Parameter	Convection mode		Steam mode	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
t_{days}	365			
CF[267]	0.90			

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 133 are based on the input assumptions from Table 131.

Table 132. Combination Ovens—Energy and Peak Demand Savings[268]

Pan capacity	kWh Savings	kW Savings	Pan capacity	kWh Savings	kW Savings
3	1,080	0.125	22	17,755	3.507
4	843	0.074	23	18,689	3.696
5	4,338	0.789	24	19,638	3.889
6	4,999	0.923	25	20,603	4.085
7	5,677	1.060	26	21,585	4.284
8	6,370	1.200	27	22,582	4.487
9	7,079	1.343	28	23,595	4.693
10	7,804	1.490	29	24,625	4.902
11	8,545	1.640	30	25,670	5.114
12	9,303	1.793	31	26,732	5.330
13	10,076	1.950	32	27,809	5.549
14	10,865	2.110	33	28,902	5.771
15	11,670	2.273	34	30,012	5.997
16	12,492	2.439	35	31,137	6.226
17	13,329	2.609	36	32,279	6.458
18	14,182	2.782	37	33,436	6.693
19	15,051	2.958	38	34,609	6.932
20	15,937	3.138	39	35,799	7.174
21	16,838	3.320	40	37,004	7.420

[267] Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

[268] ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment Calculator. http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

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) Remote Ex-Ante Database Interface (READI) tool for EUL ID Cook-ElecCombOven.[269]

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.

- Manufacturer and model number
- Pan capacity
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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 133. Combination Ovens—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.

[269] DEER READI. http://www.deeresources.com/index.php/readi.

TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. Updated previous method based upon the Food Service Technology Center (FSTC) assumptions to an approach using the newly developed ENERGY STAR Commercial Ovens Program Requirements Version 2.1, which added combination ovens under this version. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR measure.
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. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator updates. Corrected ENERGY STAR idle rate formulas. Updated tracking system requirements and EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.

2.4.2 ENERGY STAR® Electric Convection Ovens Measure Overview

TRM Measure ID: NR-FS-CV

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See eligibility criteria

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 section covers the savings from retrofit or new installation of a full-size or half-size ENERGY STAR electric convection ovens. Convection ovens cook their food by forcing hot dry air over the surface of the food product. The rapidly moving hot air strips away the layer of cooler air next to the food and enables the food to absorb the heat energy. The energy and demand savings are deemed and based on oven energy rates, cooking efficiencies, operating hours, production capacities, and building type. Average energy and demand consumption, used to calculate the savings, are determined using these assumed default input values on a per-oven basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification, with half-size and full-size electric ovens as defined below:[270, 271]

- Full-size convection oven: capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch.
- Half-size convection oven: capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch.

[270] ENERGY STAR® Program Requirements for Commercial Ovens. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf

[271] ENERGY STAR® Qualified Product Listing. https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[272]

Convection ovens eligible for rebate do not include ovens that can heat the cooking cavity with saturated or superheated steam. However, eligible convection ovens may have moisture injection capabilities (e.g., baking ovens and moisture-assist ovens). Ovens that include a "hold feature" are eligible under this specification if convection is the only method used to fully cook the food.

Products listed below are excluded from the ENERGY STAR eligibility criteria:

- Half-size gas convection ovens
- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, hearth, microwave, range, rapid cook, reel-type, and rotisserie
- Mini and quadruple gas rack ovens
- Electric rack ovens
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie

Baseline Condition

The baseline condition for retrofit situations is an electric convection oven that does not meet ENERGY STAR key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v3.0 specification, effective January 12, 2023. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 134.

[272] CEE Commercial Kitchens Initiative's overview of the food service industry. https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf

Table 134. Convection Ovens—ENERGY STAR Specification[273]

Oven size	Idle rate (W)	Cooking energy efficiency (%)
Full size ≥ 5 pans	≤ 1,400	≥ 76
Full size < 5 pans	≤ 1,000	
Half size	≤ 1,000	≥ 71

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The deemed savings from these ovens are based on the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = kWh_{base} - kWh_{ES}$$

Equation 99

$$kWh_{base} = kWh_{ph,base} + kWh_{cook,base} + kWh_{idle,base}$$

Equation 100

$$kWh_{ES} = kWh_{ph,ES} + kWh_{cook,ES} + kWh_{idle,ES}$$

Equation 101

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 102, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 135.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{cook}}\right) + E_{idle} \times \left(t_{on} - \frac{W_{food}}{PC}\right)\right) \times \frac{t_{days}}{1{,}000}$$

Equation 102

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1{,}000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 103

Where:

kWh_{base} = *Baseline annual energy consumption [kWh]*

kWh_{ES} = *ENERGY STAR annual energy consumption [kWh]*

[273] ENERGY STAR® Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

E_{ph}	=	*Preheat energy [Wh/BTU]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity [lb/hr]*
t_{on}	=	*Operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Coincidence factor*

Table 135. Convection Ovens—Savings Calculation Input Assumptions[274]

Parameter	Full size ≥ 5 pans		Full size < 5 pans		Half size	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR®	Baseline	ENERGY STAR
E_{ph}	1,563	1,389	1,563	1,389	890	700
W_{food}	100					
E_{food}	73.2					
η_{cook}	65%	76%	65%	76%	68%	70.67%
E_{idle}	2,000	1,400	2,000	1,000	1,030	1,000
PC	90	90	90	90	45	50
t_{on}	12					
t_{days}	365					
CF[275]	0.90					

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 137 are based on the input assumptions from Table 135.

[274] ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[275] Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

Table 136. Convection Ovens—Energy and Peak Demand Savings

Oven size	kWh Savings	kW Savings
Full size ≥ 5 pans	3,043	0.612
Full size < 5 pans	4,633	0.939
Half size	244	0.036

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 Cook-ElecConvOven.[276]

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.

- Manufacturer and model number
- Pan capacity
- Oven size
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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.

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

Document Revision History

Table 137. Convection Ovens—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. Updated to newer ENERGY STAR Commercial Ovens Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR Measure.
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. Corrected convection oven definitions. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated changes from March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.

2.4.3 ENERGY STAR® Dishwashers Measure Overview

TRM Measure ID: NR-FS-DW

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See eligibility criteria

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 section covers the deemed savings methodology for the installation of ENERGY STAR commercial dishwashers. On average, commercial dishwashers that have earned ENERGY STAR certification are 25 percent more energy-efficient and 25 percent more water-efficient than standard models. The energy savings associated with ENERGY STAR commercial dishwashers are primarily due to reduced water use and reduced need to heat water. A commercial kitchen may have external booster water heaters, or booster water heaters may be internal to specific equipment. Both primary and booster water heaters may be either gas or electric; therefore, dishwasher programs need to ensure the savings calculations used are appropriate for the water heating equipment installed at the participating customer's facility. The energy and demand savings are determined on a per-dishwasher basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification and fall under one of the following categories.[277, 278] These categories are described in Table 138:

- Under counter dishwasher
- Stationary rack, single tank, door type dishwasher
- Single tank conveyor dishwasher
- Multiple tank conveyor dishwasher
- Pot, pan, and utensil

[277] ENERGY STAR® Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria Version 3.0. https://www.energystar.gov/products/commercial_dishwashers/partners.

[278] ENERGY STAR® Qualified Product Listing. https://www.energystar.gov/productfinder/product/certified-commercial-dishwashers/results.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[279]

Dishwashers intended for use in residential or laboratory applications are not eligible for ENERGY STAR® under this product specification. Steam, gas, and other non-electric models also do not qualify.

Additionally, though single- and multiple-tank flight-type conveyor dishwashing machines (where the dishes are loaded directly on the conveyor rather than transported within a rack—also referred to as a rackless conveyor) are eligible as per the version 3.0 specification, they are considered ineligible for this measure, since default values are not available for flight-type dishwashers in the ENERGY STAR Commercial Kitchen Equipment Calculator.

Table 138. Dishwashers—ENERGY STAR Equipment Type Descriptions

Equipment type	Equipment description
Under-counter dishwasher	A machine with an overall height of 38" or less, in which a rack of dishes remains stationary within the machine while being subjected to sequential wash and rinse sprays and is designed to be installed under food preparation workspaces. Under-counter dishwashers can be either chemical or hot-water sanitizing, with an internal booster heater for the latter. For purposes of this specification, only those machines designed for wash cycles of ten minutes or less can qualify for ENERGY STAR®.
Stationary-rack, single-tank, door-type dishwasher	A machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. Subcategories of stationary door type machines include single- and multiple-wash tank, double rack, pot, pan and utensil washers, chemical dump type, and hooded wash compartment ("hood type"). Stationary-rack, single-tank, door-type models are covered by this specification and can be either chemical or hot-water sanitizing, with an internal or external booster heater for the latter.
Single-tank conveyor dishwasher	A washing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine. Specifically, a single-tank conveyor machine has a tank for wash water followed by a final sanitizing rinse and does not have a pumped rinse tank. This type of machine may include a pre-washing section before the washing section. Single-tank conveyor dishwashers can either be chemical or hot-water sanitizing, with an internal or external booster heater for the latter.
Multiple-tank conveyor dishwasher	A conveyor-type machine that has one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a final sanitizing rinse. This type of machine may include one or more pre-washing sections before the washing section. Multiple-tank conveyor dishwashers can be either chemical or hot-water sanitizing, with an internal or external hot-water-booster heater for the latter.
Pot, pan, and utensil	A stationary-rack, door-type machine designed to clean and sanitize pots, pans, and kitchen utensils.

[279] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf

Baseline Condition

Baseline equipment is either a low-temperature[280] or high-temperature[281] machine as defined by Table 138, which is not used in a residential or laboratory setting. For low-temperature units, the DHW is assumed to be electrically heated. For high-temperature units, the DHW can either be heated by electric or natural gas methods. For units heated with natural gas, the unit shall have an electric booster heater attached to it.

High-Efficiency Condition

Qualifying equipment must be compliant with the current ENERGY STAR v3.0 specification, effective July 27, 2021. High-temperature equipment sanitizes using hot water and requires a booster heater. Low-temperature equipment uses chemical sanitization and does not require a booster heater. Qualified products must be less than or equal to the maximum idle energy rate and water consumption requirements from Table 139.

Table 139. Dishwashers—ENERGY STAR Specification[282]

Machine type	Low-temperature efficiency requirements		High-temperature efficiency requirements	
	Idle energy rate (kW)	Water consumption (gal/rack)	Idle energy rate (kW)	Water consumption (gal/rack)
Under counter	≤ 0.25	≤ 1.19	≤ 0.30	≤ 0.86
Stationary single-tank door	≤ 0.30	≤ 1.18	≤ 0.55	≤ 0.89
Single-tank conveyor	≤ 0.85	≤ 0.79	≤ 1.20	≤ 0.70
Multiple-tank conveyor	≤ 1.00	≤ 0.54	≤ 1.85	≤ 0.54
Pot, pan, and utensil	–	–	≤ 0.90	≤ 0.58[283]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values are calculated using the following algorithms:

280 Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.
281 High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.
282 ENERGY STAR® Commercial Dishwashers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria.
283 Water consumption for pot, pan, and utensil is specified in gallons-per-square-foot rather than gallons-per-rack.

$$Energy\ Savings\ [\Delta kWh] = (V_{base} - V_{ES}) \times \left(\frac{\Delta T_{DHW} + \Delta T_{boost}}{\eta_{DHW}}\right) \times \rho_{water} \times C_p \times \frac{1\ kWh}{3{,}412\ Btu} + (E_{idle,base} - E_{idle,ES}) \times \left(t_{on} - N_{racks} \times \frac{t_{wash}}{60}\right) \times t_{days}$$

Equation 104

$$V_{base} = t_{days} \times N_{racks} \times V_{rack,base}$$

Equation 105

$$V_{ES} = t_{days} \times N_{racks} \times V_{rack,ES}$$

Equation 106

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{t_{on} \times t_{days}} \times CF$$

Equation 107

Where:

ρ_{water}	=	*Density of water [lb/gallon]*
C_p	=	*Specific heat of water [Btu/lb ºF]*
ΔT_{DHW}	=	*Inlet water temperature increase for building water heater [ºF]*
ΔT_{boost}	=	*Inlet water temperature for booster water heater [ºF]*
η_{DHW}	=	*Building electric water heater and booster heater efficiency [%]*
N_{racks}	=	*Number of racks washed per days*
V_{base}	=	*Baseline annual volume of water consumption [gal/year]*
V_{ES}	=	*ENERGY STAR annual volume of water consumption [gal/year]*
$V_{rack,base}$	=	*Baseline per rack volume of water consumption [gal/rack]*
$V_{rack,ES}$	=	*ENERGY STAR per rack volume of water consumption [gal/rack]*
$E_{Idle,base}$	=	*Baseline idle energy rate [kW]*
$E_{Idle,ES}$	=	*ENERGY STAR idle energy rate [kW]*
t_{wash}	=	*Wash time per rack [min]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
3,412	=	*Constant to convert from Btu to kWh*
60	=	*Constant to convert from minutes to hours*
CF	=	*Peak coincidence factor*

Table 140. Dishwashers—Savings Calculation Input Assumptions[284]

Inputs	Under counter	Single-door type	Single-tank conveyor	Multiple-tank conveyor	Pot, pan, and utensil
ρ_{water}	61.4 ÷ 7.48 = 8.2				
C_p	1.0				
ΔT_{DHW}	Gas water heaters: 0ºF Electric water heaters: 70 ºF				
ΔT_{boost}	Gas booster heaters: 0 ºF Electric booster heaters: 40 ºF				
η_{DHW}	98%				
t_{on}	18				
t_{days}	365				
CF[285]	0.90				
Low-temperature units					
N_{racks}	75	280	400	600	–
$V_{rack,base}$	1.73	2.10	1.31	1.04	–
$V_{rack,ES}$	1.19	1.18	0.79	0.54	–
$E_{idle,base}$	0.50	0.60	1.60	2.00	–
$E_{idle,ES}$	0.25	0.30	0.85	1.00	–
t_{wash}	2.0	1.5	0.3	0.3	–
High-temperature units					
N_{racks}	75	280	400	600	280
$V_{rack,base}$	1.09	1.29	0.87	0.97	0.70
$V_{rack,ES}$	0.86	0.89	0.70	0.54	0.58
$E_{idle,base}$	0.76	0.87	1.93	2.59	1.20
$E_{idle,ES}$	0.30	0.55	1.20	1.85	0.90
t_{wash}	2.0	1.0	0.3	0.2	3.0

284 ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

285 Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 142 are based on the input assumptions from Table 140.

Table 141. Dishwashers—Energy and Peak Demand Savings

Facility description	Under counter		Stationary single-tank door		Single-tank conveyor		Multiple-tank conveyor		Pot, pan, and utensil	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Low temp./ electric water heater	3,955	0.542	17,362	2.378	17,426	2.387	24,292	3.328	–	–
High temp./ electric water heater with electric booster heater	4,303	0.589	12,596	1.726	10,966	1.502	29,751	4.075	3,750	0.514
High temp./ gas water heater with electric booster heater	3,221	0.441	5,572	0.763	6,700	0.918	13,569	1.859	1,642	0.225
High temp./ electric water heater with gas booster heater	3,684	0.505	8,582	1.176	8,528	1.168	20,504	2.809	2,545	0.349

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) varies per eligible dishwasher type, as stated in the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

Table 142. Dishwashers—Equipment Lifetime by Machine Type

Machine type	EUL (years)
Under counter	10
Stationary single-tank door	15
Single-tank conveyor	20
Multiple-tank conveyor	20
Pot, pan, and utensil	10

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:

- Manufacturer and model number
- Energy source for primary water heater (gas, electric)
- Energy source for booster water heater (gas, electric)
- ENERGY STAR idle rate
- ENERGY STAR water consumption
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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 143. Dishwashers—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. Update savings based on the newest version of ENERGY STAR deemed input variables.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Water Use per Rack in Table 2-90.
v3.0	04/30/2015	TRM v3.0 update. Aligned calculation approach with ENERGY STAR Commercial Dishwashers Program Requirements Version 2.0. Simplified methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. Added high-efficiency requirements for pots, pans, and utensils.
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. Program tracking requirements updated.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated ENERGY STAR specification and incorporated March 2021 calculator update. Updated variable definitions.
v10.0	10/2022	TRM v10.0 update. Corrected mismatch between formula definitions and variables. Replaced URL for ENERGY STAR listing.

2.4.4 ENERGY STAR® Hot Food Holding Cabinets Measure Overview

TRM Measure ID: NR-FS-HC

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See eligibility criteria

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 section covers the deemed savings methodology for the installation of ENERGY STAR® hot food holding cabinets (HFHCs). An HFHC is a heated, fully enclosed compartment with one or more solid or transparent doors designed to maintain the temperature of hot food that has been cooked using a separate appliance. HFHCs that have earned ENERGY STAR® certification incorporate better insulation, thus reducing heat loss, and may also offer additional energy-saving devices such as magnetic door gaskets, auto-door closers, or Dutch doors. The insulation of the cabinet offers better temperature uniformity within the cabinet from top to bottom. The energy and demand savings are deemed and based on an interior volume range of the holding cabinets and the building type. An average wattage has been calculated for each volume range, half size, three-quarter size, and full size. The energy and demand savings are determined on a per-cabinet basis.

Eligibility Criteria

HFHCs must be compliant with the current ENERGY STAR® specification.[286, 287] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[288]

---

[286] ENERGY STAR® Program Requirements Product Specifications for Commercial Hot Food Holding Cabinets. Eligibility Criteria Version 2.0. https://www.energystar.gov/sites/default/files/specs/private/Commercial_HFHC_Program_Requirements_2.0.pdf.

[287] ENERGY STAR® Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-hot-food-holding-cabinets/results.

[288] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

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

- Dual function equipment (e.g., “cook-and-hold” and proofing units)
- Heated transparent merchandising cabinets
- Drawer warmers

Baseline Condition

The baseline condition is a half-size, three-quarter size, or full-size hot food holding cabinet that do not meet ENERGY STAR® key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v2.0 specification, effective October 1, 2011. Table 144 summarizes idle energy rate requirement based on cabinet interior volume.

Table 144. HFHCs—ENERGY STAR® Specification[289,290]

Product interior volume (ft^3)	Idle energy rate (W)
0 < V < 13	≤ 21.5 V
13 ≤ V < 28	≤ 2.0 V + 254.0
28 ≤ V	≤ 3.8 V + 203.5

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

Deemed values are calculated using the following algorithms:

$$Energy\ Saving\ [\Delta kWh] = \left(E_{Idle,base} - E_{Idle,ES}\right) \times \frac{1}{1{,}000} \times t_{on} \times t_{days}$$

Equation 108

$$Peak\ Demand\ [\Delta kW] = \left(E_{Idle,base} - E_{Idle,ES}\right) \times \frac{1}{1{,}000} \times CF$$

Equation 109

289 ENERGY STAR® Commercial Fryers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria.

290 V = Interior Volume which equals Interior Height x Interior Width x Interior Depth.

Where:

V	=	*Product interior volume [ft³]*
$E_{Idle,base}$	=	*Baseline idle energy rate [W]*
$E_{Idle,ES}$	=	*ENERGY STAR idle energy rate after installation [W]*
t_{on}	=	*Equipment operating hours per day [hrs/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 145. HFHCs—Savings Calculation Input Assumptions[291]

Input variable	Product interior volume range		
	$0 < V < 13$	$13 \leq V < 28$	$28 \leq V$
V[292]	8	22	53
$E_{Idle,base}$	30 × V		
$E_{Idle,ES}$	21.5 × V	2 × V + 254	3.8 × V + 203.5
t_{on}	9		
t_{days}	365		
CF[293]	0.90		

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 147 are based on the input assumptions from Table 145.

[291] ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[292] Averages of product interior volume determined based on review of ENERGY STAR® qualified product listing. Accessed 7/30/2020.

[293] Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

Table 146. HFHCs—Energy and Peak Demand Savings

Product interior volume (ft^3)	kWh Savings	kW Savings
0 < V < 13	223	0.061
13 ≤ V < 28	1,189	0.326
28 ≤ V	3,893	1.067

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 Cook-HoldCab.[294]

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:

- Manufacturer and model number
- Interior cabinet volume
- ENERGY STAR® idle rate
- Copy of ENERGY STAR® certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Hot Food Holding Cabinets

Relevant Standards and Reference Sources

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

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

Document Revision History

Table 147. HFHCs—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. Updated to newer ENERGY STAR® Hot Food Holding Cabinet Program Requirements Version 2.0. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
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. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Updated EUL reference.
V10.0	10/2022	TRM v10.0 update. Minor formatting.

2.4.5 ENERGY STAR® Electric Fryers Measure Overview

TRM Measure ID: NR-FS-EF

Market Sector: Commercial

Measure Category: Cooking equipment

Applicable Building Types: See eligibility criteria

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 section covers the deemed savings methodology for the installation of ENERGY STAR® electric fryers. Fryers that have earned ENERGY STAR® certification offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses resulting in a lower idle energy rate. The energy and demand savings are determined on a per-fryer basis.

Eligibility Criteria

Eligible units must meet be compliant with the current ENERGY STAR® specification, either counter-top or floor type designs, with standard-size and large vat fryers as defined below:[295, 296]

- Standard-size electric fryer: A fryer with a vat that measures ≥ 12 inches and < 18 inches wide, and a shortening capacity ≥ 25 pounds and ≤ 65 pounds
- Large vat electric fryer: A fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide, and a shortening capacity > 50 pounds

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[297]

---

295 ENERGY STAR® Program Requirements Product Specifications for Commercial Fryers. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Fryers%20Program%20Requirements.pdf.

296 ENERGY STAR® Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-fryers/results.

297 CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

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

- Fryers with vats measuring < 12 inches wide, or > 24 inches wide

Baseline Condition

The baseline condition is an electric standard-size fryer ≥ 12 inches and < 18 inches wide or large vat fryer > 18 inches and < 24 inches wide that do not meet ENERGY STAR® key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v3.0 specification, effective October 1, 2016. New electric standard fryers ≥ 12 inches and < 18 inches wide and large vat fryers > 18 inches and < 24 inches wide that meet or exceed the requirements listed in Table 148.

Table 148. Fryers—ENERGY STAR® Specification[298]

Inputs	Standard	Large-vat
Cooking energy efficiency	≥ 83%	≥ 80%
Idle energy rate (W)	≤ 800	≤ 1,100

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed values are calculated using the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = kWh_{base} - kWh_{ES}$$

Equation 110

$$kWh_{base} = kWh_{ph,base} + kWh_{cook,base} + kWh_{idle,base}$$

Equation 111

$$kWh_{ES} = kWh_{ph,ES} + kWh_{cook,ES} + kWh_{idle,ES}$$

Equation 112

298 ENERGY STAR® Commercial Fryers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria.

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 113, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 149.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{cook}}\right) + E_{idle} \times \left(t_{on} - \frac{t_{ph}}{60} - \frac{W_{food}}{PC}\right)\right) \times \frac{t_{days}}{1{,}000}$$

Equation 113

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1{,}000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 114

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/day]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR® preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity [lb/hr]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{ph}	=	*Preheat time [min/day]*
t_{days}	=	*Facility operating days per year [days/year]*
60	=	*Constant to convert from min to hr*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 149. Fryers—Savings Calculation Input Assumptions[299]

Parameter	Standard-sized vat		Large vat	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
E_{ph}	2,400	1,900	2,400	1,900
W_{food}	150			
E_{food}	167			
η_{cook}	75%	83%	70%	80%
E_{idle}	1,200	800	1,350	1,100
PC	65	70	100	110
t_{on}	16		12	
t_{ph}	15			
t_{days}	365			
CF[300]	0.90			

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 151 are based on the assumptions from Table 149.

Table 150. Fryers—Energy and Peak Demand Savings

Fryer type	kWh Savings	kW Savings
Standard	3,272	0.476
Large vat	2,696	0.516

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 Cook-ElecFryer.[301]

[299] ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[300] Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study: Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

[301] 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:

- Manufacturer and model number
- Fryer width
- ENERGY STAR® idle rate
- ENERGY STAR® cooking efficiency
- Copy of ENERGY STAR® certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Electric Fryers.

Relevant Standards and Reference Sources

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

Document Revision History

Table 151. Fryers—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. Updated to newer ENERGY STAR® Electric Fryers Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
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. Savings and efficiencies revised for ENERGY STAR® 3.0 specifications. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Minor variable definition updates.

2.4.6 ENERGY STAR® Electric Steam Cookers Measure Overview

TRM Measure ID: NR-FS-SC

Market Sector: Commercial

Measure Category: Cooking equipment

Applicable Building Types: See eligibility criteria

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 section covers the deemed savings methodology for the installation of ENERGY STAR® electric steam cookers. Steam cookers are available in 3-, 4-, 5-, or ≥ 6-pan capacities. Steam cookers that have earned ENERGY STAR® certification are up to 50 percent more efficient than standard models. They have higher production rates and reduced heat loss due to better insulation and a more efficient steam delivery system. The energy and demand savings are determined on a per-cooker basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR® specification. [302, 303] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[304]

It is required that the post-retrofit ENERGY STAR® electric steam cooker and the conventional steam cooker it replaces are of equivalent pan capacities.

[302] ENERGY STAR® Program Requirements Product Specifications for Commercial Steam Cookers. Eligibility Criteria Version 1.2. https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf.

[303] ENERGY STAR® Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results.

[304] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

Baseline Condition

The eligible baseline condition for retrofit situations is an electric steam cooker that does not meet ENERGY STAR® key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v1.2 specification, effective August 1, 2003. Qualified products must meet the requirements from Table 152.

Table 152. Steam Cookers—ENERGY STAR® Specification[305]

Pan capacity	Cooking energy efficiency (%)[306]	Idle rate (W)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 115

$$kWh_{base} = kWh_{ph,base} + kWh_{cook,base} + kWh_{idle,base}$$

Equation 116

$$kWh_{ES} = kWh_{ph,ES} + kWh_{cook,ES} + kWh_{idle,ES}$$

Equation 117

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 102, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 153.

305 ENERGY STAR® Commercial Steam Cookers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria.

306 Cooking Energy Efficiency is based on "heavy load (potato) cooking capacity," i.e., 12 by 20 by 2½ inch (300 by 500 by 65 mm) perforated hotel pans each filled with 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of fresh, whole, US No. 1, size B, red potatoes.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{\text{cook}}}\right) + \left[(1 - 40\%) \times E_{idle} + \frac{40\% \times PC \times P \times E_{food}}{\eta_{\text{cook}}}\right] \times \left(t_{on} - \frac{W_{food}}{PC \times P}\right)\right) \times \frac{t_{days}}{1{,}000}$$

Equation 118

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1{,}000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 119

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/day]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR® preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]. (Differs for boiler-based and steam-generator equipment)*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%] (Differs for boiler-based or steam generator equipment)*
40%	=	*Percent of time in constant steam mode [%]*
PC	=	*Production capacity [lb/hr]*
P	=	*Pan capacity*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 153.Steam Cookers—Savings Calculation Input Assumptions[307]

Parameter	Baseline value	ENERGY STAR® value
E_{ph}	1,776	1,671.7
W_{food}		100
E_{food}		30.8
η_{cook}	Boiler-based: 26% Steam generator: 30%	50%
E_{Idle}	Boiler-based: 1,000 Steam generator: 1,200	3-pan: 400 4-pan: 530 5-pan: 670 6-pan: 800
PC	23.3	16.7
P		3, 4, 5, or 6
t_{on}		9.25
t_{days}		311
CF[308]		0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 155 are based on the input assumptions from Table 153.

Table 154. Steam Cookers—Energy and Peak Demand Savings

Steam cooker type	P	kWh Savings	kW Savings
Boiler-based	3-pan	7,988	2.489
	4-pan	9,822	3.063
	5-pan	11,614	3.623
	6-pan and larger	13,408	4.185
Steam generator	3-pan	6,715	2.091
	4-pan	8,139	2.536
	5-pan	9,515	2.967
	6-pan and larger	10,891	3.397

[307] ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[308] Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study: Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

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 Cook-ElecStmCooker.[309]

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:

- Manufacturer and model number
- Steam cooker type (boiler-based or steam generator)
- Pan capacity (3, 4, 5, or 6+)
- ENERGY STAR® idle rate
- ENERGY STAR® cooking efficiency
- Copy of ENERGY STAR® certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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 155. Steam Cookers—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 EUL based on ENERGY STAR® and DEER 2014.

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

v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR® Steam Cooker Program Requirements Version 1.2. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
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. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Corrected formula errors. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Corrected formula error and minor variable definition updates.

2.4.7 ENERGY STAR® Ice Makers Measure Overview

TRM Measure ID: NR-FS-IM

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: Any commercial

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 section covers the deemed savings methodology for the installation of ENERGY STAR® automatic ice makers installed in commercial sites.

Eligibility Criteria

Eligible equipment includes air-cooled batch and continuous ice makers with the following design types: ice-making head (IMH), self-contained (SCU), and remote condensing (RCU) units. Eligible units must be compliant with the current ENERGY STAR® specification.[310, 311]

Any commercial-type building is eligible; building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[312]

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

- Water-cooled ice makers
- Ice makers with ice and water dispensing systems
- Air-cooled RCUs that are designed only for connection to remote rack compressors

---

310 ENERGY STAR® Program Requirements Product Specifications for Commercial Ice Makes. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Draft%20Version%203.0%20Automatic%20Commercial%20Ice%20Maker%20Specification.pdf.

311 ENERGY STAR® Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-ice-machines/results.

312 CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

Baseline Condition

The baseline condition is an ice maker meeting the federal standards published in 10 CFR 431 listed in Table 156. The baseline applies to automatic air-cooled commercial ice maker with capacities between 50 and 4,000 pounds per 24-hour period manufactured on or after January 28, 2018.

Table 156. Ice Makers—Federal Standard[313]

Equipment type	Harvest rate (lbs ice per 24 hrs)	Max energy use rate (kWh/100 lb ice) H=harvest rate
Batch		
IMH	< 300	10 - 0.01233H
	≥ 300 and < 800	7.05 - 0.0025H
	≥ 800 and < 1,500	5.55 - 0.00063H
	≥ 1,500 and < 4,000	4.61
RCU (but not remote compressor)	< 988	7.97 - 0.00342H
	≥ 988 and < 4,000	4.59
RCU and remote compressor	< 930	7.97 - 0.00342H
	≥ 930 and < 4,000	4.79
SCU	< 110	14.79 - 0.0469H
	≥ 110 and < 200	12.42 - 0.02533H
	≥ 200 and < 4,000	7.35
Continuous		
IMH	< 310	9.19 - 0.00629H
	≥ 310 and < 820	8.23 - 0.0032H
	≥ 820 and < 4,000	5.61
RCU (but not remote compressor)	< 800	9.7 - 0.0058H
	≥ 800 and < 4,000	5.06
RCU and remote compressor	< 800	9.9 - 0.0058H
	≥ 800 and < 4,000	5.26
SCU	< 200	14.22 - 0.03H
	≥ 200 and < 700	9.47 - 0.00624H
	≥ 700 and < 4,000	5.1

313 Code of Federal Regulations, Title 10 Part 431.136 for air-cooled batch-type and continuous-type automatic commercial ice maker with capacities between 50 and 4,000 pounds per 24-hour period manufactured on or after January 28, 2018. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v3.0 specification, effective January 28, 2018. Qualified products must meet the minimum energy consumption (kWh/100 lbs ice) from Table 157.

Table 157. Ice Makers—ENERGY STAR® Specification[314]

Equipment type	Harvest rate (lbs ice per 24 Hrs)	Max energy use rate (kWh/100 lb ice) H=harvest rate
Batch		
IMH	H < 300	< 9.20 - 0.01134H
	300 ≤ H < 800	< 6.49 - 0.0023H
	800 ≤ H < 1500	< 5.11 - 0.00058H
	1500 ≤ H ≤ 4000	< 4.24
RCU	H < 988	< 7.17 – 0.00308H
	988 ≤ H ≤ 4000	< 4.13
SCU	H < 110	< 12.57 - 0.0399H
	110 ≤ H < 200	< 10.56 - 0.0215H
	200 ≤ H ≤ 4000	< 6.25
Continuous		
IMH	H < 310	< 7.90 – 0.005409H
	310 ≤ H < 820	< 7.08 – 0.002752H
	820 ≤ H ≤ 4000	< 4.82
RCU	H < 800	< 7.76 – 0.00464H
	800 ≤ H ≤ 4000	< 4.05
SCU	H < 200	< 12.37 – 0.0261H
	200 ≤ H < 700	< 8.24 – 0.005429H
	700 ≤ H ≤ 4000	< 4.44

Energy and Demand Savings Methodology

Average harvest rates per design-type were computed for both batch and continuous ice makers utilizing the ENERGY STAR® qualified products listing for commercial ice makers for the purpose of possibly establishing deemed savings but were determined to be too variable. Therefore, savings for air-cooled batch and continuous commercial ice makers are dependent on the harvest rate and can be calculated using the following algorithms:

314 ENERGY STAR® Commercial Ice Maker Key Product Criteria . https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria.

Savings Algorithms and Input Variables

$$Energy\ Savings\ [\Delta kWh] = (E_{base} - E_{\text{ES}}) \times \frac{H}{100} \times DC \times t_{days}$$

Equation 120

$$Peak\ Demand\ Savings\ [\Delta kW] = \Delta kWh\ \times PLS$$

Equation 121

Where:

E_{base} = *Baseline rated energy consumption (kWh) per 100 pounds of ice (see Table 156)*

E_{ES} = *ENERGY STAR® rated energy consumption (kWh) per 100 pounds of ice (see Table 157)*

H = *Harvest rate in pounds of ice produced per 24 hours*

DC = *Machine duty cycle, 75%*[315]

t_{days} = *Number of days per year, default is 365 based on continuous use for both batch and continuous type ice makers.*

PLS = *Probability-weighted peak load share (see Table 158)*

Table 158. Ice Makers—Probability-Weighted Peak Load Share

<table>
<tr><th colspan="3">Probability weighted peak load share (PLS)[316]</th></tr>
<tr><th>Climate zone</th><th>Summer peak</th><th>Winter peak</th></tr>
<tr><td>Climate Zone 1: Amarillo</td><td rowspan="5">0.00012</td><td rowspan="3">0.00011</td></tr>
<tr><td>Climate Zone 2: Dallas</td></tr>
<tr><td>Climate Zone 3: Houston</td></tr>
<tr><td>Climate Zone 4: Corpus Christi</td><td rowspan="2">0.00012</td></tr>
<tr><td>Climate Zone 5: El Paso</td></tr>
</table>

Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure.

---

315 The assumed duty cycle value of 80% is taken from a PGE Emerging Technologies study, ET Project #ET12PGE3151 Food Service Technology—Efficient Ice Machines and Load Shifting, average duty cycle of preexisting machines in tables ES1 and ES2.

316 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 Commercial Refrigeration. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. http://loadshape.epri.com/enduse.

Deemed Summer and Winter Demand Savings Tables

There are no deemed demand savings tables for this measure.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for automatic ice makers is 8.5 years.[317]

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
- Manufacturer and model number
- Machine type
  - IMH, RC, or SCU
  - Batch or continuous
- Machine harvest rate
- Copy of ENERGY STAR® certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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.

[317] Department of Energy, Energy Conservation Program: Energy Conservation Standards for Automatic Commercial Ice Makers, 80 FR 4698, https://www.federalregister.gov/d/2015-00326/p-4698.

Document Revision History

Table 159. Ice Makers—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. Incorporated March 2021 calculator update.
v10.0	10/2022	TRM v10.0 update. No revision.

2.4.8 Demand-Controlled Kitchen Ventilation Measure Overview

TRM Measure ID: NR-FS-KV

Market Sector: Commercial

Measure Category: Food service

Applicable Building Types: Restaurants and buildings with commercial kitchens

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed value

Savings Methodology: Algorithms

Measure Description

This measure presents deemed savings for implementation of demand-controlled ventilation (DCV) installed in commercial kitchens. DCV systems make use of control strategies to modulate exhaust fans and make-up air units. Various control strategies may be implemented such as time-of-day scheduling; sensors including exhaust temperature, cook surface temperature, smoke, or steam sensors; or direct communication from cooking equipment to the DCV processor.

Eligibility Criteria

Kitchen ventilation systems both with and without dedicated makeup air units are eligible for this measure.

Baseline Condition

The baseline condition is a commercial kitchen operating the cooking exhaust and make up air operation at a single fixed speed with on/off controls or operating on an occupancy-based schedule.

High-Efficiency Condition

The efficient condition is a commercial kitchen varying the flow rates of cooking exhaust and make-up air operation based on periods of high and low demand as indicated by schedules or monitors of cooktop operation.

Energy and Demand Savings Methodology

Energy savings are calculated based on monitoring data gathered during field studies conducted by the Food Service Technology Center (FSTC) and published in the ASHRAE Journal.[318] Assumptions for average savings, operating hours and days, and makeup air factors are calculated as the averages for corresponding building types from FSTC monitoring data.

When there is no dedicated makeup air unit, only the exhaust fan power is expected to modulate based on demand and a makeup air unit factor is applied to the savings algorithm. The makeup air unit (MAU) factor is calculated as the percent of total kitchen ventilation system power (exhaust plus makeup air fans) that comes from exhaust fans.

Interactive heating and cooling savings are taken by multiplying the percent airflow savings from the FSTC study by the estimated heating and cooling loads output by the FSTC Outdoor Air Load Calculator (OALC).[319] This output is adjusted by population to account for the percentage of sites with electric resistance or heat pump heating.[320] Additionally, because output from the OALC is per 1,000 CFM, a CFM per HP ratio[321] is applied in order to simplify implementation tracking requirements. Interactive heating and cooling savings are presented per horsepower. Assumed efficiency of AC systems is 10 EER; assumed efficiency of electric resistance heating is 1.0 COP; assumed efficiency of HP heating is 7.7 HSPF.

Savings Algorithms and Input Variables

$$Energy\ Savings\ [\Delta kWh] = HP_{exhaust} \times (IHS + AvgSav_{kWh/HP} \times DOH \times AOD \times MAU)$$

Equation 122

$$Peak\ Demand\ Savings\ [\Delta kW] = \Delta kWh \times PWPLS$$

Equation 123

Where:

$HP_{exhaust}$ = *Total exhaust horsepower of the kitchen ventilation system included in the DCV operating strategy, facility-specific*

IHS = *Interactive heating savings per 1,000 CFM of outdoor air (see Table 161)*

$AvgSav_{kWh/HP}$ = *Average hourly energy savings per horsepower by building type (see Table 160)*

[318] Fisher, D., Swierczyna, R., and Karas, A. (February 2013) Future of DCV for Commercial Kitchens. *ASHRAE Journal,* 48-53.

[319] Food Service Technology Center Outdoor Air Load Calculator. No longer available online.

[320] Percentage of buildings with electric resistance and heat pump heat are taken from the Energy Information Administration 2012 Commercial Buildings Energy Survey (CBECS), tables b.28 Primary space-heating energy sources and b.38 Heating equipment, using data for buildings with cooking. https://www.eia.gov/consumption/commercial/data/2012.

[321] The CFM per HP ratio was calculated using data from Southern California Edison, ET 07.10 Report on Demand Control Ventilation for Commercial Kitchen Hoods, June 2009.

DOH	=	*Average daily operating hours, facility specific (if unknown, use defaults from Table 160)*
AOD	=	*Annual operating days, facility specific (if unknown use defaults from Table 160)*
MAU	=	*Make-up air unit factor applied to account for presence of dedicated MAU; value = 1 if there is a dedicated MAU; see Table 160 for values when there is no dedicated MAU*
PWPLS	=	*Probability weighted peak load share; see Table 162*

Table 160. DCKV—Savings Calculation Input Assumptions

Building type	$AvgSav_{kWh/HP}$	DOH	AOD	MAU with no dedicated MAU
Casual dining/fast food[322]	0.667	15	365	0.65
24-hr restaurant/hotel[323]	0.631	24	365	0.65
School café with summer[324]	0.566	11	325	0.51
School café without summer	0.566	11	252	0.51

Table 161. DCKV—Population-Adjusted Interactive HVAC Savings per hp

Climate zone	Building type	Interactive savings (kWh/hp)
Climate Zone 1: Amarillo	Casual dining/fast food	608
	24-hr restaurant/hotel	851
	School café with summer	455
	School café without summer	206
Climate Zone 2: Dallas	Casual dining/fast food	1,123
	24-hr restaurant/hotel	1,758
	School café with summer	838
	School café without summer	409
Climate Zone 3: Houston	Casual dining/fast food	1,191
	24-hr restaurant/hotel	1,844
	School café with summer	959
	School café without summer	571
	Casual dining/fast food	1,393

322 Pennsylvania TRM, "3.5.3 High-Efficiency Fan Motors for Walk-In Refrigerated Cases". Page 369, Table 3-93. June 2016.

323 All values are the average of Hotel Restaurant data from Future of DCV for Commercial Kitchens.

324 Savings and MAU are calculated as the average of University Dining data from Future of DCV for Commercial Kitchens; Hours per day and Days per year are calculated using operating hours from Table 160.

Climate zone	Building type	Interactive savings (kWh/hp)
Climate Zone 4: Corpus Christi	24-hr restaurant/hotel	2,262
	School café with summer	1,119
	School café without summer	689
Climate Zone 5: El Paso	Casual dining/fast food	1,023
	24-hr restaurant/Hotel	1,510
	School café with summer	775
	School café without summer	450

Table 162. DCKV—Probability Weighted Peak Load Share[325]

Climate zone	Summer PWPLS	Winter PWPLS
Climate Zone 1: Amarillo	1.33E-04	1.46E-04
Climate Zone 2: Dallas	1.36E-04	1.45E-04
Climate Zone 3: Houston	1.34E-04	1.43E-04
Climate Zone 4: Corpus Christi	1.31E-04	1.45E-04
Climate Zone 5: El Paso	1.45E-04	1.46E-04

Deemed Energy and Demand Savings Tables

Table 163. DCKV—Energy Savings per hp

Climate zone	Building type	Annual savings (kWh/hp)	
		With dedicated MAU	Without dedicated MAU
Climate Zone 1: Amarillo	Casual dining/fast food	4,253	2,990
	24-hr restaurant/hotel	6,376	4,418
	School café with summer	2,480	1,498
	School café without summer	1,779	1,016
Climate Zone 2: Dallas	Casual dining/fast food	4,768	3,504
	24-hr restaurant/hotel	7,282	5,324
	School café with summer	2,864	1,881
	School café without summer	1,981	1,218
Climate Zone 3: Houston	Casual dining/fast food	4,836	3,572
	24-hr restaurant/hotel	7,368	5,410
	School café with summer	2,985	2,002

325 PWPLS factors are calculated according to the methods described in TRM Volume 1, Section 4.3. The load shape source is the Pacific Northwest National Laboratory Technical Support Document: 50% Energy Savings for Quick-Service Restaurants, Table B.4, Schedule for Kitchen exhaust flow.

Climate zone	Building type	Annual savings (kWh/hp)	
		With dedicated MAU	Without dedicated MAU
	School café without summer	2,144	1,381
Climate Zone 4: Corpus Christi	Casual dining/fast food	5,038	3,775
	24-hr restaurant/hotel	7,787	5,829
	School café with summer	3,144	2,162
	School café without summer	2,261	1,499
Climate Zone 5: El Paso	Casual dining/fast food	4,668	3,404
	24-hr restaurant/hotel	7,034	5,077
	School café with summer	2,801	1,818
	School café without summer	2,023	1,260

Table 164. DCKV—Summer and Winter Peak Demand Savings per hp

Climate zone	Building type	Summer demand savings (kW/hp)		Winter demand savings (kW/hp)	
		With dedicated MAU	Without dedicated MAU	With dedicated MAU	Without dedicated MAU
Climate Zone 1: Amarillo	Casual dining/fast food	0.57	0.40	0.62	0.44
	24-hr restaurant/hotel	0.85	0.59	0.93	0.65
	School café with summer	0.33	0.20	0.36	0.22
	School café without summer	0.24	0.14	0.26	0.15
Climate Zone 2: Dallas	Casual dining/fast food	0.65	0.48	0.69	0.51
	24-hr restaurant/hotel	0.99	0.72	1.05	0.77
	School café with summer	0.39	0.26	0.41	0.27
	School café without summer	0.27	0.17	0.29	0.18
Climate Zone 3: Houston	Casual dining/fast food	0.65	0.48	0.69	0.51
	24-hr restaurant/hotel	0.99	0.72	1.05	0.77
	School café with summer	0.40	0.27	0.43	0.29
	School café without summer	0.29	0.18	0.31	0.20
Climate Zone 4 Corpus Christi	Casual dining/fast food	0.66	0.50	0.73	0.55
	24-hr restaurant/hotel	1.02	0.76	1.13	0.85
	School café with summer	0.41	0.28	0.46	0.31
	School café without summer	0.30	0.20	0.33	0.22
Climate Zone 5: El Paso	Casual dining/fast food	0.68	0.49	0.68	0.50
	24-hr restaurant/hotel	1.02	0.74	1.03	0.74
	School café with summer	0.41	0.26	0.41	0.27
	School café without summer	0.29	0.18	0.30	0.18

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 ID HVAC-VSD-fan.[326]

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:

- Kitchen ventilation system exhaust fan horsepower
- Building type
- Kitchen ventilation makeup air unit fan horsepower, if present
- Presence of dedicated makeup air unit
- Testing and balancing report, 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 165. DCKV—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. Formula updates and corrected table error.

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

2.4.9 Pre-Rinse Spray Valves Measure Overview

TRM Measure ID: NR-FS-SV

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See Table 167

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Direct install or point of sale

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 pre-rinse sprayers to reduce hot water usage which, in turn, saves energy associated with heating the water. Water heating is assumed to be electric. The energy and demand savings are determined on a per-sprayer basis and are algorithmically based.

Eligibility Criteria

Units must be used for commercial food preparation only and have flow rates which are no greater than the baseline flow rates specified in Table 166 (on a per product class or spray force in ounce-force (ozf) basis.

Baseline Condition

Effective January 28, 2019, reference baseline equipment is a pre-rinse spray valve with a flow rate that does not exceed the maximum flow rate per product class as specified in Table 166.[327]

Table 166. PRSVs—Flow Rate Limits

Product class (ozf)	Flow rate (gpm)
Product class 1 (≤ 5 ozf)	1.00
Product class 2 (> 5 ozf and ≤ 8 ozf)	1.20
Product class 3 (> 8 ozf)	1.28

327 Federal Energy Conservation Standard, Code of Federal Regulations, Title 10, Chapter 22, Subchapter D, Part 431, Subpart O, Section §431.266.

High-Efficiency Condition

Following the passing of the Energy Policy Act of 2005, the EPA announced on September 21st, 2005 that it would no longer pursue an ENERGY STAR® specification for pre-rinse spray valves.[328] Rather than simply disallowing pre-rinse spray valves altogether, it has been decided that the savings resulting from the retrofitting of this measure be algorithm-based (as opposed to deemed using baseline and high-efficiency assumptions). If identification of a standard flow rate for post-retrofit equipment can be identified, future updates will address the transformation of this measure from an algorithm-based approach to one which is deemed.

The eligible high-efficiency equipment is a pre-rinse spray valve that has a flow rate no greater than the flow rate specified in Table 166 for the pre-rinse spray valve's respective product class. The sprayer should be capable of the same cleaning ability as the old sprayer.[329]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy and demand savings are calculated using the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = \frac{\mathrm{U} \times (F_B - F_P) \times \mathrm{AOD} \times (T_H - T_C) \times \rho \times C_P}{RE \times 3{,}412}$$

Equation 124

$$Peak\ Demand\ Savings\ [\Delta kW] = \Delta kWh \times \frac{HPLS}{100{,}000}$$

Equation 125

Where:

U = *Water usage duration (see Table 167)*

F_B = *Baseline flow rate of sprayer (GPM) (see Table 166)*

F_P = *PRSV flow rate (GPM), use actual*

328 "Summary of ENERGY STAR® Specification Development Process and Rationale for PreRinse Spray Valves". March 2006. https://www.energystar.gov/ia/partners/prod_development/downloads/PRSV_Decision_Memo_Final.pdf?1e37-d3b8.

329 FEMP Performance Requirements for Federal Purchases of Pre-rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-rinse Spray Valves.

T_H	=	*Average mixed hot water (after spray valve) temperature [ºF] = 140.5°F*[330]
T_C	=	*Average supply (cold) water temperature [ºF] = 71.4°F*[331]
AOD	=	*Facility annual operating days (see Table 167)*
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*[332]
3,412	=	*Constant to convert from Btu to kWh*
HPLS/100,000	=	*Hourly peak load share (see Table 168)*

Table 167. PRSVs – Assumed Variables for Energy and Peak Demand Savings Calculations

Variable	Assumed value
U[333]	Fast food restaurant: 45 min/day/unit Casual dining restaurant: 105 min/day/unit Institutional: 210 min/day/unit Dormitory: 210 min/day/unit K-12 school: 105 min/day/unit
AOD[334]	Fast food restaurant: 360 Casual dining restaurant: 360 Institutional: 360 Dormitory: 270 K-12 school: 193

330 Texas Administrative Code for Retail Food Equipment Operations, Title 25, Part 1, Chapter 228, Subchapter D, Rule §228.111. Average of minimum values for manual warewashing equipment, 110°F (paragraph (i)) and 171°F (paragraph (k)).

331 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.

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

333 “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.

334 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 168. PRSV—Probability-Weighted Hourly Peak Load Share[335]

Climate zone	Summer PLS			Winter PLS		
	Full-service restaurant and cafeterias	Fast food	Schools	Full-service restaurants and cafeterias	Fast food	Schools
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.[336]

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

[335] Peak load-share factors 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 20112019. 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. PLS values are multiplied by 100,000 to allow for easier readability of the values.

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

- 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 169. 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.

2.4.10 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 is 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.[337] 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.[338] 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 170. 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.[339]

---

337 "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.

338 See Volume 1, Section 4.

339 "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 171. 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.

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 ($T_{d\text{-}in}$) can be calculated from outdoor dew point ($T_{d\text{-}out}$) 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 126[340]

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.[341] Between these values, the door heaters' duty cycle changes proportionally:

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

Equation 127

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[342] at:

For medium temperature (coolers):

$$kW_{ASH} = 0.109 \text{ per door or } 0.0436 \text{ per horizontal linear foot of door}$$[343]

Equation 128

---

340 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.

341 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.

342 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.

343 Ibid.

For low temperature (freezers):

$$kW_{ASH} = 0.191 \text{ per door or } 0.0764 \text{ per horizontal linear foot of door}$$[344]

Equation 129

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 130

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

Equation 131

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,[345] 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 132

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.[346]

[344] Ibid.

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

[346] 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 133[347]

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 134[348]

Where:

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

[347] 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.

[348] 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 135

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

Equation 136

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 137

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

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

Equation 138

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;[349] Table 172 provides these deemed values. Savings are specified per horizontal linear feet of door.

Table 172. 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.[350]

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

349 http://texasefficiency.com/index.php/regulatory-filings/deemed-savings
350 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 173. 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 133 and Equation 134.
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.

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[351]

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.

[351] 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 139

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

Equation 140

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

Equation 141

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

Equation 142

Freezer

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

Equation 143

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

Equation 144

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

Equation 145

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

Equation 146

Where:

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

$DC_{EvapFreeze}$	=	*Duty cycle of evaporator fan motor for freezer*
COP_{cooler}	=	$12/EER_{MT}$, *the coefficient of performance of compressor in the cooler*
$COP_{freezer}$	=	$12/EER_{LT}$, *the coefficient of performance of compressor in the freezer*
Hours	=	*The annual operating hours are assumed to be 8,760 for coolers and 8,273*[352] *for walk-ins (see Table 174)*
%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%.*[353]
1,000	=	*Constant to convert from W to kW*

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.[354]

---

352 The Pennsylvania TRM, June 2016, utilizes the Efficiency Vermont source reproduced below this footnoted statement for an assumption of 8,273 hours for walk-in freezers. This is, furthermore, equivalent to stating the freezer's duty cycle is approximately 94.4% (8,273 / 8,760 ≈ 0.944), an assumed value which appears in Table 174 for the $DC_{EvapFreeze}$ variable. The Maine TRM, July 2019, details the derivation of 8,273 and thus approximately 94.4%: "A[n] evaporator fan in a cooler runs all the time, but a freezer runs only 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)".

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

353 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."

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

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

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

Equation 147[355]

Where:

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

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

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

Equation 148[356]

Where:

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

[355] 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.

[356] Ibid.

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 174. ECM Evaporator Fan Motors—Savings Calculation Input Assumptions

Variable	Deemed values
W_{base}	See Table 175
W_{ee}	See Table 175
LF[357]	0.9
$DC_{EvapCool}$[358]	100%
$DC_{EvapFreeze}$[359]	94.4%
COP_{cooler}	$12/EER_{MT}$
$COP_{freezer}$	$12/EER_{LT}$
Hours[360]	8,760 or 8,273
%OFF	0 or 46%

[357] 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.

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

[359] See footnotes 352 and 358.

[360] See footnote 352 for the explanation of the assumption of 8,273 for walk-in freezers.

Table 175. ECM Evaporator Fan Motors—Motor Sizes, Efficiencies, and Input Watts[361,362]

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

Table 176. ECM Evaporator Fan Motors—Cooler & Freezer Compressor COP

Climate zone	Summer design dry-bulb temperature[363]	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.

361 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.

362 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.

363 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

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.[364]

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

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

Document Revision History

Table 177. 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.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added *schools* as an eligible building type.

2.5.3 Electronic Defrost Controls Measure Overview

TRM Measure ID: NR-RF-DC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools[365]

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.

[365] 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 149

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

Equation 150

Medium temperature:

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

Equation 151

Low temperature:

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

Equation 152

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

Equation 153

Where:

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

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

$kW_{defrost}$ = *Load of electric defrost, default = 0.9 kW*[366]

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

Hours = *Number of hours defrost occurs over a year without defrost controls, 487*[367]

DRF = *Defrost reduction factor—percent reduction in defrosts required per year, see Table 178*

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.[368]

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

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

Equation 154[369]

Where:

a = *3.75346018700468*

b = *-0.049642253137389*

c = *29.4589834935596*

[367] 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.

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

[369] 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 x* 10^{-6}
h	=	*6.80170133906075*
I	=	*-0.020187240339536*
j	=	*0.000657941213335828*
PLR	=	*1/1.15 = 0.87*
SCT_{MT}	=	T_{db} *+ 15*
T_{DB}	=	*Dry-bulb temperature*

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

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

Equation 155[370]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	*-7.57495453950879 x* 10^{-6}
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
SCT_{LT}	=	T_{db} *+10*

[370] Ibid.

Table 178. Defrost Controls—Savings Calculation Input Assumptions

Climate zone	DRF[371]	COP_{MT}[372]	COP_{LT}[373]
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.[374]

Program Tracking Data and Evaluation Requirements

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

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

[371] 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

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

[373] Ibid.

[374] 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 179. 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.

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[375]

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.

[375] 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 156

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

Equation 157

Where:

kW_{evap}	=	*Connected load kW of each evaporator fan, see Table 180*
kW_{circ}	=	*Connected load kW of the circulating fan, see Table 180*
n_{fans}	=	*Number of evaporator fans*
DC_{comp}	=	*Duty cycle of the compressor, see Table 180*
DC_{evap}	=	*Duty cycle of the evaporator fan, see Table 180*
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 180*
8,760	=	*Annual hours per year*

Table 180. Evaporator Fan Controls—Savings Calculation Input Assumptions[376]

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

[376] 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.

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 GrocWkIn-WEvapFMtrCtrl.[377]

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)

- 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."

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

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 181. 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 EUL reference.
v10.0	10/2022	TRM v10.0 update. Added *schools* as an eligible building type.

2.5.5 Night Covers for Open Refrigerated Display Cases Measure Overview

TRM Measure ID: NR-RF-NC

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

Eligible high-efficiency equipment is considered any suitable low-emissivity material sold as a night cover. The night cover must be applied for a period of at least six hours[378] per day (i.e., average continuous overnight use).

[378] 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 158

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*[379]

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

[379] 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"

[380] 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 182.
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 182. Night Covers—Energy and Peak Demand Savings per Lin. Ft.

Temperature[381]	Condensing unit configuration	Equipment family	Average annual energy consumption/lin. ft. ($kWh_{baseline}$)	kWh Savings	kW Savings[382]
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.[383]

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)

[381] 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

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

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

- Operating temperature (low or medium as defined in Table 182)

- 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 183. 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.

2.5.6 Solid and Glass Door Reach-Ins Measure Overview

TRM Measure ID: NR-RF-RI

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Solid- or glass-door reach-in vertical refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements (See Table 185).

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

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

Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 184.

Table 184. Door Reach-Ins—Baseline Energy Consumption[384,385]

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 185.

Table 185. Door Reach-Ins—Efficient Energy Consumption Requirements[386]

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

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

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

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy and demand savings of solid and glass door reach-in refrigerators and freezers are calculated using values in Table 184 and Table 185, based on the volume of the units.

The savings calculations are specified as:

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

Equation 159

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

Equation 160

Where:

kWh_{base} = *Baseline maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 184)*

kWh_{ee} = *Efficient maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 185)*

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*[387] *= 1.0*

[387] 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 186. Door Reach-Ins—Energy and Peak Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume[388]	kWh Savings	kW Savings
Refrigerator	Vertical Solid Door	0 < V < 15	8.54	16	0.002
		15 ≤ V < 30	21.00	892	0.102
		30 ≤ V < 50	41.53	1,256	0.143
		V ≥ 50	67.19	1,919	0.219
	Vertical Glass Door	0 < V < 15	8.84	1,137	0.130
		15 ≤ V < 30	21.30	1,355	0.155
		30 ≤ V < 50	42.76	1,782	0.203
		V ≥ 50	68.93	2,002	0.229
Freezer	Vertical Solid Door	0 < V < 15	7.76	713	0.081
		15 ≤ V < 30	19.99	1,726	0.197
		30 ≤ V < 50	43.13	3,301	0.377
		V ≥ 50	66.86	5,177	0.591
	Vertical Glass Door	0 < V < 15	5.98	1,766	0.202
		15 ≤ V < 30	19.49	4,321	0.493
		30 ≤ V < 50	42.29	8,630	0.985
		V ≥ 50	65.89	13,093	1.495

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.[389]

---

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

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 187. 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.

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[390], which utilizes calculations that determine refrigeration load due to infiltration by air exchange from ASHRAE's Refrigeration Handbook.

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

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

Equation 161

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

Equation 162

Where:

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

[390] 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 188)*

$°R_{Refrig}$ = *Refrigeration box absolute temperature, $t_{DB,Refrig}$ + 459.67 (see Table 188)*

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

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

Equation 163

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

Equation 164

Where:

W_{Adj} = *Humidity ratio of the adjacent space*

W_{Refrig} = *Humidity ratio of the refrigerated space*

Rh_{Adj} = *Relative humidity of the adjacent space (see Table 188)*

Rh_{Refrig} = *Relative humidity of the refrigerated space (see Table 188)*

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

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

Equation 165

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

Equation 166

Where:

h_{Adj} = *Air enthalpy of the adjacent space*

h_{Refrig} = *Air enthalpy of the refrigerated space*

$t_{DB,Adj}$ = *Dry-bulb temperature of the adjacent space (see Table 188)*

$t_{DB,Refrig}$ = *Dry-bulb temperature of the refrigerated space (see Table 188)*

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:

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

Equation 167

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

Equation 168

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

Equation 169

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

Equation 170

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

Equation 171

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

Equation 172

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 188)*
w	=	*Doorway width (see Table 188)*

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 173

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

Equation 174

Where:

$Q_{baseline}$	=	*Baseline total infiltration load*
$Q_{retrofit}$	=	*Total infiltration load, post-retrofit*

m	=	*Time the door is open per day (see Table 188)*
DFF	=	*Doorway flow factor (see Table 188)*
$E_{baseline}$	=	*Baseline assumed effectiveness against infiltration, 0*
$E_{retrofit}$	=	*Assumed effectiveness against infiltration post-retrofit (see Table 188)*

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 175

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

Equation 176

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

Equation 177

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

Equation 178

Where:

$kW_{baseline}$	=	*Baseline demand consumption of the compressor*
$kW_{retrofit}$	=	*Demand consumption of the compressor, post-retrofit*
$kWh_{baseline}$	=	*Baseline energy consumption of the compressor*
$kWh_{retrofit}$	=	*Energy consumption of the compressor, post-retrofit*
EER	=	*EER per facility type (see Table 188), which are averaged or weighted across suction-group types (see Table 189)*
FLH	=	*Assumed full-load hours per facility type (see Table 188)*
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 179

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

Equation 180

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

Equation 181

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

Equation 182

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 188. 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 189:

Table 188. Strip Curtains—Savings Calculation Input Assumptions[391]

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	–

391 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.

EER[392]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	–

392 EER is not an independent variable but is rather dependent on Table 189. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 189. Strip Curtains—Default EER by System Configuration[393]

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 190. 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	–

[393] 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 191.

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

Table 191. Strip Curtains—Energy and Peak Demand Savings (per sq. ft.)

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-StripCrtn.[394]

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

[394] 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 192. 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.

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.[395]

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.

[395] 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.