	0.013
Zone 3: Houston		0.005	0.013
Zone 4: Corpus Christi		0.005	0.014
Zone 5: El Paso		0.003	0.014

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Plug-VendCtrler.[478]

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly:

- Vending machine type (refrigerated cold drink unit, refrigerated reach-in unit, or non-refrigerated snack unit with lighting)
- Vending machine manufacture date

[476] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.
[477] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.
[478] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A: https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF.
- PUCT Docket 36779—Provides EUL for Vending Machine Controls.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56. https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel10_Paper05.pdf.~~
- ~~DEER 2014 EUL update.~~

Document Revision History

Table 228. Nonresidential Vending Machine Controls Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. Clarified baseline condition and updated demand savings for compliance with current peak definition.
v9.0	10/2021	TRM v9.0 update. General text edits.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.7.2 Lodging Guest Room Occupancy-Sensor Controls Measure Overview

TRM Measure ID: NR-MS-LC

Market Sector: Commercial

Measure Category: HVAC, Indoor Lighting

Applicable Building Types: Hotel/motel guestrooms, schools/colleges (dormitory)

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling

Measure Description

This measure, commonly referred to as a guest room energy management (GREM) system, captures the potential energy and demand savings resulting from occupancy sensor control of HVAC and lighting in unoccupied hotel/motel guest rooms. Hotel and motel guest room occupancy schedules are highly variable, and guests often leave HVAC equipment and lighting on when they leave the room. Installation of occupancy controls can reduce the unnecessary energy consumption in unoccupied guest rooms. Savings have also been developed for the use of this measure in college dormitories.[479]

Eligibility Criteria

To be eligible for HVAC savings, controls must be capable of either a 5ºF or 10ºF temperature offset. To be eligible for lighting savings, at least 50 percent of all the lighting fixtures in a guest room—both hardwired and plug-load lighting—must be actively controlled.

Baseline Condition

The baseline condition is a guest room or dorm room without occupancy controls.

[479] The original petition also includes savings for HVAC-only control in master-metered multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is significantly different from the transitory occupation of hotel/motels and even dormitories. This measure is not currently being implemented and is not likely to be used in the future, but it can be added to a future TRM if warranted.

High-Efficiency Condition

The high-efficiency condition is a guest room or dorm room with occupancy controls. The occupancy sensors can control either the HVAC equipment only or the HVAC equipment and the interior lighting (including plug-in lighting).

The occupancy-based control system must include, but not be limited to, infrared sensors, ultrasonic sensors, door magnetic strip sensors, and/or card-key sensors. The controls must be able to either completely shut-off the HVAC equipment serving the space and/or place it into an unoccupied temperature setback/setup mode.

Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies[480] and prototypical ASHRAE 90.1-1999 occupancy schedules were used in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system, which was compared to the baseline models.[481]

Savings Algorithms and Inputs

A building simulation approach was used to produce savings estimates.

Deemed Energy and Demand Savings Tables

Energy and demand savings are provided by region, for HVAC-only, HVAC + lighting control configurations, and for three facility types: motel guest rooms, hotel guest rooms, and dormitory rooms.

[480] HVAC occupancy rates appear to be based on a single HVAC study of three hotels, but not dorms or multifamily buildings. For the lighting study, a typical guest room layout was used as the basis for the savings analysis. Hotel guest rooms are quite different from either dorms or multifamily units.

[481] A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 229. Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Climate zone[482]	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo ~~(Panhandle)~~	0.059	267	0.075	380	0.059	341	0.075	441
Dallas ~~(North)~~	0.076	315	0.091	443	0.076	365	0.091	485
Houston ~~(South)~~	0.082	324	0.097	461	0.082	351	0.097	484
Corpus Christi~~McAllen (Valley)~~	0.086	354	0.103	500	0.086	369	0.103	513
El Paso ~~(West)~~	0.063	251	0.078	379	0.063	283	0.078	406
10-degree setup/setback offset								
Amarillo ~~(Panhandle)~~	0.111	486	0.126	598	0.111	627	0.126	726
Dallas ~~(North)~~	0.146	559	0.161	686	0.146	640	0.161	761
Houston ~~(South)~~	0.151	559	0.166	695	0.151	602	0.166	735
Corpus Christi~~McAllen (Valley)~~	0.163	617	0.179	761	0.163	650	0.179	792
El Paso ~~(West)~~	0.118	432	0.133	561	0.118	482	0.133	607

Table 230. Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Climate zone[482]	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo ~~(Panhandle)~~	0.053	232	0.072	439	0.053	303	0.072	530
Dallas ~~(North)~~	0.073	258	0.093	452	0.073	303	0.093	505
Houston ~~(South)~~	0.074	242	0.094	430	0.074	260	0.094	450
Corpus Christi~~McAllen (Valley)~~	0.081	260	0.102	451	0.081	267	0.102	459
El Paso ~~(West)~~	0.056	178	0.075	360	0.056	196	0.075	380
10-degree setup/setback offset								
Amarillo ~~(Panhandle)~~	0.102	426	0.121	568	0.102	557	0.121	684
Dallas ~~(North)~~	0.134	452	0.154	617	0.134	517	0.154	676
Houston ~~(South)~~	0.136	423	0.156	599	0.136	446	0.156	621

[482] Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo ~~(Panhandle)~~ was “Panhandle”, Dallas-Ft Worth ~~(North)~~ was “North”, Houston ~~(South)~~ was “South Central”, El Paso ~~(West)~~ was “Big Bend”, and ~~McAllen~~ Corpus Christi~~(Valley)~~ was “Rio Grande Valley” using McAllen as a reference city.

Climate zone[482]	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Corpus Christi~~McAllen (Valley)~~	0.149	467	0.169	652	0.149	483	0.169	667
El Paso~~ (West)~~	0.106	312	0.126	479	0.106	338	0.126	501

Table 231. Deemed Energy and Demand Savings for Dormitories per Room, by Region

Climate zone[482]	Heat pump				Electric heat			
	HVA only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo~~ (Panhandle)~~	0.034	136	0.061	319	0.034	152	0.061	316
Dallas~~ (North)~~	0.048	214	0.076	425	0.048	223	0.076	428
Houston~~ (South)~~	0.051	242	0.078	461	0.051	244	0.078	462
Corpus Christi~~McAllen (Valley)~~	0.053	265	0.081	492	0.053	266	0.081	492
El Paso~~ (West)~~	0.031	110	0.059	327	0.031	110	0.059	326
10-degree setup/setback offset								
Amarillo~~ (Panhandle)~~	0.073	261	0.084	404	0.073	289	0.084	417
Dallas~~ (North)~~	0.078	293	0.105	505	0.078	304	0.105	511
Houston~~ (South)~~	0.081	326	0.108	543	0.081	328	0.108	545
Corpus Christi~~McAllen (Valley)~~	0.088	368	0.114	591	0.088	370	0.114	593
El Paso~~ (West)~~	0.045	151	0.060	448	0.045	153	0.060	450

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study[483]. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

483 Energy and Resource Solutions (2005). *Measure Life Study.* Prepared for the Massachusetts Joint Utilities; Table 1-1, Prescriptive Common Measure Life Recommendations, Large C&I retrofit, HVAC Controls, EMS.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Climate zone
- HVAC system and equipment type
- Heating type (heat pump, electric resistance)
- Temperature offset category (5 or 10° F)
- Control type (HVAC only, HVAC and lighting)
- Building type (hotel, motel, dormitory)
- Number of rooms

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40668—Provides deemed energy and demand savings values under "Guestroom, Dormitory and Multi-family Occupancy Controls for HVAC and Lighting Systems," page 25 and Attachment pages A-46 through A-58.
- PUCT Docket 36779—Provides EULs for commercial measures.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~ASHRAE Standard 90.1-1999~~
- ~~Measure Life Study. Prepared for The Massachusetts Joint Utilities by ERS. November 17, 2005.~~
- ~~Codes and Standards Enhancement Initiative (CASE): Guest Room Occupancy Controls, 2013 California Building Energy Efficiency Standards. October 2011.~~

Document Revision History

Table 232. Nonresidential Lodging Guest Room Occupancy Sensor Controls Revision History

TRM version	Date	Description of change
v2.0	04/18/2014	TRM v2.0 origin.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revisions.
v10.0	10/2022	TRM v10.0 update. Changed climate zone 4 reference city to Corpus Christi from McAllen.

2.7.3 Pump-Off Controllers Measure Overview

TRM Measure ID: NR-MS-PC

Market Sector: Commercial

Measure Category: Controls

Applicable Building Types: Industrial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Field study, engineering algorithms, and estimates

Measure Description

Pump-off controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions (i.e., when the fluid in the well bore is insufficient to warrant continued pumping). These controllers are used to shut down the pump when the fluid falls below a certain level and “fluid pounding”[484] occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number[485] prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a *conventional* well (above ground or vertical, with a standard induction motor of 480V or less).

Baseline Condition

The baseline condition is an existing conventional well (with an API number prior to September 11, 2014) with rod pumps operating on time clock controls or less efficient control devices.

[484] Fluid pounding occurs when the downhole pump rate exceeds the production rate of the formation. The pump strikes the top of the fluid column on the down stroke causing extreme shock loading of the components which can result in premature equipment failure.

[485] The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.

High-Efficiency Condition

The efficient condition is the same well, retrofitted with a pump-off controller.

Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*[486] (SPE 16363), which identified a relationship between volumetric efficiency and pump run times and the *2006-2008 Evaluation Report for PG&E Fabrication, Process, and Manufacturing Contract Group,*[487] which showed a reduction in savings from the SPE 16363 paper. These two methods were the basis of the current savings calculations and deemed inputs listed below. To develop Texas-specific stipulated values, field and metering data will be collected when there is sufficient uptake in the measure and used to calibrate and update the savings calculation methods and input variables for a future version of the TRM.[488]

Savings Algorithms and Inputs

The energy and demand algorithms and associated input variables are listed below:

$$Energy\ Savings\ [kWh] = kW_{avg} * (TimeClock\%On - POC\%On) * 8760$$

Equation 213

$$Demand\ Savings\ [kW] = \frac{EnergySavings}{8760}$$

Equation 214[489]

The inputs for the energy and peak coincident demand savings are listed below:

$$kW_{avg} = HP \times 0.746 \times \frac{\frac{LF}{ME}}{SME}$$

Equation 215

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486 Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production*", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

487 *2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group.* CALMAC Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.

488 The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

489 The equations in the petition for peak demand simplify to the equation shown.

$$POC\%On = \frac{Run_{Constant} + Run_{Coefficient} \times VolumetricEfficiency\% \times TimeClock\%On \times 100}{100}$$

Equation 216[490]

Where:

kW_{avg}	=	*The demand used by each rod pump*
HP	=	*Rated pump-motor horsepower*
0.746	=	*Conversion factor from hp to kW*
LF	=	*Motor load factor—ratio of average demand to maximum demand, see Table 233*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 234*
SME	=	*Mechanical efficiency of sucker-rod pump, see Table 233*
Time_Clock%On	=	*Stipulated-baseline time_clock setting, see Table 233*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956, derived from SPE 16363* [491]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

Deemed Energy and Demand Savings Tables

Table 233. Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/deemed values
LF (Load factor)	25%[492]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[493]
Time_clock%On	65%[494]

[490] This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is ($Run_{contstant}$ + $Run_{coefficient}$ * VolumetricEfficiency%) with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25 percent).

[491] Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production,* (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

[492] *Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL*. Tetra Tech. March 28, 2011. Adjusted based on Field Measurements provided by ADM Associates, based on 2010 custom projects.

[493] Engineering estimate for standard gearbox efficiency.

[494] A Time_Clock%On of 80 percent is typical from observations in other jurisdictions, but that was adjusted to 65 percent for a conservative estimate. This value will be reevaluated once Texas field data is available.

Table 234. NEMA Premium Efficiency Motor Efficiencies[495]

Motor horsepower	Nominal full-load efficiency					
	Open motors (ODP)			Enclosed motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
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%	93.6%
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%

Claimed Peak Demand Savings

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8,760 hours) is used, as shown in Equation 214.

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years.[496]

[495] DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=6&action=viewlive.

[496] CPUC 2006-2008 Industrial Impact Evaluation "SCIA_06-08_Final_Report_Appendix_D-5": An EUL of 15 years was used for the ex-post savings, consistent with the SPC—Custom Measures and System Controls categories in the CPUC Energy Efficiency Policy Manual (Version 2) and with DEER values for an energy management control system.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Motor manufacturer
- Motor model number
- Rated motor horsepower
- Motor type (TEFC or ODP)
- Rated motor RPM
- Baseline control type and time clock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times[497]

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 42551—Provides energy and demand savings calculations and EUL

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

- ~~Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).~~
- ~~79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I]~~
- ~~2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group. CALMAC Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.~~
- ~~Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011.~~

[497] Per PUCT Docket 42551, Southwestern Public Service Company (SPS)/Xcel Energy has agreed to collect field data in 2015 on post-run times for a sample of wells to improve the accuracy of POC saving estimates.

Document Revision History

Table 235. Nonresidential Pump-Off Controllers Revision History

TRM version	Date	Description of change
v2.1	01/30/2015	TRM v2.1 origin.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revisions.

2.7.4 ENERGY STAR® Pool Pumps Measure Overview

TRM Measure ID: NR-MS-PP

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit~~, new construction~~

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable speed pool pump.

Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa[498].

Multi-speed pool pumps are not permitted. The multi-speed pump uses an induction motor that functions as 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.[499] The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

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[498] These pump products are ineligible for ENERGY STAR® v3.0 certification: https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification.pdf

[499] Hunt, A. and Easley, S., "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf.

Baseline Condition

The baseline condition is a 1 to 3 5 horsepower (hp) standard efficiency single-speed pool pump. This measure is only applicable to retrofit applications. New construction applications are not eligible as of July 19, 2021.[500]

High-Efficiency Condition

The high-efficiency condition is a 1 to 3 5 hp ENERGY STAR® certified variable speed pool pump that is compliant with the current ENERGY STAR® Version 3.1 sSpecification v3.1, effective July 19, 2021.

Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR® Pool Pump Savings Calculator.

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator with Texas selected as the applicable location, so Texas-specific assumptions were used.[501]

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

Equation 217

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:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours \times days}{EF_{conv} \times 1000}$$

Equation 218

$$kWh_{ES} = \frac{V gal \times TO turn_{day} \times days}{EF_{ES} \times 1000}$$

[500] Federal standard for dedicated-purpose pool pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67 .

[501] The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumpshttps://www.energystar.gov/productfinder/product/certified-pool-pumps/results.

Equation 219

Where:

~~*hours* = *Conventional single-speed pump daily operating hours (see Table 232)*~~

~~*days* = *Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*~~

PFR_{conv} = *Conventional single-speed pump flow rate [gal/min] (see Table 236)*

EF_{conv} = *Conventional single-speed pump energy factor [gal/W·hr] (see Table 236)*

EF_{ES} = *ENERGY STAR®-weighted energy factor [gal/W·hr] (see Table 207)*

hours = *Conventional single-speed pump daily operating hours (see Table 236)*

days = Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)

V

~~*gal*~~ = ~~*The volume of the p*~~*Pool volume* ~~*in*~~ *[gal]*~~*lons*~~ *(see Table 237)*

TO~~*turn*~~$_{day}$ = *Turnovers per day, number of times the volume of the pool is run through the pump per day (see Table 207)*

~~EF_{ES} = *ENERGY STAR®-weighted energy factor [gal/W·hr] (see Table 207)*~~

~~*60*~~*60* = *Constant to convert between minutes and hours*

~~*1,000*~~*1,000* = *Constant to convert from kilowatts to watts*

Table 236. Conventional Pool Pumps Assumptions[502]

New ~~rated~~ pump HP	Hours limited hours[503]	Hours, 24/7 Operation	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
≤ 1.25	12	24	75.5000	2.5131
1.25 < hp ≤ 1.75			78.1429	2.2677
1.75 < hp ≤ 2.25			88.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ ~~3~~5			101.6667	1.9987

Table 237. ENERGY STAR® Pool Pumps Assumptions[504,505]

New ~~rated~~ pump HP	~~Turnovers/day~~TO limited hours	~~Turnovers/day~~TO 24/7 Operation	~~Gallons~~V [gal]	EF_{ES} (gal/W·h)
≤ 1.25	2.7	5.4	20,000	8.7
1.25 < hp ≤ 1.75	2.8	5.6	20,000	8.9
1.75 < hp ≤ 2.25	2.9	5.8	22,000	9.3
2.25 < hp ≤ 2.75	2.7	5.4	25,000	7.4
2.75 < hp ≤ ~~3~~5	2.6	5.2	28,000	7.1

Demand Savings Algorithms

$$kW_{Savings} = \frac{kWh_{conv} - kWh_{ES}}{hours} \times \frac{\sout{D}CF}{days}$$

Equation 220

Where:

~~*hours* = *Conventional single-speed pump daily operating hours (see Table 232)*~~

~~*days* = *Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*~~

~~DF~~CF = *~~Demand~~ Coincidence factor from Table 238*

Table 238. ~~Demand~~ Coincidence Factors[506]

Operation	Summer ~~D~~CF	Winter ~~D~~CF
24/7 operation	1.0	1.0
Seasonal/limited hours	1.0	0.5

502 Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

503 Limited hours assumes that pump operating hours are 12 hours per day, based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

504 ENERGY STAR® turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

505 Turnovers calculated as TO = hours x 60 x PFR_{conv} ÷ V.

506 Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

Deemed Energy and Demand Savings Tables

Table 239. ENERGY STAR® Variable Speed Pool Pump Energy Savings[507]

	Year-round operation		Seasonal operation (7 months)
	24/7 operation	Limited hours	
New ~~rated~~ pump HP	kWh savings	kWh savings	kWh savings
≤ 1.25	11,259	5,630	3,282
1.25 < hp ≤ 1.75	13,518	6,759	3,941
1.75 < hp ≤ 2.25	15,263	7,632	4,449
2.25 < hp ≤ 2.75	15,773	7,887	4,598
2.75 < hp ≤ ~~3~~5	19,250	9,625	5,612

Table 240. ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings

New ~~rated~~ pump (HP)	24/7 operation or year-round limited hours demand savings (kW)	Seasonal operation demand savings (kW)
≤ 1.25	1.285	0.749
1.25 < hp ≤ 1.75	1.543	0.900
1.75 < hp ≤ 2.25	1.742	1.016
2.25 < hp ≤ 2.75	1.801	1.050
2.75 < hp ≤ ~~3~~5	2.198	1.281

Table 241. ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings

New ~~rated~~ pump HP	24/7 operation demand savings (kW)	Year-round limited hours demand savings (kW)	Season operation demand savings (kW)
≤ 1.25	1.285	0.643	0.375
1.25 < hp ≤ 1.75	1.543	0.772	0.450
1.75 < hp ≤ 2.25	1.742	0.871	0.508
2.25 < hp ≤ 2.75	1.801	0.900	0.525
2.75 < hp ≤ ~~3~~5	2.198	1.099	0.641

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

[507] The results in this table may vary slightly from results produced by the ENERGY STAR® Calculator because of rounding of default savings coefficients throughout the measure and pool volume.

Additional Calculators and Tools

ENERGY STAR® Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR® website at https://www.energystar.gov/productfinder/product/certified-pool-pumps/resultshttps://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.[508]

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- For all projects
    - Climate zone
    - Pool pump rated horsepower
    - Proof of purchase including quantity, make, and model information
    - Copy of ENERGY STAR® certification
    - Facility operation type: 24/7, year-round limited hours, seasonal
- For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs)
    - Items listed above for all projects
    - Decision/action type: early retirement, replace-on-burnout, or new construction
    - Rated horsepower of existing pool pump
    - Existing and new pump operating hours

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 47612—Provides deemed savings for ENERGY STAR® pool pumps

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

[508] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- The applicable version of the ENERGY STAR® specifications and requirements for pool pumps

Document Revision History

Table 242. Nonresidential ENERGY STAR® Pool Pumps Revision History

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. Added ineligible products list. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General text edits. Corrected turnovers/day values in the assumptions table.
v10.0	10/2022	TRM v10.0 update. Updated for ENERGY STAR® Version 3.0 sSpecification 3.0. Increased upper limit for pump horsepower to 5 to better reflect product availability.