T_H	=	*Average mixed hot water (after spray valve) temperature for prewashing [ºF] = 120°F*[354]
T_C	=	*Average supply (cold) water temperature [ºF] = 71.4°F*[355]
ρ	=	*Water density [lbs/gal] = 8.33*
C_P	=	*Specific heat of water [Btu/lb°F] = 1*
RE	=	*Recovery efficiency of an electric water heater = 0.98*[356]
3,412	=	*Constant to convert from Btu to kWh*
CF	=	*Seasonal peak coincidence factor (see Table 176)*
100,000	=	*Constant to convert values for easier readability*

Table 175. PRSVs—Assumed Variables for Energy and Peak Demand Savings Calculations

Variable	Assumed value
U[357]	Food service: Full-service restaurant: 105 min/day/unit Office: Cafeteria: 210 min/day/unit Education: College/university cafeteria: 210 min/day/unit Food service: Quick-service restaurant: 45 min/day/unit Education: K-12 cafeteria: 105 min/day/unit
AOD[358]	Food service: Full-service restaurant: 360 Office: Cafeteria: 360 Education: College/university cafeteria: 270 Food service: Quick-service restaurant: 360 Education: K-12 school cafeteria: 193

[354] "CEE Commercial Kitchens Initiative Program Guidance on Pre-Rince Spray Valves," Consortium of Energy Efficiency (CEE). Page 3. https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf.

[355] Average calculated input water temperature for five Texas climate zone cities, based on typical meteorological year (TMY) dataset for TMY3: Available at http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

[356] Recovery efficiency of electric water heaters as listed on the AHRI Directory of Certified Product Performance. https://www.ahridirectory.org.

[357] "CEE Commercial Kitchens Initiative Program Guidance on pre-rinse valves", page 3. Midpoint of typical hours of operation in footnoted building types. https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf.

[358] For facilities that operate year-round: assume operating days of 360 days/year; For schools open weekdays except summer: 360 x(5/7) x (9/12) = 193; For dormitories with few occupants in the summer: 360 x (9/12) = 270.

Table 176. PRSV—Seasonal Peak CFs[359]

Climate zone	Summer CF			Winter CF		
	Food service: Full-service restaurant and cafeterias[360]	Food service: Quick-service restaurant	Education: K-12 school cafeteria	Food service: Full-service restaurant and cafeterias[361]	Food service: Quick-service restaurant	Education: K-12 school cafeteria
Climate Zone 1: Amarillo	3.151	6.298	2.537	5.026	6.205	0.666
Climate Zone 2: Dallas	4.767	5.850	2.630	4.279	5.868	0.899
Climate Zone 3: Houston	3.544	6.237	2.627	3.219	5.015	1.556
Climate Zone 4: Corpus Christi	3.092	6.214	2.768	5.462	6.754	1.561
Climate Zone 5: El Paso	6.805	5.660	3.934	7.063	8.490	0.000

Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please see the High-Efficiency Condition section for the rationale used in opting for an algorithm-based approach.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-LowPreRinse.[362]

---

359 CFs are developed according to the method described in the Texas TRM Volume 1, using load profiles derived from the American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., ASHRAE Handbook 2019. HVAC Applications. Chapter 50 51 - Service Water Heating, Section 9 – Hot Water Load and Equipment Sizing, Figure 24 – Hourly Flow Profiles for Various Building Types. CF values are multiplied by 100,000 to allow for easier readability of the values.

360 This building type should be used for Food Service: Full-service restaurant, Office: Cafeteria, and Education: College/university cafeteria.

361 Ibid.

362 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.

- Spray force in ounce-force (ozf)
- Baseline equipment flow-rate
- Retrofit equipment flow-rate
- Building type

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Attachment A: https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF.
- PUCT Docket 36779—Provides EUL for pre-rinse sprayers

Relevant Standards and Reference Sources

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

Document Revision History

Table 177. PRSVs—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. Updated the baseline and post-Retrofit minimum flow rate values, based on federal standards. Removed reference to a list of qualifying pre-rinse spray valves.
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. General reference checks, updates to input assumptions, and update peak demand savings. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Formula and variable definition updates.
v11.0	10/2023	TRM v11.0 update. Adjusted mixed water hot temperature to match CEE guidance. Aligned building type names across all commercial measures.

2.4.11 Vacuum-Sealing and Packaging Machines Measure Overview

TRM Measure ID: NR-MS-VS

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Supermarket, Grocery, Food Store

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

This measure involves the replacement of always-on commercial electric vacuum-sealing and packaging machines with on-demand commercial electric vacuum-sealing and packaging machines. Packaging machines consist of a heating bar and heating platform. The heating bar is used to cut the wrapping film as it meets the heating bar. The heating platform is used to heat up the wrapping film. When the wrapping film is heated, the film sticks to the package and seals the product.

Eligibility Criteria

Eligible vacuum-sealing and packaging machines must use either a mechanical or optical control system. A mechanical system applies downward pressure onto a larger heating element platform, engaging a switch that activates a heating element until the switch is disengaged (or for a maximum of three seconds). An optical system uses an optical eye to detect that an item is being sealed. The eye is placed in the front center of a large heating element. When a package is set on the heating element, light is reflected into the eye, engaging the heating element until it is removed (or for a maximum of three seconds).

The measure is restricted to supermarket, grocery, and other food store building types.

Baseline Condition

The baseline is a conventional (always-on) packaging machine. With conventional machines, both heating elements are kept at a constant temperature of 280°F.

High-Efficiency Condition

The high-efficiency condition is an on-demand packaging machine. On-demand machines are similar but have a more powerful heating platform, which defaults to off and is switched on/off by a controller.

Savings Algorithms and Input Variables

Southern California Edison (SCE) and the Food Service Technology Center (FSTC) conducted a field study to evaluate and compare energy savings and demand reduction potential between baseline and on-demand package sealers in supermarkets.[363] The study included four supermarket chains, with three sites selected for each chain. Each test site operated approximately 20 hours per day. Package sealers were located in deli, meat, and or produce departments. Power data was measured in 10-second intervals over a six-week monitoring period. A low sample interval was chosen to accurately capture the pulsing of the heating elements.

The study estimated demand savings by averaging power draw during the peak hours from 2-5 PM to account for the cycling of the larger heating element on the on-demand unit. This measure uses 10-minute average load shape to estimate coincidence factors consistent with the Texas peak definition.[364] This approach is more consistent with the 15-minute interval data typically used in calculated demand and energy charges by utilities. Demand savings are calculated by dividing energy savings by 8,760 and multiplying against the coincidence factor.

Deemed Energy and Demand Savings Tables

Table 178. Vacuum-Sealing & Packaging Machines—Energy and Peak Demand Savings

Building type	kWh/machine	Summer kW/ machine	Winter kW/ machine
Supermarkets, grocery, and food stores	1,568	0.06	0.06

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) for vacuum-sealing and packaging machines is 10 years, based on the University of California Useful Life Indices.[365]

363 "Vacuum-Sealing and Packaging Machines for Food Service Field Test, ET13SCE1190 Report," SCE & FTSC. December 2014. https://www.etcc-ca.com/sites/default/files/reports/ET10SCE1450%20Vacuum%20Sealing%20Packaging%20Machine%20Report_Final.pdf.

364 See Volume 1, Section 4.

365 "Useful Life Indices for Equipment Depreciation", University of California Office of the President. https://eulid.ucop.edu/.

Program Tracking Data and Evaluation Requirements

The below list 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.

- Building type
- Number of packaging machines
- Packaging machine manufacturer and model

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 179. Vacuum-Sealing & Packaging Machines—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

2.5 NONRESIDENTIAL: REFRIGERATION

2.5.1 Door Heater Controls Measure Overview

TRM Measure ID: NR-RF-HC

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 door heater controls for glass-door refrigerated cases with anti-sweat heaters (ASH). A door heater controller senses dew point (DP) temperature in the store and modules power supplied to the heaters accordingly. DP inside a building is primarily dependent on the moisture content of outdoor ambient air. Because the outdoor DP varies between climate zones, weather data from each climate zone must be analyzed to obtain a DP profile. The reduced heating results in a reduced cooling load. The savings are on a per-horizontal-linear-foot-of-display-case basis.

Eligibility Criteria

The efficient equipment must be a standard-heat configuration door heater control utilized in an eligible commercial retail facility on glass-door refrigerated cases for the purpose of dynamically controlling humidity.

Baseline Condition

The baseline efficiency case is a cooler or a freezer door heater that operates 8,760 hours per year without any controls.

High-Efficiency Condition

Eligible high efficiency equipment is a cooler or a freezer door heater connected to a heater control system, which controls the door heaters by measuring the ambient humidity and temperature of the store, calculating the dew point (DP) temperature, and using pulse width modulation to control the anti-sweat door heater based on specific algorithms for freezer and cooler doors.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of anti-sweat heater controls are a result of both the decrease in length of time the heater is running (kWh_{ASH}) and the reduction in load on the refrigeration (kWh_{refrig}). These savings are calculated using the following procedures:

Indoor dew point (T_{d-in}) can be calculated from outdoor dew point (T_{d-out}) per climate zone using the following equation:

$$T_{d-in} = 0.005379 \times T_{d-out}^2 + 0.171795 \times T_{d-out} + 19.87006$$

Equation 134[366]

The baseline assumes door heaters are running on an 8,760-hour operating schedule. In the post-retrofit case, the duty for each hourly reading is calculated by assuming a linear relationship between indoor DP and duty cycle for each bin reading. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89ºF DP and all on (duty cycle of 100%) at 52.87ºF DP for a typical supermarket.[367] Between these values, the door heaters' duty cycle changes proportionally:

$$Door\ Heater\ ON\% = \frac{T_{d-in} - All\ OFF\ setpt\ (42.89°F)}{All\ ON\ setpt\ (52.87°\mathrm{F}) - All\ OFF\ setpt\ (42.89°F)}$$

Equation 135

The controller only changes the run-time of the heaters, so the instantaneous door heater power (kW_{ASH}) as a resistive load remains constant per linear foot of door heater[368] at:

For medium temperature (coolers):

kW_{ASH} = 0.109 per door or 0.0436 per horizontal linear foot of door[369]

Equation 136

[366] 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.

[367] Ibid, "Direct ASH Power", page 6.
42.89ºF DP and 52.87ºF DP correspond to relative humidity of 35 percent and 50 percent, respectively, for a 72ºF indoor space. These relative humidity values are common practice setpoints for a typical supermarket of this temperature.

[368] Pennsylvania TRM, "3.5.6 Controls: Anti-Sweat Heater Controls". page 381, Table 3-101. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx. Additional reference from Pennsylvania TRM: State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual. Table 4-75., March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf.

[369] Ibid.

For low temperature (freezers):

$$kW_{ASH} = 0.191 \text{ per door or } 0.0764 \text{ per horizontal linear foot of door}$$ [370]

Equation 137

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 138

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

Equation 139

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,[371] the cooling load contribution from door heaters for each hour of the year 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 140

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

---

370 Ibid.

371 A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

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

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

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

Equation 141[373]

Where:

a	=	*3.75346018700468*
b	=	*-0. 049642253137389*
c	=	*29.4589834935596*
d	=	*0.000342066982768282*
e	=	*-11.7705583766926*
f	=	*-0.212941092717051*
g	=	*-1.46606221890819 x* 10^{-6}
h	=	*6.80170133906075*
I	=	*-0.020187240339536*
j	=	*0.000657941213335828*
PLR	=	*1/1.15 = 0.87*
SCT	=	T_{db} *+ 15*
T_{DB}	=	*Dry-bulb temperature*

For low temperature compressors, the following equation is used to determine the 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 142[374]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*

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

[374] Ibid.

d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	*-7.57495453950879 x* 10^{-6}
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.87*
SCT_{LT}	=	T_{db} *+10*
T_{DB}	=	*Dry-bulb temperature*

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 143

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

Equation 144

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of both annual kWh consumption variables:

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

Equation 145

Total energy savings is the difference between the baseline and post-retrofit case:

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

Equation 146

Peak demand savings are calculated as the weighted average of the probability of winter or summer peak load's top twenty hours' coincidence with system peak and the hourly calculated kWh_{total} for said twenty hours per climate zone.

Deemed Energy and Demand Savings Tables

The energy and demand savings of anti-sweat door heater controls are deemed values based on city/climate zone and refrigeration temperature, with hourly dry-bulb temperatures and outdoor dew points determined using TMY3 Hourly Weather Data by Climate Zone;[375] Table 180 provides these deemed values. Savings are specified per horizontal linear feet of door.

Table 180. Door Heater Controls—Energy and Peak Demand Savings per Lin. Ft. of Door

Climate zone	Medium temperature		Low temperature	
	Energy savings (kWh/ft)	Peak demand savings (kW/ft)	Energy savings (kWh/ft)	Peak demand savings (kW/ft)
Climate Zone 1: Amarillo	342	0.047	610	0.081
Climate Zone 2: Dallas	232	0.047	413	0.081
Climate Zone 3: Houston	170	0.047	304	0.082
Climate Zone 4: Corpus Christi	131	0.047	234	0.083
Climate Zone 5: El Paso	380	0.047	682	0.084

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-ASH.[376]

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
- Refrigeration temperature (medium, low)
- Linear feet of door length

[375] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings
[376] 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. Attachment A: https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF. https://interchange.puc.texas.gov/Documents/40669_7_736775.PDF.
- PUCT Docket 36779—Provides EUL for Anti-Sweat Heater Controls

Relevant Standards and Reference Sources

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

Document Revision History

Table 181. Door Heater 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. In the energy savings equation used to determine the EER, rounded off the regression coefficients to 4 or 5 significant figures.
v2.1	01/30/2015	TRM v2.1 update. Correction to state that savings are on a per-linear foot of display case.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Update Deemed kW_{ASH} for Medium temperature cases and add kW_{ASH} for Low-temperature cases. Added more significant digits to the input variables a-j for Equation 141 and Equation 142.
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 peak demand methodology to follow Volume 1 methods. Changed Zone 4 reference location from McAllen to Corpus Christi. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

2.5.2 ECM Evaporator Fan Motors Measure Overview

TRM Measure ID: NR-RF-FM

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools[377]

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 algorithm methodology for the replacement of existing evaporator fan motors with electronically commutated motors (ECMs) in cooler and freezer display cases. ECMs can provide up to 65 percent reduction in fan energy use with higher efficiencies, automatic variable-speed drive, lower motor operating temperatures, and less maintenance.

Eligibility Criteria

All ECMs must be suitable, size-for-size replacements of evaporator fan motors.

Baseline Condition

The baseline efficiency case is an existing shaded pole evaporator fan motor in a refrigerated case.

High-Efficiency Condition

Eligible high-efficiency equipment is an electronically commutated motor which replaces an existing evaporator fan motor.

---

[377] 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 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 147

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

Equation 148

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

Equation 149

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

Equation 150

Freezer

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

Equation 151

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

Equation 152

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

Equation 153

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

Equation 154

Where:

N = *Number of motors replaced*

W_{base} = *Input wattage of existing/baseline evaporator fan motor (see Table 182)*

W_{ee} = *Input wattage of new energy efficient evaporator fan motor (see Table 182)*

LF	=	*Load factor of evaporator fan motor = 0.9 (default)*[378]
$DC_{EvapCool}$	=	*Duty cycle of evaporator fan motor for cooler = 100% (default)*[379]
$DC_{EvapFreeze}$	=	*Duty cycle of evaporator fan motor for freezer = 97.8% (default)*[380,381]
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.* [382,383]
%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%.*[384]
1,000	=	*Constant to convert from W to kW*

[378] 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.

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

[380] 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.

[381] "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.

[382] 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.

[383] "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.

[384] 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.[385]

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 155[386]

Where:

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

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

386 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 156[387]

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 182. ECM Evaporator Fan Motors—Motor Sizes, Efficiencies, and Input Watts[388,389]

Nominal motor size	Motor output (W)	Shaded pole eff	Shaded pole input (W)	PSC eff	PSC input (W)	ECM eff	ECM input (W)
(1-14W)	9	30%	30	60%	15	70%	13
1/40 HP (16-23W)	19.5	30%	65	60%	33	70%	28
1/20 HP (37W)	37	30%	123	60%	62	70%	53

387 Ibid.

388 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.

389 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)	Shaded pole eff	Shaded pole 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 183. ECM Evaporator Fan Motors—Cooler & Freezer Compressor COP

Climate zone	Summer design dry-bulb temperature[390]	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.[391]

[390] 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

[391] 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
- Motor efficiency
- Motor power rating
- Evaporator fan control type
- Refrigeration type (cooler, freezer)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 184. 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.

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[392]

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.

[392] 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 157

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

Equation 158

Medium temperature:

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

Equation 159

Low temperature:

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

Equation 160

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

Equation 161

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*[393]

[393] 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*[394]
DRF	=	*Defrost reduction factor—percent reduction in defrosts required per year, see Table 185*
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.[395]

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 162[396]

Where:

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

[394] 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.

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

[396] 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 163[397]

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}	=	$T_{db} + 10$

[397] Ibid.

Table 185. Defrost Controls—Savings Calculation Input Assumptions

Climate zone	DRF[398]	COP_{MT}[399]	COP_{LT}[400]
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.[401]

Program Tracking Data and Evaluation Requirements

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

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

---

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

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

400 Ibid.

401 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 186. 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.

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[402]

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.

[402] 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:

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

Equation 164

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

Equation 165

Where:

kW_{evap}	=	*Connected load kW of each evaporator fan, see Table 187*
kW_{circ}	=	*Connected load kW of the circulating fan, see Table 187*
n_{fans}	=	*Number of evaporator fans*
DC_{comp}	=	*Duty cycle of the compressor, see Table 187*
DC_{evap}	=	*Duty cycle of the evaporator fan, see Table 187*
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 187*
8,760	=	*Annual hours per year*

Table 187. Evaporator Fan Controls—Savings Calculation Input Assumptions[403]

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-WEvapFMtrCtrl.[404]

[403] 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."

[404] 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 188. 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.

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

[405] 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 166

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*[406]

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

[406] 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"

[407] In 2013, the U.S. DOE conducted an extensive life-cycle cost (LCC) analysis of the commercial refrigeration equipment classes listed in the current federal standard 10 CFR 431.66 to determine average annual unit energy consumption per equipment class. In this analysis, 10,000 separate simulations yielded probability distributions for various parameters associated with each equipment class, among them: the efficiency level in kWh/yr. These efficiency levels were then subject to roll-up calculations to determine market shares of each efficiency level, which were then utilized to compute the average consumption for said efficiency level listed in Table 189.
Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. LCC Summary Statistics: Section 8B2; Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf.

Table 189. Night Covers—Energy and Peak Demand Savings per Lin. Ft.

Temperature[408]	Condensing unit configuration	Equipment family	Average annual energy consumption/lin. ft. ($kWh_{baseline}$)	kWh Savings	kW Savings[409]
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.[410]

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)

408 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

409 The demand savings for this measure are 0 because energy savings exist at night only.

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

- Operating temperature (low or medium as defined in Table 189)

- 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 190. 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.

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 192).

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 191.

Table 191. Door Reach-Ins—Baseline Energy Consumption[411,412]

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 192.

Table 192. Door Reach-Ins—Efficient Energy Consumption Requirements[413]

<table>
<tr><th>Door type</th><th>Product volume (cubic feet)</th><th>Refrigerator daily consumption (kWh)</th><th>Freezer daily consumption (kWh)</th></tr>
<tr><td rowspan="4">Vertical closed solid door</td><td>0 < V < 15</td><td>0.0267V + 0.8</td><td>0.21V + 0.9</td></tr>
<tr><td>15 ≤ V < 30</td><td rowspan="2">0.05V + 0.45</td><td>0.12V + 2.248</td></tr>
<tr><td>30 ≤ V < 50</td><td>0.2578V – 1.886</td></tr>
<tr><td>V ≥ 50</td><td>0.025V + 1.6991</td><td>0.14V + 4.0</td></tr>
<tr><td rowspan="4">Vertical glass door</td><td>0 < V < 15</td><td>0.095V + 0.445</td><td rowspan="4">0.232V + 2.36</td></tr>
<tr><td>15 ≤ V < 30</td><td>0.05V + 1.12</td></tr>
<tr><td>30 ≤ V < 50</td><td>0.076V + 0.34</td></tr>
<tr><td>V ≥ 50</td><td>0.105V - 1.111</td></tr>
<tr><td>Horizontal closed door (solid or glass)</td><td>All volumes</td><td>0.05V + 0.28</td><td>0.057V + 0.55</td></tr>
</table>

411 10 CFR 431.66. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8.

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

413 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 191 and Table 192, based on the volume of the units.

The savings calculations are specified as:

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

Equation 167

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

Equation 168

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 191)*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 192)*
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[414] = 1.0*

[414] 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 193. Door Reach-Ins—Energy and Peak Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume[415,416]	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	.0230
	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

[415] 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.

[416] 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[415,416]	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	0.0387
		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.[417]

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)

[417] 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 194. 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.

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[418], 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:

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

Equation 169

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

Equation 170

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*

[418] 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 195)
$°R_{Refrig}$	=	Refrigeration box absolute temperature, $t_{DB,Refrig}$ + 459.67 (see Table 195)

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 171

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

Equation 172

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 195)*
Rh_{Refrig}	=	*Relative humidity of the refrigerated space (see Table 195)*

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 173

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

Equation 174

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 195)*
$t_{DB,Refrig}$	=	*Dry-bulb temperature of the refrigerated space (see Table 195)*

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:

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

Equation 175

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

Equation 176

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

Equation 177

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

Equation 178

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

Equation 179

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

Equation 180

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 195)*
w	=	*Doorway width (see Table 195)*

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 181

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

Equation 182

Where:

$Q_{baseline}$	=	*Baseline total infiltration load*
$Q_{retrofit}$	=	*Total infiltration load, post-retrofit*
m	=	*Time the door is open per day (see Table 195)*
DFF	=	*Doorway flow factor (see Table 195)*
$E_{baseline}$	=	*Baseline assumed effectiveness against infiltration, 0*
$E_{retrofit}$	=	*Assumed effectiveness against infiltration post-retrofit (see Table 195)*

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 183

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

Equation 184

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

Equation 185

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

Equation 186

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 195), which are averaged or weighted across suction-group types (see Table 196)*
FLH	=	*Assumed full-load hours per facility type (see Table 195)*
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 187

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

Equation 188

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

Equation 189

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

Equation 190

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 195. 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 196.

Table 195. Strip Curtains—Savings Calculation Input Assumptions[419]

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[420]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	–

[419] 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.

[420] EER is not an independent variable but is rather dependent on Table 196. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 196. Strip Curtains—Default EER by System Configuration[421]

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 197. 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	–

[421] 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 198.

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

Table 198. Strip Curtains—Energy and Peak Demand Savings (per sq. ft.)

Savings	Restaurant		Convenience store		Grocery		Refrigerated warehouse	
	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door	Cooler main door	Freezer main door
kW	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.[422]

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

[422] 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 199. 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.

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.[423]

High-Efficiency Condition

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

[423] 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:

$$kW_{ASH} = 0.109 \text{ per door}$$ [424]

For low temperature:

$$kW_{ASH} = 0.191 \text{ per door}$$ [425]

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 191

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

Equation 192

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,[426] 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 193

---

[424] 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.

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

[426] *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.[427]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 200.

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

Equation 194[428]

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*

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

428 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 195[429]

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 200. Zero-Energy Doors—Savings Calculations Input Assumptions

Climate zone	T_{DB}[430]	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 196

429 Ibid.

430 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

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

Equation 197

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 198

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 199

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 200

Table 201. 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.[431]

[431] 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 202. 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.

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.[432] An average baseline gasket efficacy[433] of 90 percent is assumed for this measure.

---

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

[433] 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.[434,435] 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 203 below.

Table 203. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. of Installed Door Gasket)[436]

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[437] 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[438] 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.

---

[434] 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.

[435] 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.

[436] Ibid., Table 5-3.

[437] 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.

[438] 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)

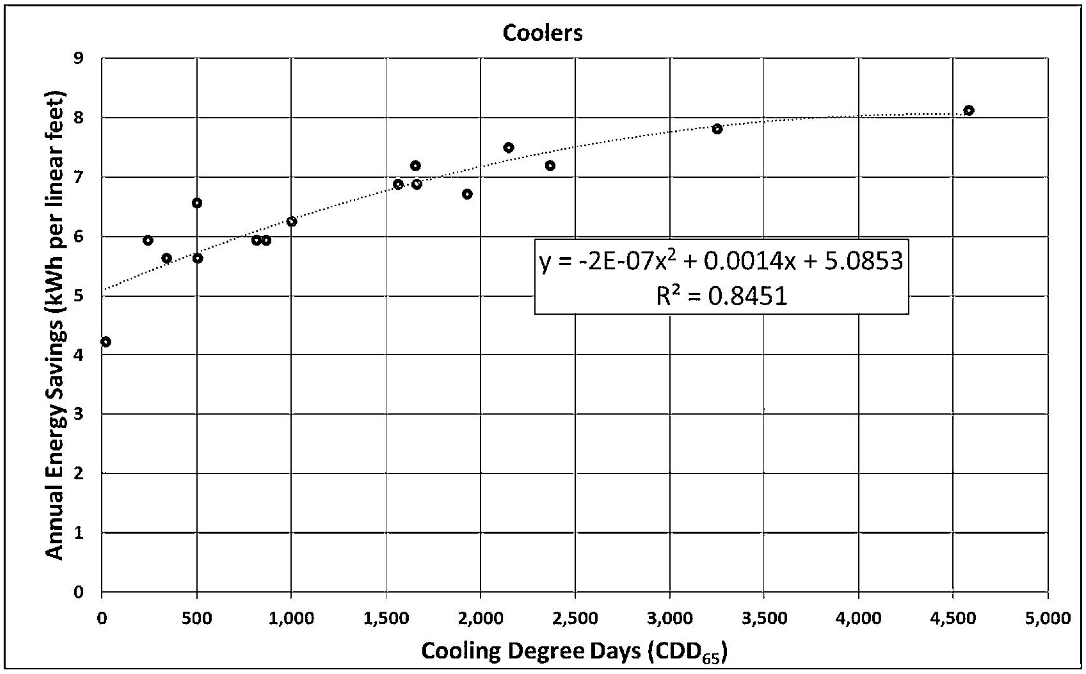
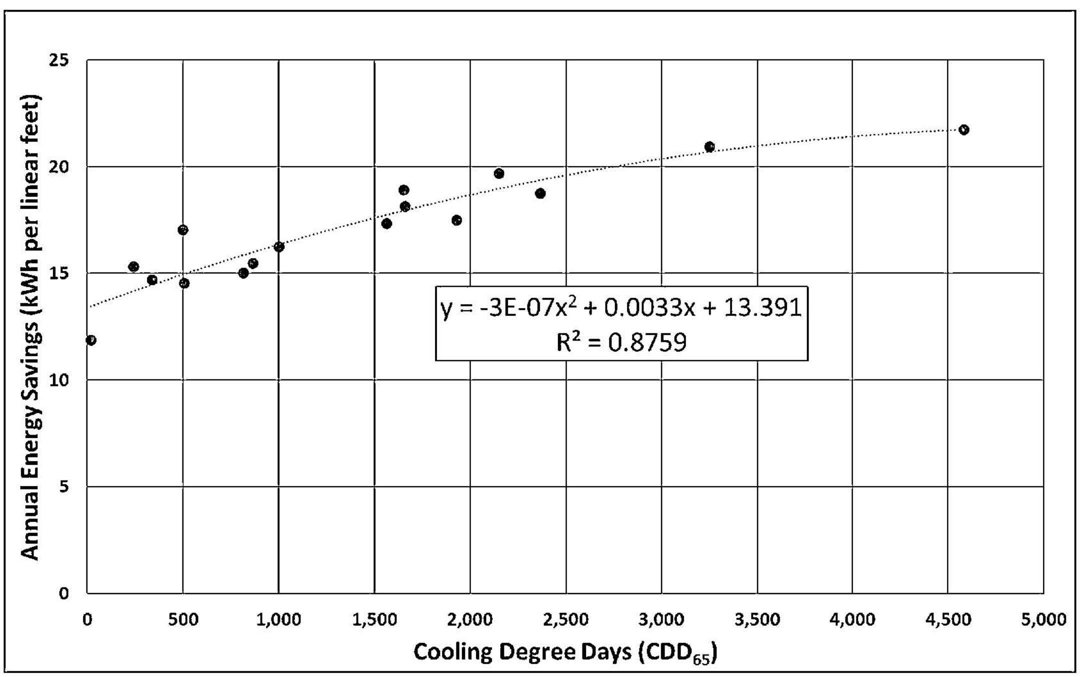


Figure 4. Door Gaskets—Comparison of Projected Annual Energy Savings to Cooling Degree CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Freezers)



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 203 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 204 below.

Table 204. 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 201

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

Equation 202

Where:

ΔkWh/ft = *Annual energy savings per linear foot of gasket (see Table 205)*

L = *Total gasket length (ft.)*

Deemed Energy and Demand Savings Tables

Table 205. 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.[439]

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.

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

Document Revision History

Table 206. 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.

2.5.10 High-Speed Doors for Cold Storage Measure Overview

TRM Measure ID: NR-RF-HS

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithms

Savings Methodology: Algorithms

Measure Description

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

Eligibility Criteria

Eligible equipment includes high-speed doors with a minimum opening rate of 32 inches per second, a minimum closing rate of 24 inches per second, and a means to automatically reclose the door, as defined by the Door and Access Systems Manufacturers' Association, International (DASMA).[440] 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.

[440] 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 203

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

Equation 204

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

Equation 205

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

Equation 206

Where:

w	=	*Width of the door opening (ft.)*
h	=	*Height of the door opening (ft.)*
EF	=	*The outcome of Equation 204 based on climate zone and cold storage application, see Table 207 and Table 208*
CF	=	*The outcome of Equation 206 based on climate zone and cold storage application, see Table 209, Table 210, and Table 211*
hours	=	*Operating hours, 3,798*[441]

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

3,790 = *Constant*[442]

q_s/A = *Sensible heat load of infiltration air per square foot of door opening, ton/ft², see Table 212*

R_s = *Sensible heat ratio of the infiltration air heat gain, see Table 213*

ΔD_t = *Change in percent of time the doorway is open, 0.33*[443]

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*[444]

ΔE = *Change in door effectiveness, 0.2*[445]

COP = *Coefficient of performance, assume 2.8 COP*[446]

3,412 = *Constant to convert from Btu to kWh and from Btuh to kW*

Table 207. 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

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

443 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.

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

445 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.

446 Air cooled chiller efficiency from IECC 2009.

Table 208. 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 209. High-Speed Doors—Summer and Winter Coincidence Factors for Door to Conditioned Area

Climate zone	All temperatures
All climate zones	1.0

Table 210. 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 211. 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 212. High-Speed Doors—Sensible Heat Load of Infiltration Air[447]

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 213. High-Speed Doors—Sensible Heat Ratio of Infiltration Air[448]

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			

447 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.

448 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 206 implies Equation 203 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 5 years based on published manufacturer warranty duration.

Program Tracking Data and Evaluation Requirements

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

- Climate zone 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.

Document Revision History

Table 214. 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.

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.[449]

---

[449] 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.[450] The TRM will add an early retirement baseline after the effective date for the new standard.

Table 215. HPWHs—Federal Standard for Consumer Electric Storage Water Heaters

Rated storage volume	Draw pattern	FHR [451,452]	UEF[453]
≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	$0.8808 - (0.0008 \times V_r)$
	Low usage	18 ≤ FHR < 51	$0.9254 - (0.0003 \times V_r)$
	Medium usage	51 ≤ FHR < 75	$0.9307 - (0.0002 \times V_r)$
	High usage	75 ≤ FHR	$0.9349 - (0.0001 \times V_r)$
> 55 gal and ≤ 120 gal	Very small usage	0 ≤ FHR < 18	$1.9236 - (0.0011 \times V_r)$
	Low usage	18 ≤ FHR < 51	$2.0440 - (0.0011 \times V_r)$
	Medium usage	51 ≤ FHR < 75	$2.1171 - (0.0011 \times V_r)$
	High usage	75 ≤ 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 216.[454]

Table 216. 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

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

[451] "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.

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

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

[454] 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.[455]

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.[456]

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.[457] Temperature data are based on TMY3 dataset.[458] 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.

[455] 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.

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

[457] 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.

[458] 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

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

Equation 207

Where:

ρ = *Water density [lbs/gal] = 8.33*

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

GPY = *Estimated annual hot water use in gallons/year.*

Calculation options: [GPY/SF x A] or [DD x Quantity x days/yr] (see Table 217).

Table 217. HPWHs—Water Heater Consumption (Gal/Year)[459]

Building type	Unit used for consumption measurement	Daily demand per unit per day (DD)	Units per 1,000 sq ft	Applicable days per year (days/yr)	Gallons per 1,000 sq. ft. per day	GPY/SF
Small office	person	1	2.3	250	2.3	0.575
Large office	person	1	2.3	250	2.3	0.575
Retail	employee	2	1.0	365	2	0.73
Warehouse	employee	2	0.5	250	1	0.25
Elementary school	person	0.6	9.5	200	5.7	1.14
Secondary school	Person	1.8	9.5	200	17.1	3.42
Motel (lodging)	unit (room)	20	5.0	365	100	36.5
Hotel (lodging)	unit (room)	14	2.2	365	30.8	11.242
Other	employee	1	0.7	250	0.7	0.175
Master meter multifamily	Energy savings identified Volume 2, Residential, Measure 2.4.2					

459 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.

A	=	*Building square footage served by the water heater*
DD	=	*Daily demand per day*
Quantity	=	*Quantity of the units identified in Table for building type*
$T_{setpoint}$	=	*Water heater setpoint temperature [°F]*[460] *= 120*
$T_{supply,annual}$	=	*Average annual supply water temperature [°F] (see Table 218)*
UEF_{pre}	=	*Baseline uniform energy factor (calculate per Table 215)*
UEF_{post}	=	*Uniform energy factor of new water heater*
3,412	=	*Constant to convert from Btu to kWh*

Table 218. HPWHs—Water Mains Temperature (°F)[461]

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 208

Where:

$T_{supply,seasonal}$	=	*Seasonal supply water temperature [°F] (see Table 218)*
$CF_{S/W}$	=	*Seasonal peak coincidence factor (see Table 219)*

460 120°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.

461 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 219. HPWHs—Seasonal Peak CFs[462]

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 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 217 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.

[462] 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.[463]

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.

Document Revision History

Table 220. Commercial Heat Pump Water Heaters—Revision History

TRM version	Date	Description of change
v11.0	10/2023	TRM v11.0 origin.

463 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.

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 209

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

Equation 210

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%*[464]
Hours	=	*Hours per year = 8,760*
CF	=	*Seasonal peak coincidence factor, see Table 221*

Table 221. Central DHW Controls—Seasonal Peak CFs[465]

Building type	Commercial		Lodging[466]	
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

464 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.

465 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.

466 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[466]	
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 211

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

Equation 212

Where:

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

$kWh_{reference}$ = *Annual kWh energy savings from reference study (see Table 222)*

HDD Adjustment = *Climate adjustment for Texas heating degree days (see Table 223)*

Table 222. Central DHW Controls—Reference kWh by Water Heater and Building Type[467]

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

Table 223. Central DHW Controls—HDD Adjustment Factors[468]

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

[467] 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.

[468] 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 224 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 224. 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 225 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 225. 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 226. 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 227. 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.[469]

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 228. 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.

[469] 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)[470] 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.

[470] 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 213

Where:

SHFR	=	*Showerhead flow rate, gallons per minute [gpm] (see Table 229)*
BW	=	*Behavioral waste, minutes per shower (see Table 229)*
n_S	=	*Number of showers per occupied room per day (see Table 229)*
365	=	*Constant to convert days to years (see Table 229)*
OCC	=	*Occupancy rate (see Table 229)*
n_{SH}	=	*Number of showerheads per room (see Table 229)*

Applying the formula to the values used for Texas from Table 229 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 229.

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

Equation 214

Where:

HW% = *Hot water percentage (see Table 229)*

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

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

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

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

Table 229. 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)[471]				1.742
Showers/occupied room/day[472]				1.756
Occupancy rate[473]				65.9%
Showerheads/room[474]				1.0
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water[475]				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 215

[471] 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.

[472] 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.

[473] 2001-2021 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 5 pre-COVID years (2015-2019).

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

[475] 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 229)*
$T_{Setpoint}$	=	*Water heater setpoint [°F]*[476] *= 120*
$T_{Supply,Avg}$	=	*Average supply water temperature [°F] (see Table 230)*
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.*[477]
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 216

Where:

$T_{Supply,Seasonal}$	=	*Seasonal supply water temperature (see Table 230)*
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor (see Table 231)*

[476] 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.

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

Table 230. Showerhead TSRVs—Water Mains Temperatures

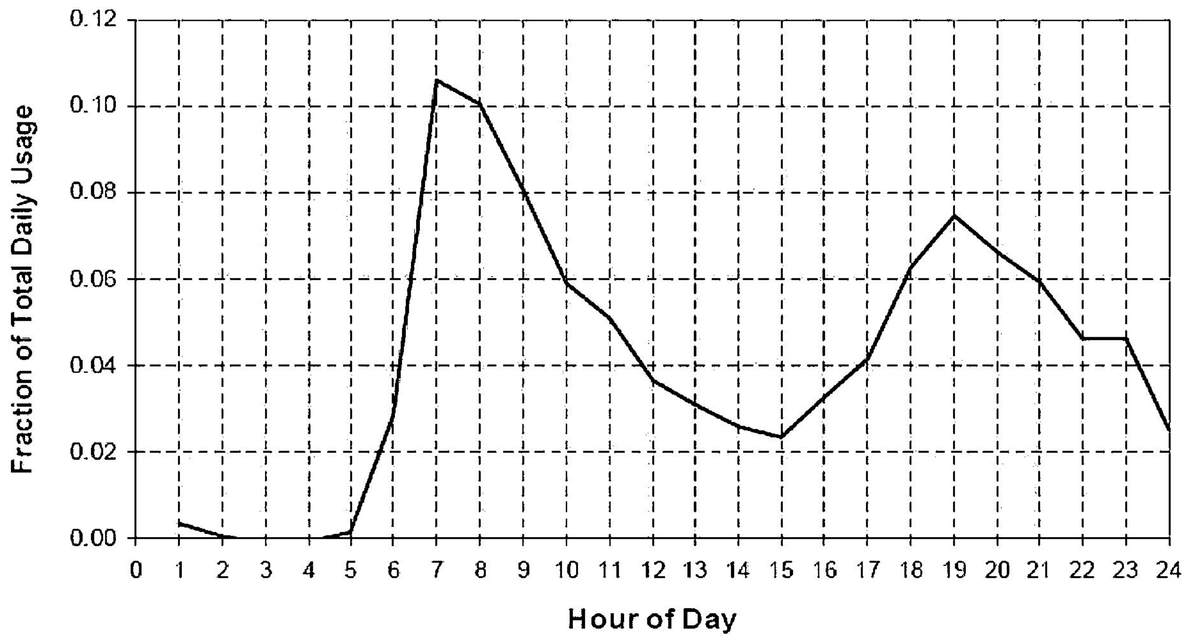
Climate zone	Water mains temperature (°F)[478]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 231. 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

[478] 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[479]



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.

[479] 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.[480] This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[481]

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 232. 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.

[480] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[481] 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)[482] 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.

[482] 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 217

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

Equation 218

Where:

$\%WUE_{SH}$	=	*Showerhead percentage of warm-up events (see Table 233)*
$\%WUE_{TS}$	=	*Tub spout percentage of warm-up events (see Table 233)*
SHFR	=	*Showerhead flow rate, gallons per minute (gpm) (see Table 233)*
TSFR	=	*Tub spout flow rate, gallons per minute (gpm) (see Table 233)*
BW	=	*Behavioral waste, minutes per shower (see Table 233)*
n_S	=	*Number of showers per occupied room per day (see Table 233)*
365	=	*Constant to convert days to years (see Table 233)*
OCC	=	*Occupancy rate (see Table 233)*
n_{SH}	=	*Number of showerheads per room (see Table 233)*

Applying the formula to the values from Table 233 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 219

Where:

DLR = *Diverter leakage rate (gpm) (see Table 233)*

t_S = *Shower time (min/shower) (see Table 233)*

Applying the formula to the values used for Texas from Table 233 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 233.

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

Equation 220

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 233)*
$HW\%_{D}$	=	*Diverter hot-water percentage (see Table 233)*

Applying the formula to the values from Table 233 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 233. 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)[483]	–	5.0		–
Percentage of warm-up events[484]	60%	40%		–
Average behavioral waste (minutes per shower)[485]		1.742		–
Average diverter leakage-rate (gpm)[486]		–	0.80	–
Average shower time (minutes)[487]		–	7.8	–
Showers/occupied room/day[488]				1.756
Occupancy rate[489]				65.9%

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

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

485 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.

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

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

488 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.

489 2001–2021 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 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[490]				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[491]	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 221

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 233)*

490 Assuming industry standard for standard one-bathroom rooms.

491 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]* [492] *= 120*

$T_{Supply,Avg}$ = *Average supply water temperature [°F] (see Table 234)*

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*[493]

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 222

Where:

$T_{Supply,Seasonal}$ = *Seasonal-supply water temperature (see Table 234)*

$CF_{S/W}$ = *Summer/winter seasonal peak coincidence factor (see Table 235)*

Table 234. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature (°F)[494]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$ Summer	$T_{SupplySeasonal}$ 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

492 120°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.

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

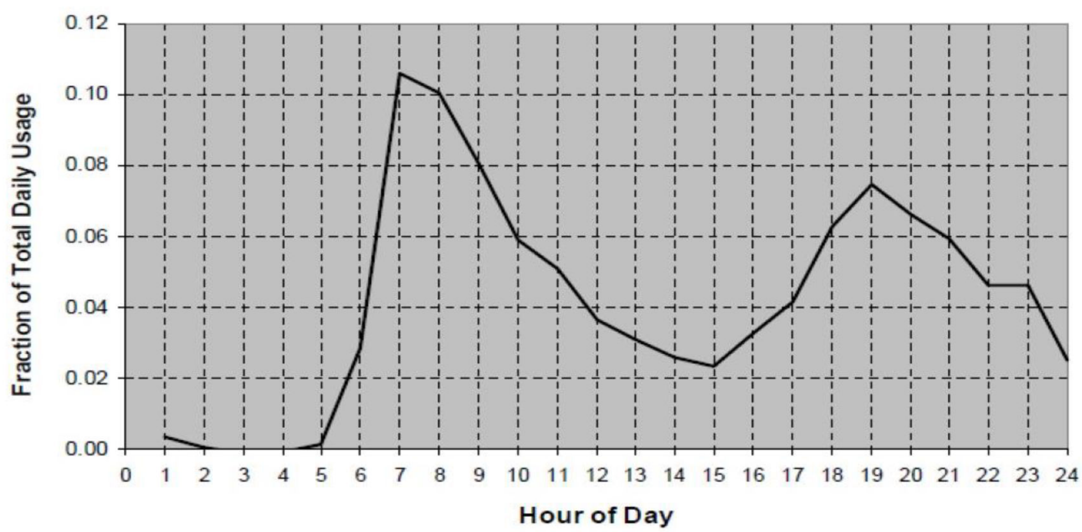
494 Based on typical meteorological year (TMY) dataset for TMY3: https://sam.nrel.gov/weather-data.htmlhttps://nsrdb.nrel.gov/about/tmy.html.

Climate zone	Water mains temperature (°F)[494]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		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 235. 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[495]



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.

[495] 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.[496]

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 236. 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.

[496] 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

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[497]:

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

Equation 223

Where:

%GPM	=	*Percentage flow rate (see Table 237)*
i	=	*Each hour of the year*

Table 237. Water Pumping VFDs—Water Demand Profile[498]

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[499]:

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

Equation 224

[497] 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.

[498] 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.

[499] 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).