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

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

Equation 178

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1{,}000 \times LF \times DC_{EvapCool} \times \left(1 + \frac{1}{COP_{cooler}}\right)$$

Equation 179

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

Equation 180

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

Equation 181

Freezer

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

Equation 182

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1{,}000 \times LF \times DC_{EvapFreeze} \times \left(1 + \frac{1}{COP_{freezer}}\right)$$

Equation 183

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

Equation 184

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

Equation 185

Where:

N	=	*Number of motors replaced*
W_{base}	=	*Input wattage of existing/baseline evaporator fan motor (see Table 236)*
W_{ee}	=	*Input wattage of new energy efficient evaporator fan motor (see Table 236)*

LF	=	*Load factor of evaporator fan motor = 0.9 (default)*[446]
$DC_{EvapCool}$	=	*Duty cycle of evaporator fan motor for cooler = 100% (default)*[447]
$DC_{EvapFreeze}$	=	*Duty cycle of evaporator fan motor for freezer = 97.8% (default)*[448,449]
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 freezers.* [450,451]
%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%.*[452]
1,000	=	*Constant to convert from W to kW*

446 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.

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

448 The December 2018 VT TRM Evaporator Fan Motors measure attributes reduced operating hours to freezers. This is expressed through a reduced duty cycle of approximately 8,567 / 8,760 = 97.8 percent. https://puc.vermont.gov/document/ev-technical-reference-manual.

449 "Commercial Refrigeration Loadshape Project Final Report," The Cadmus Group. Northeast Energy Efficiency Partnerships (NEEP), Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

450 The December 2018 VT TRM Evaporator Fan Motors measure attributes reduced operating hours to freezers. This is expressed through a reduced duty cycle of approximately 8,567 / 8,760 = 97.8 percent. https://puc.vermont.gov/document/ev-technical-reference-manual.

451 "Commercial Refrigeration Loadshape Project Final Report," The Cadmus Group. Northeast Energy Efficiency Partnerships (NEEP), Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

452 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."

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.[453]

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 186[454]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*
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*

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

[454] 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 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 187[455]

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*
SCT_{LT}	=	$T_{db} + 10$

Table 236. ECM Evaporator Fan Motors—Motor Sizes, Efficiencies, and Input Watts[456,457]

Nominal motor size	Motor output (W)	SP eff	SP 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

455 Ibid.

456 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.

457 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.

Nominal motor size	Motor output (W)	SP eff	SP input (W)	PSC eff	PSC input (W)	ECM eff	ECM input (W)
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 237. ECM Evaporator Fan Motors—Cooler & Freezer Compressor COP

Climate zone	Summer design dry-bulb temperature[458]	EER_{MT}	COP_{cooler}	EER_{LT}	$COP_{freezer}$
Climate Zone 1: Amarillo	98.6	6.18	1.94	4.77	2.51
Climate Zone 2: Dallas	101.4	5.91	2.03	4.56	2.63
Climate Zone 3: Houston	97.5	6.29	1.91	4.86	2.47
Climate Zone 4: Corpus Christi	96.8	6.36	1.89	4.91	2.44
Climate 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.

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.[459]

[458] 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

[459] 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.

- Climate zone or county
- Building type
- Motor quantity
- Baseline motor type (SP, PSC)
- Motor power rating
- 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.

Document Revision History

Table 238. 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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
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 revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.

TRM version	Date	Description of change
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.
v11.0	10/2023	TRM v11.0 update. Clarified duty cycle assumptions and references.
v12.0	10/2024	TRM v12.0 update. Clarified baseline condition and documentation requirements.

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, grocery stores, hotels, restaurants, convenience stores, and schools[460]

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.

[460] 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:

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

Equation 188

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

Equation 189

Medium temperature:

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

Equation 190

Low temperature:

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

Equation 191

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

Equation 192

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*[461]

461 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 900 W 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*[462]
CF	=	*Coincidence factor—percentage reduction in defrosts required per year, see Table 239*
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.[463]

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 193[464]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*
c	=	*29.4589834935596*

[462] 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.

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

[464] 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.

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 194[465]

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*
SCT_{LT}	=	$T_{db} + 10$

[465] Ibid.

Table 239. Defrost Controls—Savings Calculation Input Assumptions

Climate zone	CF[466]	COP_{MT}[467]	COP_{LT}[468]
Climate Zone 1: Amarillo	35%	1.94	2.51
Climate Zone 2: Dallas		2.03	2.63
Climate Zone 3: Houston		1.91	2.47
Climate Zone 4: Corpus Christi		1.89	2.44
Climate 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.[469]

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 or county
- Hours that defrost occurs over a year without defrost controls

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[466] 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?bylnode=true

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

[468] Ibid.

[469] 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"

- 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.

Document Revision History

Table 240. 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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Corrected peak factor naming convention.

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, grocery stores, hotels, restaurants, convenience stores, and schools[470]

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.

[470] 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:

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

Equation 195

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

Equation 196

Where:

kW_{evap}	=	*Connected load kW of each evaporator fan, see Table 241*
kW_{circ}	=	*Connected load kW of the circulating fan, see Table 241*
n_{fans}	=	*Number of evaporator fans*
DC_{comp}	=	*Duty cycle of the compressor, see Table 241*
DC_{evap}	=	*Duty cycle of the evaporator fan, see Table 241*
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 241*
8,760	=	*Annual hours per year*

Table 241. Evaporator Fan Controls—Savings Calculation Input Assumptions[471]

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 GrocWkln-WEvapFMtrCtrl.[472]

[471] 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."

[472] 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.

Document Revision History

Table 242. 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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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. Added schools as an eligible building type.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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[473] per day (i.e., average continuous overnight use).

[473] 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.

$$Energy\ Savings\ [\Delta kWh] = L \times kWh_{baseline} \times 9\%$$

Equation 197

Where:

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*[474]

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.[475] Vertical and horizontal *open* equipment types were selected for inclusion given the nature of this measure.

[474] 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"

[475] In 2013, the US 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 243.
Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, US 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 243. Night Covers—Energy and Peak Demand Savings per Lin. Ft.

Temperature[476]	Condensing unit configuration	Equipment family	Average annual energy consumption/lin. ft. ($kWh_{baseline}$)	kWh Savings	kW Savings[477]
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.[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:

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

[476] 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
[477] The demand savings for this measure are 0 because energy savings exist at night only.
[478] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Operating temperature (low or medium as defined in Table 243)

- 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.

Document Revision History

Table 244. Night Covers—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 revision.
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 revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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 vertical or horizontal closed solid and glass (transparent) door reach-in refrigerators and freezers.

- Vertical closed: Equipment with hinged or sliding doors and a door angle less than 45 degrees.
- Horizontal closed: Equipment with hinged or sliding doors and a door angle greater than or equal to 45 degrees.

Eligibility Criteria

Solid- or glass-door reach-in vertical and horizontal refrigerators and freezers must meet ENERGY STAR minimum efficiency requirements (See Table 246).

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

- Residential refrigerators and freezers. Residential equipment is eligible for installation in commercial applications. In this scenario, refer to the residential savings methodology described in Volume 2.
- Prep tables, horizontal open equipment, vertical open equipment, semi-vertical open equipment, remote condensing equipment, convertible temperature equipment, and ice cream freezers.

Chef base (or griddle stands) and service over counter equipment are included in the ENERGY STAR specification, but they are excluded from this measure.

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 245.

Table 245. Door Reach-Ins—Baseline Energy Consumption[479,480]

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 246.

Table 246. Door Reach-Ins—Efficient Energy Consumption Requirements[481]

Door type	Product volume (cubic feet)	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Vertical closed solid door	0 < V < 15	0.0267V + 0.8	0.21V + 0.9
	15 ≤ V < 30	0.05V + 0.45	0.12V + 2.248
	30 ≤ V < 50		0.2578V – 1.886
	V ≥ 50	0.025V + 1.6991	0.14V + 4.0
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	
Horizontal closed door (solid or glass)	All volumes	0.05V + 0.28	0.057V + 0.55

479 10 CFR 431.66. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8.

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

481 ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 5.0, US Environmental Protection Agency. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20%28Rev.%20November%20-%202022%29%20Commercial%20Refrigerators%20and%20Freezers%20Specification.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 245 and Table 246, based on the volume of the units.

The savings calculations are specified as:

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

Equation 198

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

Equation 199

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 245)*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 246)*
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_S	=	*Summer peak coincidence factor*[482] *= 1.0*

482 The summer peak coincidence factor is assumed equal to 1.0, since the annual kWh savings is divided by the total annual hours (8,760), effectively resulting in the average kW reduction during the peak period.

Deemed Energy and Demand Savings Tables

Table 247. Door Reach-Ins—Energy and Peak Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume[483,484]	kWh savings	kW savings
Refrigerator	Vertical closed solid door	0 < V < 15	9.0	693	0.079
		15 ≤ V < 30	20.6	956	0.109
		30 ≤ V < 50	41.7	1,341	0.153
		V ≥ 50	67.5	1,972	0.225
	Vertical closed glass door	0 < V < 15	47.9	1,129	0.129
		15 ≤ V < 30	21.0	1,347	0.154
		30 ≤ V < 50	42.1	1,771	0.202
		V ≥ 50	70.7	2,012	0.230
	Horizontal closed solid	0 < V < 15	11.4	850	0.097
		15 ≤ V < 30	18.6	982	0.112
		30 ≤ V < 50	30.0	1,190	0.136
		V ≥ 50	50.0	1,555	0.178
	Horizontal closed glass	0 < V < 15	3.0	1,194	0.136
		15 ≤ V < 30	20.2	1,633	0.186
		30 ≤ V < 50	30.0	1,883	0.215
		V ≥ 50	50.0	2,394	0.273

483 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 2023). https://www.energystar.gov/productfinder/product/certified-commercial-refrigerators-and-freezers/results.

484 For product types with no ENERGY STAR certified units, the low end of the volume range was used as a placeholder in the event that additional products are certified before the TRM can be updated, with one exception. Horizontal closed glass door units assume the product volume specified for the equivalent refrigerator category to avoid using a volume of zero.

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume[483,484]	kWh savings	kW savings
Freezer	Vertical closed solid door	0 < V < 15	9.4	827	0.094
		15 ≤ V < 30	20.0	1,727	0.197
		30 ≤ V < 50	42.3	3,388	0.387
		V ≥ 50	68.8	5,573	0.636
	Vertical closed glass door	0 < V < 15	6.8	1,921	0.219
		15 ≤ V < 30	20.7	4,549	0.519
		30 ≤ V < 50	41.9	8,557	0.977
		V ≥ 50	72.5	14,343	1.637
	Horizontal closed solid	0 < V < 15	14.2	2,081	0.238
		15 ≤ V < 30	19.1	2,694	0.308
		30 ≤ V < 50	30.0	4,059	0.463
		V ≥ 50	50.0	6,563	0.749
	Horizontal closed glass	0 < V < 15	3.0	2,055	0.235
		15 ≤ V < 30	15.0	5,090	0.581
		30 ≤ V < 50	30.0	8,884	1.014
		V ≥ 50	50.0	13,943	1.592

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.[485]

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 (vertical or horizontal)
- Baseline unit door type (solid or glass)

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

- Baseline unit temperature (refrigerator or freezer)
- New unit volume
- New unit orientation (vertical or horizontal)
- New unit door type (solid or glass)
- New unit temperature (refrigerator or freezer)
- Copy of ENERGY STAR certification or alternative

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.

Document Revision History

Table 248. 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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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.
v11.0	10/2023	TRM v11.0 update. Updated ENERGY STAR efficiency requirements. Clarified that residential refrigerator and freezer equipment can be installed in commercial applications following the methodology in Volume 2 of the TRM. Updated documentation requirements.
v12.0	10/2024	TRM v12.0 update. Minor corrections.

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[486], 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:

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

Equation 200

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

Equation 201

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*

[486] 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 249)
$°R_{Refrig}$	=	Refrigeration box absolute temperature, $t_{DB,Refrig}$ + 459.67 (see Table 249)

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

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

Equation 202

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

Equation 203

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 249)
Rh_{Refrig}	=	Relative humidity of the refrigerated space (see Table 249)

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

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

Equation 204

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

Equation 205

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 249)
$t_{DB,Refrig}$	=	Dry-bulb temperature of the refrigerated space (see Table 249)

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:

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

Equation 206

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

Equation 207

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

Equation 208

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

Equation 209

$$DF = \frac{2}{1 + \frac{\rho_{Refrig}}{\rho_{Adj}}^{\frac{1}{3}}}^{\frac{3}{2}}$$

Equation 210

$$q = 795.6 \times h \times w \times \left(h_{Adj} - h_{Refrig}\right) \times r_{Refrig} \times \left(1 - \frac{\rho_{Adj}}{\rho_{Refrig}}\right)^{\frac{1}{2}} \times (32.174 \times h)^{\frac{1}{2}} \times DF$$

Equation 211

Where:

v_{Adj}	=	*Specific volume of the adjacent space*
v_{Refrig}	=	*Specific volume of the refrigerated space*
ρ_{Adj}	=	*Air temperature density of the adjacent space*
ρ_{Refrig}	=	*Air temperature density of the refrigerated space*
DF	=	*Density factor*
q	=	*Refrigeration load for fully established flow*
h	=	*Doorway height (see Table 249)*
w	=	*Doorway width (see Table 249)*

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:

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

Equation 212

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

Equation 213

Where:

$Q_{baseline}$	=	*Baseline total infiltration load*
$Q_{retrofit}$	=	*Total infiltration load, post-retrofit*
m	=	*Time the door is open per day (see Table 249)*
DFF	=	*Doorway flow factor (see Table 249)*
$E_{baseline}$	=	*Baseline assumed effectiveness against infiltration, 0*
$E_{retrofit}$	=	*Assumed effectiveness against infiltration post-retrofit (see Table 249)*

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

$$kW_{baseline} = \frac{Q_{baseline}}{EER \times 1{,}000}$$

Equation 214

$$kW_{retrofit} = \frac{Q_{retrofit}}{EER \times 1{,}000}$$

Equation 215

$$kWh_{baseline} = kW_{baseline} \times EFLH$$

Equation 216

$$kWh_{retrofit} = kW_{retrofit} \times EFLH$$

Equation 217

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 249), which are averaged or weighted across suction-group types (see Table 250)*
FLH	=	*Assumed full-load hours per facility type (see Table 249)*
1,000	=	*Constant to convert from W to kW*

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 218

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

Equation 219

$$Peak\ Demand\ Savings\ [kW_{Savings}] = \frac{\Delta kW}{h \times w}$$

Equation 220

$$Energy\ Savings\ [kWh_{Savings}] = \frac{\Delta kWh}{h \times w}$$

Equation 221

Where:

ΔkW	=	*Whole-door demand savings*
ΔkWh	=	*Whole-door energy savings*

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 249. 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 250.

Table 249. Strip Curtains—Savings Calculation Input Assumptions[487]

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	–
Refrigeration box temperature		39	8	39	5	37	5	28	–
Relative humidity of adjacent surroundings	Rh	0.55	0.55	0.55	0.55	0.55	0.55	0.3	–
Relative humidity of refrigeration box		0.65	0.4	0.4	0.6	0.5	0.45	0.86	–
Height	$Height$	7	7	7	7	7	7	12	–
Width	$Weight$	3	3	3	3	3	3	10	–
Doorway flow factor	D_F	0.51	0.51	0.51	0.51	0.625	0.625	0.8	–
Effectiveness against infiltration – post-retrofit	$E_{retrofit}$	0.8	0.81	0.79	0.83	0.88	0.88	0.89	–
Time door is open per day	m	45	38	38	9	132	102	494	–
Full-load-hours (FLH) of operation	FLH	5,509	5,509	6,887	6,887	6,482	6,482	2,525	–
EER[488]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	–

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

[488] EER is not an independent variable but is rather dependent on Table 250. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 250. Strip Curtains—Default EER by System Configuration[489]

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 251. Strip Curtains—Energy Consumption and Demand for Coolers and Freezers

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	–
	$kW_{retrofit}$	0.02	0.10	0.02	0.02	0.05	0.22	0.90	–
Deemed annual energy usage	$kWh_{baseline}$	590.72	2,956	626.86	838.78	2,861	11,796	20,678	–
	$kWh_{retrofit}$	118.14	561.60	131.64	142.59	343.30	1,416	2,275	–

489 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 252.

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

Table 252. Strip Curtains—Energy and Peak Demand Savings (per sq. ft.)

	Restaurant		Convenience store		Grocery		Refrigerated warehouse	
Savings	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	0.004	0.021	0.003	0.005	0.018	0.076	0.061	–
kWh	22.50	114.01	23.58	33.15	119.88	494.32	153.36	–

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.[490]

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

[490] 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.

Document Revision History

Table 253. Strip Curtains—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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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.[491]

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 °F). Doors must have either heat-reflective treated glass, be gas-filled, or both.

[491] 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:

$$kW_{ASH} = 0.109 \text{ per door}$$ [492]

For low temperature:

$$kW_{ASH} = 0.191 \text{ per door}$$ [493]

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

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

Equation 222

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

Equation 223

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,[494] 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 224

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[492] 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.

[493] Ibid. Here, "low temperature" is equivalent to the categorization "freezers".

[494] *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.[495]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 254.

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

Equation 225[496]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*
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	=	$T_{DB} + 15$
T_{DB}	=	*Dry-bulb temperature*

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

[496] 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 226[497]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.4886737934442*
f	=	*-0.248051519588758*
g	=	*-7.57495453950879 x* 10^{-6}
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
SCT	=	$T_{DB} + 10$

Table 254. Zero-Energy Doors—Savings Calculations Input Assumptions

Climate zone	T_{DB}[498]	SCT_{MT}	SCT_{LT}	EER_{MT}	EER_{LT}
Climate Zone 1: Amarillo	98.6	113.6	108.6	6.18	4.74
Climate Zone 2: Dallas	101.4	116.4	111.4	5.91	4.56
Climate Zone 3: Houston	97.5	112.5	107.5	6.29	4.86
Climate Zone 4: Corpus Christi	96.8	111.8	106.8	6.36	4.91
Climate Zone 5: El Paso	101.1	116.1	111.1	5.94	4.58

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 227

[497] Ibid.

[498] 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

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

Equation 228

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 229

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

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

Equation 230

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:

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

Equation 231

Table 255. Zero-Energy Doors—Energy and Peak Demand Savings

Climate zone	Medium temperature		Low temperature	
	Energy savings (kWh/door)	Peak demand savings (kW/door)	Energy savings (kWh/door)	Peak demand savings (kW/door)
Climate Zone 1: Amarillo	1,139	0.130	2,092	0.239
Climate Zone 2: Dallas	1,148	0.131	2,111	0.241
Climate Zone 3: Houston	1,136	0.130	2,084	0.238
Climate Zone 4: Corpus Christi	1,134	0.129	2,080	0.237
Climate 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.[499]

[499] 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.

- 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.

Document Revision History

Table 256. Zero-Energy Doors—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 revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
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 revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
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.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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.[500] An average baseline gasket efficacy[501] of 90 percent is assumed for this measure.

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

[501] 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.[502,503] 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 257 below.

Table 257. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. of Installed Door Gasket)[504]

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[505] 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[506] 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.

502 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.

503 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.

504 Ibid., Table 5-3.

505 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.

506 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. Door Gaskets—Comparison of Projected Annual Energy Savings to CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Coolers)

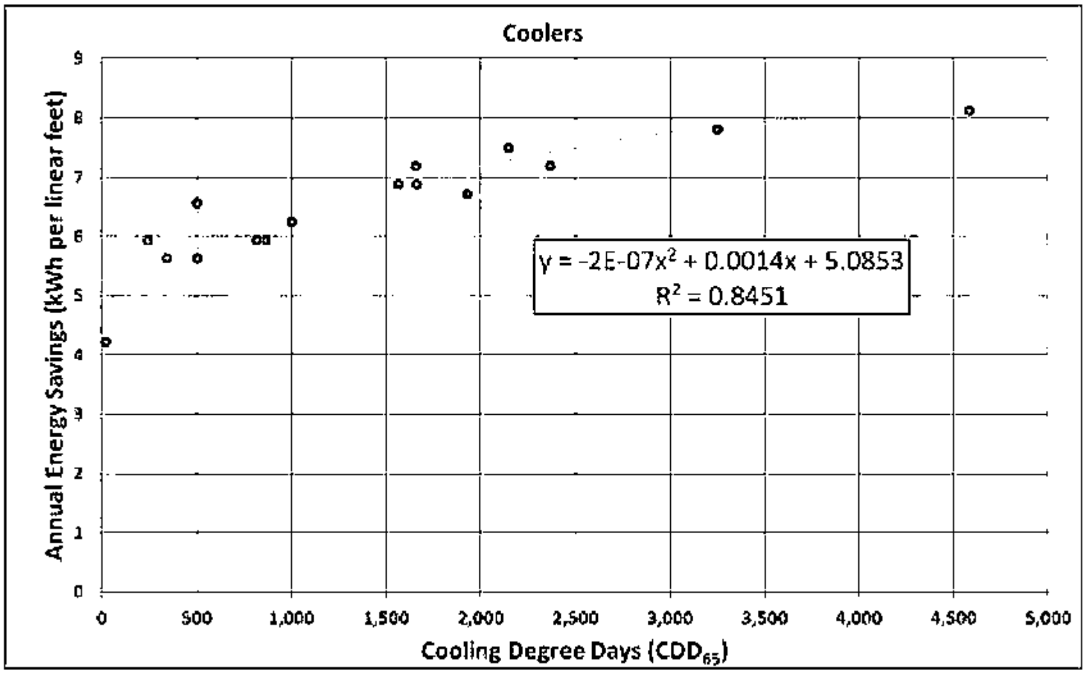
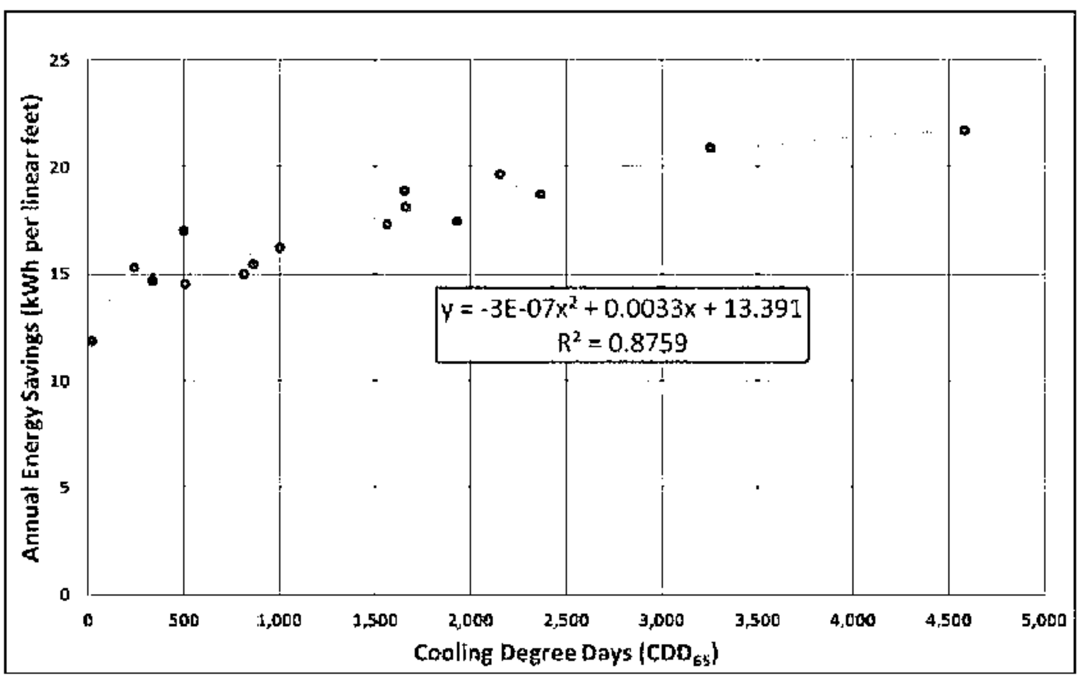


Figure 4. Door Gaskets—Comparison of Projected Annual Energy Savings to Cooling Degree CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Freezers)



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 257 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 258 below.

Table 258. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. 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:

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

Equation 232

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{kWh_{Savings}}{8{,}760} \times L$$

Equation 233

Where:

$\Delta kWh/ft$ = *Annual energy savings per linear foot of gasket (see Table 259)*

L = *Total gasket length (ft.)*

Deemed Energy and Demand Savings Tables

Table 259. Door Gaskets—Energy and Peak Demand Savings per Lin. Ft. of 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.[507]

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.

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

Document Revision History

Table 260. Door Gaskets—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 revision.
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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

2.5.10High-Speed Doors for Cold Storage Measure Overview

TRM Measure ID: NR-RF-HS

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: All commercial with cold storage

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).[508] 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.

[508] 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

$$Energy\ Savings\ [\Delta kWh] = \frac{w \times h^{1.5} \times EF}{COP\ \times 3{,}412}$$

Equation 234

$$EF = hours\ \times 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times DFF \times \Delta E$$

Equation 235

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{w \times h^{1.5} \times CF}{COP\ \times 3{,}412}$$

Equation 236

$$CF = 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times DFF \times \Delta E$$

Equation 237

Where:

w = *Width of the door opening (ft.)*

h = *Height of the door opening (ft.)*

EF = *The outcome of Equation 235 based on climate zone and cold storage application, see Table 261 and Table 262*

CF = *The outcome of Equation 237 based on climate zone and cold storage application, see Table 263, Table 264, and Table 265*

hours = *Operating hours, 3,798*[509]

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

3,790	=	*Constant*[510]
q_s/A	=	*Sensible heat load of infiltration air per square foot of door opening, ton/ft², see Table 266*
R_s	=	*Sensible heat ratio of the infiltration air heat gain, see Table 267*
ΔD_t	=	*Change in percent of time the doorway is open, 0.33*[511]
DFF	=	*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*[512]
ΔE	=	*Change in door effectiveness, 0.2*[513]
COP	=	*Coefficient of performance, assume 2.8 COP*[514]
3,412	=	*Constant to convert from Btu to kWh and from Btuh to kW*

Table 261. High-Speed Doors—Energy Factors for Door to Unconditioned Area

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

510 From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

511 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.

512 ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 17 notes.

513 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.

514 Air cooled chiller efficiency from IECC 2009.

Table 262. High-Speed Doors—Energy Factors for Door to Conditioned Area

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

Table 263. High-Speed Doors—Coincidence Factor for Door to Conditioned Area

Climate zone	All temperatures
All climate zones	1.0

Table 264. High-Speed Doors—Summer Coincidence Factors for Door to Unconditioned Area

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

Table 265. High-Speed Doors—Winter Coincidence Factors for Door to Unconditioned Area

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

Table 266. High-Speed Doors—Sensible Heat Load of Infiltration Air[515]

Cold room temperature	Climate zone: 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
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 267. High-Speed Doors—Sensible Heat Ratio of Infiltration Air[516]

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
Climate Zone 1: Amarillo	0.77	0.73	0.71	0.81	1.0	1.0	1.0
Climate Zone 2: Dallas	0.70	0.66	0.62	0.62			
Climate Zone 3: Houston	0.66	0.62	0.57	0.55			
Climate Zone 4: Corpus Christi	0.63	0.58	0.53	0.50			
Climate Zone 5: El Paso	0.80	0.77	0.78	0.92			

515 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.

516 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.

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 237 implies Equation 234 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

The estimated useful life (EUL) for this measure is 16 years based on Navigant's 2018 ComEd Effective Useful Life Research Report.[517]

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 or county
- 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.

[517] "ComEd Effective Useful Life Research Report." Navigant. May 14, 2018. Table A-4. https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf.

Document Revision History

Table 268. High-Speed Doors—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Updated EUL from 5 to 16 years to match recommendations from 2018 Navigant report.

2.6 NONRESIDENTIAL: WATER HEATING

2.6.1 Heat Pump Water Heaters Measure Overview

TRM Measure ID: C-WH-HW

Market Sector: Commercial

Measure Category: Water heating

Applicable Building Types: Office, retail, warehouse, schools, lodging, master-metered multifamily

Fuels Affected: Electricity and gas

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 an electric storage water heater with an ENERGY STAR compliant heat pump water heater (HPWH) in a commercial application.

Eligibility Criteria

This measure applies to commercial consumer electric storage HPWHs. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

First hour rating (FHR) is a proxy for draw pattern. There are no certified ENERGY STAR water heaters in the very small usage category, and that draw pattern is not covered in the current ENERGY STAR specification. Ninety-eight percent of certified units are in the *medium* and *high* usage categories. However, HPWHs with low usage draw patterns are eligible as long as they comply with minimum ENERGY STAR FHR requirements.

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency uniform energy factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.[518]

[518] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8.

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.[519] The TRM will add an early retirement baseline after the effective date for the new standard.

Table 269. HPWHs—Federal Standard for Consumer Electric Storage Water Heaters

Rated storage volume	Draw pattern	FHR [520,521]	UEF[522]
≥ 20 gal and ≤ 55 gal	Very small usage	$0 \le FHR < 18$	$0.8808 - (0.0008 \times V_r)$
	Low usage	$18 \le FHR < 51$	$0.9254 - (0.0003 \times V_r)$
	Medium usage	$51 \le FHR < 75$	$0.9307 - (0.0002 \times V_r)$
	High usage	$75 \le FHR$	$0.9349 - (0.0001 \times V_r)$
> 55 gal and ≤ 120 gal	Very small usage	$0 \le FHR < 18$	$1.9236 - (0.0011 \times V_r)$
	Low usage	$18 \le FHR < 51$	$2.0440 - (0.0011 \times V_r)$
	Medium usage	$51 \le FHR < 75$	$2.1171 - (0.0011 \times V_r)$
	High usage	$75 \le FHR$	$2.2418 - (0.0011 \times V_r)$

The DOE efficiency standard effectively requires HPWHs (assuming electric water heating) for storage water heaters with tank sizes greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 270.[523]

Table 270. HPWHs—ENERGY STAR Specification

Criteria		ENERGY STAR requirement
UEF	Integrated HPWH	UEF ≥ 3.30
	Integrated HPWH, 120 volt/15 amp circuit	UEF ≥ 2.20
	Split-system HPWHT	UEF ≥ 2.20

[519] Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063.

[520] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[521] Assume FHR equal to that of installed water heater.

[522] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

[523] ENERGY STAR HPWH Key Product Criteria. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.

Criteria	ENERGY STAR requirement
First-hour rating	FHR ≥ 45 gallons per hour
Warranty	Warranty ≥ 6 years on sealed system
Safety	UL 174 and UL 1995 or UL 60335-2-40
Lower compressor cut-off temperature (reporting requirement only)	Report ambient temperature below which the compressor cuts off and electric-resistance-only operation begins

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.[524]

HPWHs depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces where temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.[525]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

HPWH savings are calculated on a per-unit basis. Deemed savings are calculated utilizing the standard algorithms outlined below for water heating. Consumption in gallons per year us estimated using data from Building America Performance Analysis Procedures for Existing Homes.[526] Temperature data are based on TMY3 dataset.[527] The area served by the HPWH may only be a portion of a commercial building, the area served by the water heater must be documented. Alternately, the daily demand per unit in the table may also be used to estimate consumption and translated to annual consumption.

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524 ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

525 Heat Pump Water Heaters. Department of Energy, May 2012. http://energy.gov/energysaver/articles/heat-pump-water-heaters

526 Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

527 TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Energy Savings Algorithm

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times \frac{GPY}{SF} \times A \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

Equation 238

Where:

ρ = *Water density [lbs/gal] = 8.33*

C_p = *Specific heat of water [Btu/lb·°F] = 1*

GPY/SF = *Estimated annual hot water use intensity [gal/year/sf] (see Table 271)*

Table 271. HPWHs—Water Heater Consumption (Gal/Year)[528]

Building type	Unit	Daily demand (gal/unit/day)	Units/ 1,000 ft^2	Applicabl e days/yea r	GPY/SF
Education (primary)	Person	0.6	9.5	200	1.14
Education (secondary)	Person	1.8	9.5	200	3.42
Lodging (hotel)	Unit (room)	14	2.2	365	11.242
Lodging (motel)	Unit (room)	20	5.0	365	36.5
Mercantile	Employee	2	1.0	365	0.73
Office	Person	1	2.3	250	0.575
Warehouse	Employee	2	0.5	250	0.25
Other	Employee	1	0.7	250	0.175
Master meter multifamily	Energy savings identified Volume 2, Residential, Measure 2.4.2				

A = *Building square footage served by the water heater [sf]*

DD = *Daily demand per unit per day (see Table 271)*

Quantity = *Necessary number of units (HPWHs) per 1,000 sq ft. depending on the building type (see Table 271)*

[528] Osman S, & Koomey, J. G J 1995, National Laboratory 1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting. Table 2. https://escholarship.org/uc/item/2j42t2c3.

$T_{setpoint}$	=	*Water heater setpoint temperature [°F]*[529] *= 120*
$T_{supply,annual}$	=	*Average annual supply water temperature [°F] (see Table 272)*
UEF_{pre}	=	*Baseline uniform energy factor (calculate per Table 269)*
UEF_{post}	=	*Uniform energy factor of new water heater*
3,412	=	*Constant to convert from Btu to kWh*

Table 272. HPWHs—Water Mains Temperature (°F)[530]

Climate zone	$T_{supply,annual}$	$T_{supply,seasonal}$	
		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
Zone 5: El Paso	70.4	81.5	60.4

Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412} \times CF_{S/W}$$

Equation 239

Where:

$T_{supply,seasonal}$	=	*Seasonal supply water temperature [°F] (see Table 272)*
$CF_{S/W}$	=	*Seasonal peak coincidence factor (see Table 273)*

[529] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The 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.

[530] Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Table 273. HPWHs—Seasonal Peak CFs[531]

Building type	Commercial		Lodging	
Climate zone	Summer	Winter	Summer	Winter
Zone 1: Amarillo	0.00016	0.00011	0.00012	0.00015
Zone 2: Dallas	0.00017	0.00011	0.00012	0.00012
Zone 3: Houston	0.00016	0.00011	0.00012	0.00015
Zone 4: Corpus Christi	0.00016	0.00011	0.00012	0.00015
Zone 5: El Paso	0.00018	0.00011	0.00012	0.00014

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.

Note that this measure does not account for the interactive air conditioning energy savings and heating penalty associated with the HPWH when installed inside a conditioned space.

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.

Upstream/Midstream Delivery

For upstream/midstream program designs where the building type is known, use the GPY identified in Table 271 associated with the proper building type and the area of the building must be reported.

For program designs where the building type is unknown, you use the savings coefficients from the *other* building type and assume the area served by the water heater is equal to 5,000 square feet.

[531] Probability weighted seasonal peak CFs are calculated according to the method in Section 4 of 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 are used for summer calculations. Off Peak Season, Peak Weekday values are used for winter calculations. http://loadshape.epri.com/enduse

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 13 years.[532]

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 or county
- Building type
- Building area served or daily demand and quantity of units identified
- Manufacturer and model number of new HPWH
- Baseline volume (gallons), FHR, and UEF
- New HPWH volume (gallons), FHR, and UEF
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

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.

532 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, "Heat Pump Water Heaters and American Homes: A Good Fit?" p 9-74. https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf.

Document Revision History

Table 274. Commercial Heat Pump Water Heaters—Revision History

TRM version	Date	Description of change
v11.0	10/2023	TRM v11.0 origin.
v12.0	10/2024	TRM v12.0 update. Cleaned up table column labels and equation parameter definitions. Updated building type names to align with Volume 3 naming convention.

2.6.2 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

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

Equation 240

$$Pump\ Peak\ Demand\ Savings\ [\Delta kW] = kWh_{savings,pump} \times CF$$

Equation 241

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%*[533]
Hours	=	*Hours per year = 8,760*
CF	=	*Seasonal peak coincidence factor, see Table 275*

Table 275. Central DHW Controls—Seasonal Peak CFs[534]

Building type	Commercial		Lodging[535]	
Climate zone	Summer	Winter	Summer	Winter
Climate Zone 1: Amarillo	0.00016	0.00011	0.00012	0.00015
Climate Zone 2: Dallas	0.00017	0.00011	0.00012	0.00014
Climate Zone 3: Houston	0.00016	0.00011	0.00012	0.00015

533 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.

534 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.

535 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[535]	
Climate zone	Summer	Winter	Summer	Winter
Climate Zone 4: Corpus Christi	0.00016	0.00011	0.00012	0.00015
Climate Zone 5: El Paso	0.00018	0.00011	0.00012	0.00014

Thermal Distribution Savings Algorithm

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

Equation 242

$$Thermal\ Peak\ Demand\ Savings\ [\Delta kW] = kWh_{\ savings,thermal} \times CF$$

Equation 243

Where:

# Units	=	*The number of dwelling units at the project site*
$kWh_{reference}$	=	*Annual kWh energy savings from reference study (see Table 276)*
HDD Adjustment	=	*Climate adjustment for Texas heating degree days (see Table 277)*

Table 276. Central DHW Controls—Reference kWh by Water Heater and Building Type[536]

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

Table 277. Central DHW Controls—HDD Adjustment Factors[537]

Climate zone	HDD adjustment
Climate Zone 1: Amarillo	1.9
Climate Zone 2: Dallas	1.1
Climate Zone 3: Houston	0.7
Climate Zone 4: Corpus Christi	0.5
Climate Zone 5: El Paso	1.1

536 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.

537 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 278 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 278. Central DHW Controls—Circulation Pump Energy 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 279 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 279. Central DHW Controls—Thermal Distribution Energy Savings per Dwelling Unit

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

Deemed Summer and Winter Demand Savings Tables

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

Table 280. Central DHW Controls—Circulation Pump Peak Demand Savings

		Commercial		Lodging	
Pump size	Climate zone	Summer kW	Winter kW	Summer kW	Winter kW
≤ 50	Climate Zone 1: Amarillo	0.065	0.045	0.049	0.061
	Climate Zone 2: Dallas	0.069	0.045	0.049	0.057
	Climate Zone 3: Houston	0.065	0.045	0.049	0.061
	Climate Zone 4: Corpus Christi	0.065	0.045	0.049	0.061
	Climate Zone 5: El Paso	0.073	0.045	0.049	0.057

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

Table 281. Central DHW Controls—Thermal Distribution Peak Demand 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
Climate Zone 1: Amarillo	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Climate Zone 2: Dallas	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Climate Zone 3: Houston	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Climate Zone 4: Corpus Christi	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Climate Zone 5: El Paso	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.[538]

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 or county
- 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.

Document Revision History

Table 282. 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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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

2.6.3 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)[539] 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.

[539] 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 244

Where:

SHFR = *Showerhead flow rate, gallons per minute [gpm] (see Table 283)*

BW = *Behavioral waste, minutes per shower (see Table 283)*

n_S = *Number of showers per occupied room per day (see Table 283)*

365 = *Constant to convert days to years (see Table 283)*

OCC = *Occupancy rate (see Table 283)*

n_{SH} = *Number of showerheads per room (see Table 283)*

Applying the formula to the values used for Texas from Table 283 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 283.

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

Equation 245

Where:

HW% = *Hot water percentage (see Table 283)*

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

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

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

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

Table 283. 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)[540]	1.742			
Showers/occupied room/day[541]	1.756			
Occupancy rate[542]	65.9%			
Showerheads/room[543]	1.0			
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water[544]	80-85%, or 82.5% on average			
Hot water saved/year (gal)	1,516	1,213	1,062	910

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV\ [\Delta kWh] = \frac{\rho \times C_P \times V \times (T_{Setpoint} - T_{Supply,Avg})}{RE \times 3{,}412}$$

Equation 246

[540] 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.
[541] 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.
[542] 2001-2021 US 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).
[543] Assuming industry standard for standard one-bathroom rooms.
[544] 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.

Where:

ρ	=	*Water density [lb/gal] = 8.33*
C_p	=	*Specific heat of water [Btu/lb°F] = 1*
V	=	*Hot water saved per year per showerhead [gal] (see Table 283)*
$T_{Setpoint}$	=	*Water heater setpoint [°F]*[545] *= 120*
$T_{Supply,Avg}$	=	*Average supply water temperature [°F] (see Table 284)*
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.*[546]
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.

$$Demand\ Savings\ per\ TSRV\ [\Delta kW] = \frac{\rho \times C_P \times V \times (T_{Setpoint} - T_{Supply,Seasonal})}{RE \times 3{,}412 \times 365} \times CF_{S/W}$$

Equation 247

Where:

$T_{Supply,Seasonal}$	=	*Seasonal supply water temperature (see Table 284)*
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor (see Table 285)*

[545] 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.

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

Table 284. Showerhead TSRVs—Water Mains Temperatures

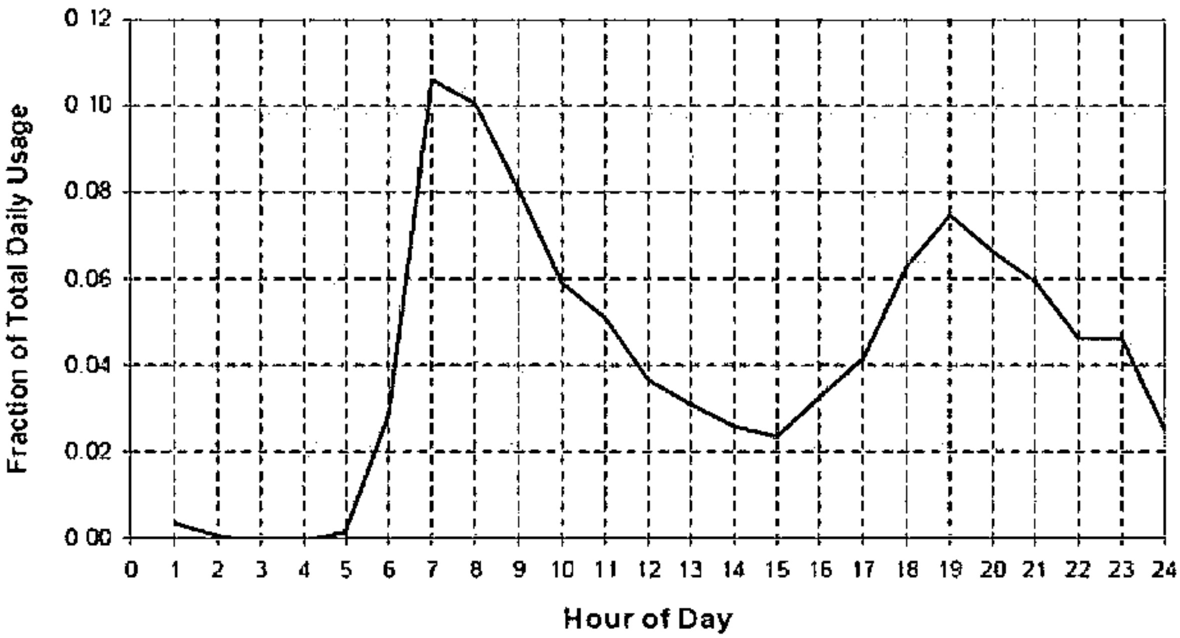
Climate zone	Water mains temperature (°F)[547]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 285. 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

547 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[548]



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.

[548] 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.[549] This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[550]

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 or county
- 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 286. Showerhead TSRVs—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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

[549] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[550] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.

2.6.4 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)[551] 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.

[551] 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 248

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

Equation 249

Where:

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 287)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 287)*

SHFR = *Showerhead flow rate, gallons per minute (gpm) (see Table 287)*

TSFR = *Tub spout flow rate, gallons per minute (gpm) (see Table 287)*

BW = *Behavioral waste, minutes per shower (see Table 287)*

n_S = *Number of showers per occupied room per day (see Table 287)*

365 = *Constant to convert days to years (see Table 287)*

OCC = *Occupancy rate (see Table 287)*

n_{SH} = *Number of showerheads per room (see Table 287)*

Applying the formula to the values from Table 287 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 250

Where:

DLR = *Diverter leakage rate (gpm) (see Table 287)*

t_S = *Shower time (min/shower) (see Table 287)*

Applying the formula to the values used for Texas from Table 287 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 287.

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

Equation 251

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 287)*

HW%$_{D}$ = *Diverter hot-water percentage (see Table 287)*

Applying the formula to the values from Table 287 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 287. 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			–
Tub-spout flow rate (gpm)[552]	–	5.0		–
Percentage of warm-up events[553]	60%	40%		–
Average behavioral waste (minutes per shower)[554]	1.742			–
Average diverter leakage-rate (gpm)[555]	–		0.80	–
Average shower time (minutes)[556]	–		7.8	–
Showers/occupied room/day[557]	1.756			
Occupancy rate[558]	65.9%			

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

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

554 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.

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

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

557 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.

558 2001–2021 US hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last five 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[559]				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[560]	80-85%, or 82.5% average		73.7%	–
Gallons of hot water saved per year (1.5 gpm)			–	3,700
Gallons of hot water saved per year (1.75 gpm)			–	3,791
Gallons of hot water saved per year (2.0 gpm)			–	3,882
Gallons of hot water saved per year (2.5 gpm)			–	4,064

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TS\ System\ [\Delta kWh] = \frac{\rho \times C_P \times V \times (T_{Setpoint} - T_{Supply,Avg})}{RE \times 3{,}412}$$

Equation 252

Where:

ρ = *Water density [lb/gal] = 8.33*

C_p = *Specific heat of water [Btu/lb°F] = 1*

V = *Hot water saved per year per showerhead [gal] (see Table 287)*

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

[560] 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 [°F]*[561] *= 120*
$T_{Supply,Avg}$	=	*Average supply water temperature [°F] (see Table 288)*
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*[562]
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.

$$Demand\ Savings\ per\ TS\ System\ [\Delta kW] = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3{,}412 \times 365} \times CF_{S/W}$$

Equation 253

Where:

$T_{Supply,Seasonal}$	=	*Seasonal-supply water temperature (see Table 288)*
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor (see Table 289)*

Table 288. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature (°F)[563]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	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

[561] 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.

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

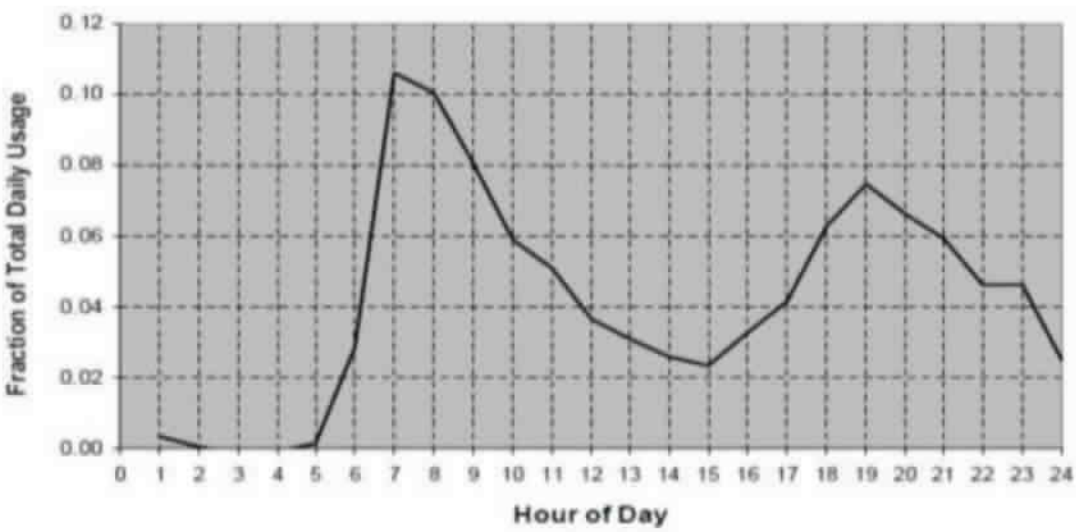
[563] Based on typical meteorological year (TMY) dataset for TMY3: https://sam.nrel.gov/weather-data.htmlhttps://nsrdb.nrel.gov/about/tmy.html.

Climate zone	Water mains temperature (°F)[563]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	Summer	Winter
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 289. Tub Spout/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

Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[564]



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.

564 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.[565]

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 or county
- 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 290. Tub Spout/Showerhead TSRVs—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 revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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

2.7 NONRESIDENTIAL: MISCELLANEOUS

2.7.1 Variable Frequency Drives for Water Pumping Measure Overview

TRM Measure ID: NR-MS-WP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All commercial

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 measure involves the installation of a variable frequency drive (VFD) in a water pumping application such as for domestic water supply, wastewater treatment, and conveyance.

Eligibility Criteria

Water pumps must be less than or equal to 100 hp. Custom applications are more appropriate for applications above 100 hp. New construction systems are ineligible. Equipment used for irrigation or process loads are ineligible.

Baseline Condition

The baseline condition is a water pump with no variable speed-control ability.

High-Efficiency Condition

The high-efficiency condition is the installation of a VFD on a water pump.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Demand savings are calculated for each hour over the course of the year:

Step 1: Determine the percentage flow rate for each of the year (*i*)

Baseline Technology[566]:

$$\%power_{base} = 2.5294 \times \%GPM_i^3 - 4.7443 \times \%GPM_i^2 + 3.2485 \times \%GPM_i + 0$$

Equation 254

Where:

%GPM	=	*Percentage flow rate (see Table 291)*
i	=	*Each hour of the year*

Table 291. Water Pumping VFDs—Water Demand Profile[567]

Hour ending	% flow rate	Hour ending	% flow rate
1	0.078	13	0.529
2	0.039	14	0.471
3	0.010	15	0.412
4	0.010	16	0.471
5	0.039	17	0.549
6	0.275	18	0.725
7	0.941	19	0.863
8	1.000	20	0.824
9	0.961	21	0.745
10	0.843	22	0.608
11	0.765	23	0.529
12	0.608	24	0.294

VFD Technology[568]:

$$\%power_{VFD} = 0.7347 \times \%GPM_i^3 - 0.301 \times \%GPM_i^2 + 0.5726 \times \%GPM_i + 0$$

Equation 255

566 PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

567 NREL, Development of Standardized Domestic Hot Water Event Schedules for Residential Buildings, Fig. 2 Combined domestic hot water use profile for the Benchmark, representing average use. https://www.nrel.gov/docs/fy08osti/40874.pdf.

568 PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

Step 3 - Calculate kW_{full} using the hp from the motor nameplate, load factor and the applicable motor efficiency. Use that result and the %power results to determine power consumption at each hour:

$$kW_{full} = 0.746 \times HP \times \frac{LF}{\eta}$$

Equation 256

$$kW_i = kW_{full} \times \%power_i$$

Equation 257

Where:

$\%power_i$	=	*Percentage of full load pump power needed at the i^{th} hour calculated by an equation based on the control type*
kW_{full}	=	*Fan motor demand operating at typical design conditions*
kW_i	=	*Pump real-time power at the i^{th} hour of the year*
HP	=	*Rated horsepower of the motor*
LF	=	*Load factor—ratio of the operating load to the nameplate rating of the motor; default assumption is 75%*
0.746	=	*Constant to convert from hp to kW*
η	=	*Motor efficiency of a standard efficiency motor (see Table 292)*

Table 292. Water Pumping VFDs—Motor Efficiencies[569]

Motor hp	Full load efficiency	Motor hp	Full load efficiency
1	0.855	25	0.936
2	0.865	30	0.941
3	0.895	40	0.941
5	0.895	50	0.945
7.5	0.910	60	0.950
10	0.917	75	0.950
15	0.930	100	0.954
20	0.930		

[569] Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

Step 4 - Calculate the kW savings for each of the top 20 hours within the applicable peak probability analysis for the building's climate zone from Volume 1.

Hourly and Peak Demand Savings Calculations

$$kW_{i,Saved} = kW_{i,Baseline} - kW_{i,VFD}$$

Equation 258

$$kW_{PDPF,Saved} = \frac{\sum_{i=1}^{20}\left(kW_{i,Saved} * PDPF_i\right)}{\sum_{i=1}^{20}(PDPF_i)}$$

Equation 259

Where:

PDPF = *Winter peak demand probability factor from the applicable climate zone table in Volume 1; there are no summer demand savings for this measure*

Energy Savings are calculated in the following manner:

Step 1 – For both the baseline and new technology, calculate the sum of individual kWh consumption in each hour of the year:

$$Enegy\ Savings\ [\Delta kWh] = \sum_{i=1}^{8,760}(kW_i)$$

Equation 260

Where:

8,760 = *Total number of hours in a year*

Step 2 – Subtract Annual kWh_{new} from Annual $kWh_{baseline}$ to get the energy savings:

$$Energy\ Savings\ [kWh] = kWh_{baseline} - kWh_{new}$$

Equation 261

Deemed Energy and Demand Savings Tables

Table 334 presents the deemed summer and winter peak kilowatt savings per motor horsepower.

Table 293. Water Pumping VFDs—Energy and Peak Demand Savings per Motor HP

Climate zone	kWh savings per motor HP	Winter peak demand kW savings per motor HP
Climate Zone 1: Amarillo	1,389	0.097
Climate Zone 2: Dallas		0.069
Climate Zone 3: Houston		0.067

Climate zone	kWh savings per motor HP	Winter peak demand kW savings per motor HP
Climate Zone 4: Corpus Christi		0.138
Climate Zone 5: El Paso		0.106

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 12.5 years, which is the average EUL for pump VSD applications as specified in the California Database of Energy Efficiency Resources (DEER) READI tool.[570]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Unit quantity
- Motor horsepower

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 294. Water Pumping VFDs—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. General text edits.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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

2.7.2 Water Pumps Measure Overview

TRM Measure ID: NR-MS-WP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All commercial

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

This measure is defined as the installation of a clean water pump with pump energy index (PEI) as specified below. This document presents the methodology for calculating the savings realized from installing efficient commercial water pumps.

Eligibility Criteria

Clean water pumps that are intended for agricultural, commercial, and industrial sectors with a nominal pump motor horsepower rating of ≤ 250 must meet the PEI requirements specified below. Additionally, the PEI should be confirmed on the Hydraulic Institute (HI) database (https://er.pumps.org/ratings/search).

Any of the following clean water rotodynamic pump classes are eligible:

- End suction frame mount (ESFM)
- End suction close coupled (ESCC)
- In-line (IL)
- Radially split multi-stage vertical in-line diffuser casing (RSV)
- Vertical turbine submersible (ST)

For variable speed pumps, programs must verify that the pumps are operating at variable speed to achieve variable flow. Verification process includes providing photographs of the pump controls, pump management system, and/or a written description of the pump control strategy.

Baseline Condition

The baseline condition for this measure is a clean water pump with a PEI rating specified in Table 295 below. Under Title 10 Section 431.462, the US Department of Energy (DOE) developed the Energy Conservation Standard (ECS) for commercial, industrial, and agricultural clean water pumps.[571] As of January 2020, all clean water pumps sold are required to have an ECS label with a PEI rating of ≤ 1.0.

These baseline values were calculated from a database of performance data collected from major manufacturers and the HI. The baseline PEI ratings are representative of the most commonly available (mode) of the data set for each control strategy and pump motor horsepower range.

High-Efficiency Condition

The high-efficiency condition is a constant speed or variable speed clean water pump that meets or exceeds the conditions in Table 295 below.

Table 295. Water Pumps—Baseline and High-Efficiency Conditions

Pump motor horsepower	Control strategy	Baseline PEI	Efficient PEI
1 ≤ hp ≤ 15	Variable Speed	0.47	≤ 0.45
1 ≤ hp ≤ 15	Constant Speed	0.94	≤ 0.92
15 < hp ≤ 50	Variable Speed	0.49	≤ 0.47
15 < hp ≤ 50	Constant Speed	0.94	≤ 0.92
50 < hp ≤ 250	Variable Speed	0.49	≤ 0.47
50 < hp ≤ 250	Constant Speed	0.95	≤ 0.93

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

The energy savings analysis was adopted from the pump savings analysis approved by the Regional Technical Forum (RTF) for the Northwest Energy Efficiency Alliance (NEEA) Efficient Commercial and Industrial Pumps (ECIP) Project.[572] This analysis was approved in April 2022, and included extensive pump modeling, DOE database information, and customer/vendor field data.

[571] Code of Federal Regulations at 10 CFR Subpart Y. https://www.caetrm.com/media/reference-documents/CFR-2018-title10-vol3-sec431-462.pdf.
[572] RTF. 2016. "Research Strategy for Efficient Pumps." December 6.

The energy savings from retrofitting a base case pump to a more efficient measure case pump is based on the NEEA modification of the HI pump energy savings calculation.[573] The HI energy savings calculation assumes a conservative base case efficiency scenario and does not include adjustment factors to account for pump nominal power and actual pump performance variances. The NEEA modifications of the HI calculation considered baseline market average pump efficiencies and adjustment factors that consider nominal versus actual power draw and actual pump system curves.

The energy savings analysis NEEA was streamlined for this measure. The electric energy savings for installing high efficiency pumps is calculated using the equation below.

$$Energy\ Savings\ [\Delta kWh] = \frac{P_{Pump}}{P_{Motor}} \times (PEI_{base} - PEI_{eff}) \times AOH \times AF_{OPHr} \times 0.746$$

Equation 262

Where:

HRS_{OPYr}	=	*Annual operating hours, see Table 332*
AF_{OPHr}	=	*Final load profile adjustment factors by application and speed control case, see Table 332*
P_{Pump}	=	*Nominal pump size in horsepower (hp)*
P_{Motof}	=	*Nominal motor size in horsepower (hp)*
PEI_{base}	=	*Base PEI of the pump, see Table 295*
PEI_{Eff}	=	*Efficient PEI of the pump*
AOH	=	*Annual operating hours, see Table 332*
AF	=	*Final load profile adjustment factors by application and speed control case, see Table 332*
0.746	=	*Constant to convert from hp to kW*

Table 296. Water Pumps—Annual Operating Hours and Adjustment Factors[574]

Control strategy	Sector	AOH	AF
Constant speed	Agricultural	2,358	1.325
	Commercial	3,753	1.250
	Industrial	6,175	1.310
Variable speed	Agricultural	2,358	1.845
	Commercial	3,753	1.000
	Industrial	6,175	1.214

573 https://www.caetrm.com/measure/SWWP004/03/.
574 Pacific Gas and Electric Company (PG&E). 2023. "SWWP004 Savings_and_Cost_Analysis_12-14-2023.xlsm"

Summer Peak Demand Savings

There are no summer peak demand savings for this measure.

Winter Peak Demand Savings

There are no winter peak demand savings for this measure.

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 15 years as specified in Database of Energy Efficiency Resources (DEER) 2008.[575]

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:

- Quantity
- Application type (agricultural, commercial, industrial)
- Pump model number
- Efficient pump horsepower
- Efficient motor horsepower
- Control strategy
    - For variable speed, provide photos of the pump controls and pump management system
- Efficient pump PEI rating
- Proof of purchase (e.g., invoices, commissioning reports, photos)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

[575] www.deeresources.com

Relevant Standards and Reference Sources

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

Document Revision History

Table 297. Water Pumps—Revision History

TRM version	Date	Description of change
v12.0	10/2024	TRM v12.0 origin

2.7.3 Premium Efficiency Motors Measure Overview

TRM Measure ID: NR-MS-PM

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Currently a wide variety of NEMA premium efficiency motors from 1 to 500 horsepower (hp) are available. Deemed saving values for demand and energy savings associated with this measure must be for electric motors with an equivalent operating period (hours x load factor) over 1,000 hours.

Eligibility Criteria

To qualify for early retirement, the premium efficiency unit must replace an existing, full-size unit with a maximum age of 16 years. To determine the remaining useful life of an existing unit, see Table 302. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Baseline and High-Efficiency Conditions

New Construction or Replace-on-Burnout

EISA 2007 Sec 313 adopted new federal standards for motors manufactured in the United States from December 19, 2010, to before June 1, 2016, with increased efficiency requirements for 250-500 hp motors as of June 1, 2016. These standards replace legislation commonly referred to as EP Act 1992 (the Federal Energy Policy Act of 1992). The standards can also be found in section 431.25 of the Code of Federal Regulations (10 CFR Part 431).[576]

[576] Federal Standards for Electric Motors, Table 1: Nominal Full-load Efficiencies of General Purpose Electric Motors (Subtype I), Except Fire Pump Electric Motors, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b. Accessed July 2020.

With these changes, motors ranging from one to 500 hp bearing the "NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

Additionally, NEMA premium standards include general purpose electric motors, subtype II (i.e., motors ranging from 1-200 hp and 200-500 hp) including:

- U-frame motors
- Design C motors
- Close-coupled pump motors
- Footless motors
- Vertical solid shaft normal thrust (tested in a horizontal configuration)
- 8-pole motors
- All poly-phase motors up to 600 volts (minus 230/460 volts, covered EPAct-92)

Under these legislative changes, 200-500 hp and subtype II motor baselines will be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct)[577] (see Table 301) and are thus no longer equivalent to pre-1992/pre-EPAct defaults.

Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct)[578], as listed in Table 303.

NEMA premium efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for replacement motors for both replace-on-burnout and early retirement projects exceeds that listed in Table 301.

For early retirement, the maximum age of eligible equipment is capped at the expected 75 percent of the equipment failure (17 years). ROB savings should be applied when age of the unit exceeds 75 percent failure age. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure. 1-200 hp motors manufactured as of December 19, 2010 and 250-500 hp motors manufactured as of June 1, 2016 are not eligible for early retirement.

[577] Federal Standards for Electric Motors, Table 4: Nominal Full-load Efficiencies of NEMA Design B General Purpose Electric Motors (Subtype I and II), Except Fire Pump Electric Motors, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

[578] Federal Standards for Electric Motors, Tables 3 (≤ 200 hp), and 4 (> 200hp), https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Actual motor operating hours are expected to be used to calculate savings. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 298 or Table 299 can be used.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{savings,ROB} = HP \times 0.746 \times LF \times \left(\frac{1}{\eta_{baseline,ROB}} - \frac{1}{\eta_{post}}\right) \times Hrs$$

Equation 263

Demand Savings Algorithms

HVAC Applications:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{Hrs}\right) \times CF$$

Equation 264

Industrial Applications[579]:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{8{,}760\ hours}\right)$$

Equation 265

Where:

HP	=	*Nameplate horsepower data of the motor*
0.746	=	*Constant to convert from hp to kWh[580]*
LF	=	*Estimated load factor (if unknown, see Table 298 or Table 299)*

[579] Assumes three-shift operating schedule

[580] US DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 10.2.2.1 Motor Capacity". Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

$\eta_{baseline,ROB}$	=	*Assumed original motor efficiency [%] (see Table 301)*[581]
η_{post}	=	*Efficiency of the newly installed motor [%]*
Hrs	=	*Estimated annual operating hours (if unknown, see Table 298 or Table 299)*
CF	=	*Peak coincidence factor (see Table 298)*
$kWh_{savings,ROB}$	=	*Total energy savings for a new construction or ROB project*
$kW_{savings,ROB}$	=	*Total demand savings for a new construction or ROB project*

Table 298. Premium Motors—HVAC Input Assumptions

Building type	Load factor[582]	CF[583]	HVAC fan hours[584]
Education: K-12 school	0.75	1.00	4,173
Education: College/university			4,590
Food service: Quick-service restaurant			6,716
Food service: Full-service restaurant			5,256
Healthcare: Inpatient			8,760
Mercantile: All retail			5,548
Office: Large (>30k sq. ft.)			4,424
Office: Small (≤30k sq. ft.)			4,006

581 In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 300.

582 Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

583 Commercial Prototype Building Models HVAC operating schedules for hours ending 15-18. US Department of Energy. https://www.energycodes.gov/development/commercial/prototype_models

584 Factors are equivalent to Table 92 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 299. Premium Motors—Industrial Input Assumptions

Industrial processing	Load factor[585]	Hours[586]					
		Chem	Paper	Metals	Petroleum refinery	Food production	Other
1-5 hp	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20 hp	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50 hp	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100 hp	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200 hp	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500 hp	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000 hp		7,495	7,255	7,750	5,934	5,260	8,157
> 1,000 hp		7,693	8,294	7,198	6,859	6,240	2,601

Table 300. Premium Motors—Rewound Motor Efficiency Reduction Factors[587]

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

Table 301. Premium Motors—NC/ROB Baseline Efficiencies by Motor Size (%)[576,580,592]

hp	Open motors: $\eta_{baseline, ROB}$			Closed motors: $\eta_{baseline, ROB}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0

585 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

586 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

587 US DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 8.2.2.1 Annual Energy Consumption". Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.