

Public Utility Commission of Texas

Texas Technical Reference Manual

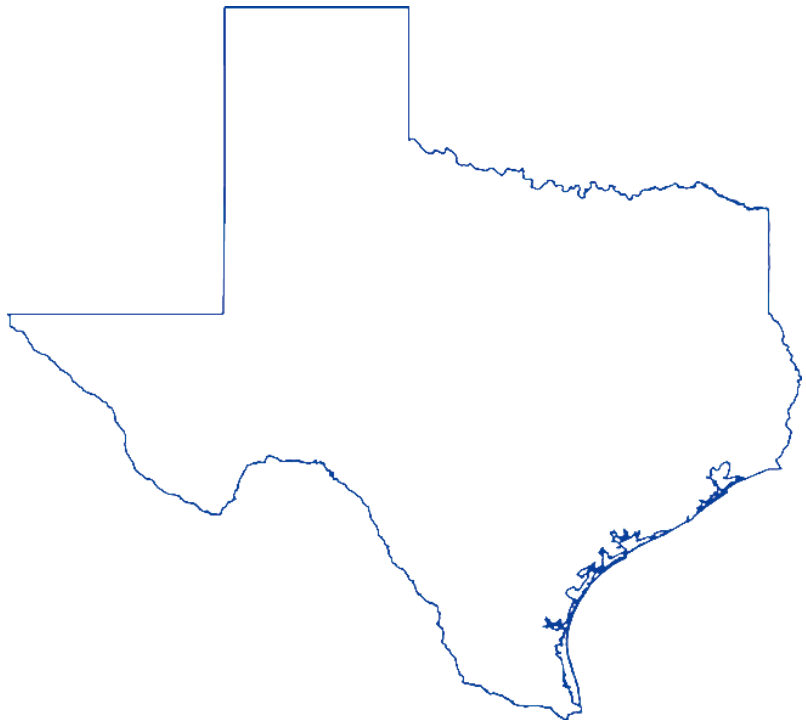
Version 13.0

Volume 3: Nonresidential Measures

Program Year 2026

Last Revision Date:

November 2025



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TRM Technical Support

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1. INTRODUCTION

This volume of the TRM contains the deemed savings for nonresidential measures that have been approved for use in Texas by the PUCT. This volume includes instructions regarding various savings calculators and reference sources of the information. The TRM serves as a centralized source of deemed savings values; where appropriate, measurement and verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1 provides an overview of the nonresidential measures contained within Volume 3 and the types of deemed savings estimates available for each one. There are five types of deemed savings estimates identified:

- Point estimates that provide a single deemed savings value that corresponds to a single measure or type of technology.
- Deemed saving tables that provide energy and peak savings as a function of size, capacity, building type, efficiency level, or other inputs.
- Savings algorithms that require user-defined inputs that must be gathered on-site and the identification of default inputs where primary data could not be collected. In many cases, these algorithms are provided as references to deemed savings tables, point estimates, or calculator explanations.
- Calculators are used by different utilities and implementers to calculate energy savings for different measures. In many cases, there are several different calculators available for a single measure. Sometimes their background calculators are similar, and in other cases, estimates can vary greatly between each calculator.
- M&V methods are also used for some measures to calculate savings in the event that standard equipment is not used, or the specified building types do not apply. For some of these measures, both a simplified M&V approach and a full M&V approach may be allowed by the utility. M&V methods as a source of claimed and projected savings are noted for informational purposes only. Standardized M&V approaches that have been reviewed by the EM&V team are incorporated into Volume 4: Measurement and Verification Protocols of this TRM.

Please consult Volume I: Overview and User Guide, Section 4: Structure and Content, for details on the organization of the measure templates presented in this volume.

Table 1. Nonresidential Deemed Savings by Measure Category

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	13.0 update
Lighting	Lamps and fixtures	–	–	X	X	X	Clarified agricultural building type application; added language to address LED to LED replacements; added 24-hour warehouse building type; updated baseline assumptions for upstream/midstream lighting measures.
	Lighting controls	–	–	X	X	X	No revision.
	Exterior photocell and time clock repair	–	–	X	X	X	No revision.
	LED traffic signals	–	–	X	X	X	No revision.
HVAC	Air conditioning and heat pump tune-ups	–	–	X	–	X	No revision.
	Split and packaged air conditioners and heat pumps	–	–	X	X	X	Updated evaluation requirements to support a reduced heating baseline for ER heat; capped all CFs at 1.
	HVAC chillers	–	–	X	X	X	Added eligible building types.
	Package terminal air conditioners/heat pumps, and room air conditioners	–	–	X	X	X	Updated EUL to align with current PTAC federal standard.
	Computer room air conditioners	–	–	X	X	–	No revision.
	Computer room air handler motor efficiency	–	–	X	X	–	No revision.
	HVAC variable frequency drives	–	X	X	–	–	Added an equivalent option for alternate motor control systems that react to environmental sensors. Added winter kW savings for all applications, and updated summer kW savings to align with Volume 1 updates. Adjusted model year parameters.
	Condenser air evaporative pre-cooling	–	–	X	–	X	No revision.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	13.0 update
	High-volume low-speed fans	–	–	X	–	–	Corrected typos and clarified units in algorithm.
	Small commercial evaporative cooling	–	X	X	–	–	No revision.
	Small commercial smart thermostats	–	–	X	X	X	No revision.
Building envelope	Cool roofs	X	–	X	X	–	Updated documentation requirements to only require roofing product rated life when available.
	Window treatments	X	–	X	X	–	No revision.
	Entrance and exit door air infiltration	–	X	X	–	–	Adjusted savings normalization from per-standard-door to treatment type (weatherstripping, door sweep, entire door). Updated curve fits developed from ASHRAE CLCM. Adjusted assumed heating setpoints. Removed ¾" gap savings.
	Commercial Ceiling Insulation	–	–	X	–	–	New measure introduced in TRM v13.0 based on IL TRM Roof Insulation for C&I Facilities measure.
Food service	ENERGY STAR® combination ovens	–	X	X	–	–	Updated CF for Education building types. Simplified savings estimates to three categories.
	ENERGY STAR® electric convection ovens	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® electric deck ovens	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® dishwashers	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® electric griddles	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® electric fryers	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® electric steam cookers	–	X	X	–	–	Updated CF for Education building types.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	13.0 update
	Contact conveyor toasters	–	X	X	–	–	Updated CF for Education building types.
	Radiant conveyor toasters	–	X	X	–	–	No revision.
	ENERGY STAR® hot food holding cabinets	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® refrigerated chef bases	–	X	X	–	–	Updated CF for Education building types.
	ENERGY STAR® ice makers	–	X	X	–	–	Updated CF for Education building types. Revised demand factors and demand calculation formula.
	ENERGY STAR® induction cooktops	–	X	X	–	–	Updated CF for Education building types. Clarified deemed savings table units. Updated documentation requirements.
	Induction soup wells	–	X	X	–	–	Updated CF for Education building types.
	Demand controlled kitchen ventilation	–	X	X	–	–	Updated CF for Education building types.
	Pre-rinse spray valves	–	X	X	–	–	No revision.
	Vacuum-sealing and packaging machines	–	X	–	–	–	No revision.
	Hand wrap machines	–	X	–	–	–	No revision.
Refrigeration	Door heater controls	–	X	X	–	–	No revision.
	ECM evaporator fan motors	–	–	X	–	–	No revision.
	Electronic defrost controls	–	–	X	–	–	No revision.
	Evaporator fan controls	–	–	X	–	–	No revision.
	Night covers for open refrigerated display cases	–	X	X	–	–	No revision.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	13.0 update
	Solid and glass door reach-ins	–	–	X	–	–	No revision.
	Strip curtains for walk-in refrigerated storage	–	X	–	–	–	No revision.
	Zero-energy doors for refrigerated cases	–	X	X	–	–	No revision.
	Door gaskets for walk-in and reach-in coolers and freezers	–	X	X	–	–	No revision.
	High speed doors for cold storage	–	X	X	–	–	No revision.
	Retrofit doors for open refrigerated display cases	–	X	X	–	–	New measure introduced in TRM v13.0 as requested by ETI and based on IL TRM.
Water heating	Heat pump water heaters	–	–	X	–	–	Revised seasonal peak coincidence factors.
	Central domestic hot water controls	–	X	X	–	–	No revision.
	Showerhead temperature sensitive restrictor valves	–	–	X	–	–	No revision.
	Tub spout and showerhead temperature sensitive restrictor valves	–	–	X	–	–	No revision.
Miscellaneous	Variable frequency drives for water pumping	–	X	X	–	–	No revision.
	Premium efficiency motors	–	–	X	–	–	No revision.
	Pump-off controllers	–	X	X	–	–	No revision.
	ENERGY STAR® pool pumps	–	X	X	–	–	No revision.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	13.0 update
	Lodging guest room occupancy sensor controls	–	X	–	–	–	Cited new construction code requirement.
	Vending machine controls	–	X	X	–	–	No revision.
	Computer power management	–	X	X	–	–	No revision.
	ENERGY STAR® electric vehicle supply equipment	–	X	X	–	–	No revision.
	Industrial high-frequency battery chargers	–	X	X	–	–	No revision.
	Steam trap repair and replacement	–	X	X	–	–	No revision.
	Hydraulic gear lubricants	–	–	X	–	–	No revision.
	Hydraulic oils	–	–	X	–	–	No revision.
	Hand dryers	–	X	X	–	–	Removed Interactive effects factors from Demand and energy savings calculations. Updated deemed savings tables based on updated calculations
	Laser projectors	–	–	X	–	–	No revision.
	Water pumps	–	–	X	–	–	No revision.

2. NONRESIDENTIAL MEASURES

2.1 NONRESIDENTIAL: LIGHTING

2.1.1 Lamps and Fixtures Measure Overview

TRM Measure ID: NR-LT-LF

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial, multifamily common areas

Fuels Affected: Electricity (interactive HVAC effects: electric/gas space heating)

Decision/Action Types: Retrofit, and new construction

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Guidance for Combination Lighting Fixture & Controls Projects

For lighting retrofits installed in combination with existing controls or controls upgrades, fixture and controls savings should be allocated as follows:

- 1) Calculate total savings, adjusting pre- and post-operating hours and coincidence factors to account for applicable controls.
- 2) Determine if project is eligible to claim controls savings:
 - a. Scenario 1: Retrofit project with no baseline controls
 - b. Scenario 2: New construction project with controls other than occupancy sensors
- 3) If controls savings are eligible, calculate controls savings using Section 0 Lighting Controls. Otherwise, set controls savings equal to zero.
- 4) Deduct controls savings from total savings.
- 5) Claim controls savings using controls estimated useful life (EUL). Claim difference of total savings and controls savings using applicable fixture EUL.

Measure Description

This section provides estimates of the energy and peak savings resulting from the installation of energy efficient lamps and/or ballasts. The installation can be the result of new construction or the replacement of existing lamps and/or ballasts. This TRM Measure ID covers the following lighting technologies:

- Linear fluorescent T5s; high performance or reduced watt T8s. Linear fluorescent measures may also involve delamping¹ with or without the use of reflectors.
- Fluorescent electrodeless induction lamps and fixtures
- Compact fluorescent lamp (CFL) screw-based lamps and hard-wired pin-based fixtures
- Pulse-start (PSMH) and ceramic metal halide (CMH) lamps; high-intensity discharge (HID) lamps
- Light emitting diode (LED) screw-based lamps; hard-wired LED fixtures.

Energy and demand savings are based on operating hours, coincident-load factors, and changes in pre-existing and post-installation lighting loads, as determined using an approved lighting Standard Fixture Wattage table², available for download from the Texas Efficiency website and in the Fixture Codes tab in the latest version of the Lighting Survey Form (LSF). The LSF is one example of a calculator that is used to determine energy and demand savings. Pre- and post-retrofit lighting inventories are entered and used with the pre-loaded stipulated values and algorithms needed to calculate energy and demand savings. Components of the calculator include:

- Instructions and project information.
- Pre- and post-retrofit lighting inventories. A tab for exempt fixtures and a description of the exemptions is also present in the calculator.
- Fixture wattages and descriptions are defined in a Standard Fixture Wattage table.
- Factor tables that contain stipulated operating hours, coincidence factors, interactive HVAC factors, control adjustment factors, and new construction lighting power density (LPD) factors.
- A summary tab displaying the final energy and demand calculations. The data from this tab is entered into the utility program tracking data as the claimed savings values.

Although the generic LSF calculator is publicly available on the Texas Energy Efficiency website, several utilities have their own versions.

¹ Delamping energy savings are eligible if done in conjunction with T-8 lamp and electronic ballast retrofits.

² Maintained by EUMMOT/Frontier Energy: <https://texasefficiency.com/dse/>.

Eligibility Criteria

This section describes the system information and certified wattage values that must be used to estimate energy and peak savings from lighting systems installed as part of the Texas utility energy efficiency programs. The fixture codes and the demand values listed in the Table of Standard Fixture Wattages are used to calculate energy and demand savings for lighting efficiency projects.

Existing lighting fixtures must be removed or demolished in place after retrofit to count towards reduced pre-install wattage. Existing lighting fixtures that remain operable after retrofit should be listed in both the pre- and post-retrofit lighting inventory.

In addition, LED and linear fluorescent T8s need to be qualified, as follows:

- High-performance (HP) and reduced-watt (RW) T8 linear fluorescent lamps need to be qualified by the Consortium for Energy Efficiency (CEE). Their respective ballasts need to be qualified by NEMA.³ See the High-efficiency Condition section for additional details.
- LED lamps and fixtures must have their input power (wattage) and an L70 rated life (hours) verified through some combination of the following references: DesignLights Consortium® (DLC), ENERGY STAR®, or independent lab testing⁴ (e.g., LM-79, LM-80, TM-21, ISTMT). Rated life for LED fixtures should be greater than or equal to 50,000 hours, which can be demonstrated by compliance with DLC v3.0 or later⁵ or through independent lab testing. Similarly, rated life for integrated LED lamps should be greater than or equal to 10,000 hours, which can be demonstrated by compliance with ENERGY STAR Version 2.1 Specification or later⁶ or through independent lab testing for integrated-ballast LED lamps. These values represent the point at which the minimum L70 was raised to levels consistent with current deemed measure life assumptions.
 - DLC- and ENERGY STAR-certified model numbers should closely align with the installed model number. However, small variances are allowed for portions of the model number that may refer to aspects of the fixture that do not affect energy performance (e.g., color temperature, fixture housing). This allowance is provided at the discretion of the state evaluator and reported model numbers should always default to the closest match available.

³ While CEE stopped qualifying ballasts in January 2015, the NEMA Premium Electronic Ballast Program has continued to be maintained and is consistent with the prior CEE specifications for high performance lamps and ballasts, tested in accordance with ANSI C82 Standards.

⁴ DLC test lab requirements: <https://www.designlights.org/solid-state-lighting/qualification-requirements/testing-lab-requirements/>.

⁵ Equivalent to the L70 rated life requirement for all categories as specified in DesignLights ConsortiumTM (DLC) Technical Requirements v3.0. https://www.designlights.org/wp-content/uploads/2021/01/DLC_Technical-Requirements-Table_V3-0.pdf.

⁶ Equivalent to the rated life requirement for all lamps as specified in the ENERGY STAR Lamps Version 2.1 Specification. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf>.

- DLC and ENERGY STAR specifications are periodically updated. Projects may report fixture wattage from older versions of product certifications according to the following certification date guidelines if a copy of the original certification is preserved.
 1. New construction: permit date
 2. Small business: date of customer acceptance or project proposal
 3. All other: installation date
- DLC currently tracks delisted products. DLC-delisted products are eligible as long as they were rated for compliance with DLC v3.0 or later. ENERGY STAR does not track delisted products. However, any delisted product may be eligible if prior compliance is documented using a downloaded copy of the prior rating certificate.
- If a product is available in various length increments but is DLC-certified for a specific fixture length, the specified DLC power may be converted to a watts-per-square-foot value to be multiplied against the installed fixture length instead of reporting as a non-qualified fixture.
- Field adjustable light output (FALO): If a product is available with field-adjustable light output (or wattage setpoints) that can be adjusted by an installation contractor to utilize some or all LED nodes on the fixture, this will be noted in the Product Capabilities section of the DLC certification. DLC will typically specify the maximum input wattage. These fixtures should be reported based on the following scenarios:
 - If the fixture is installed at a reduced setpoint, it should be reported at the rated wattage for the reduced setpoint in combination with the *none* control code. Because DLC only reports the maximum wattage, report reduced wattage setpoint as documented in the manufacturer specification sheet.
 - If the fixture is installed with additional controls (e.g., occupancy sensor, daylighting), then it should be reported using the above guidance in combination with the applicable control code.
 - If the fixture is installed at the maximum setpoint without adjustment, it should be reported at the maximum DLC input wattage.
 - Project documentation for FALO should include a screenshot of the DLC certificate and photos of the field-adjustable setpoints for a sample of the installed lighting.
 - The same guidance applies to FALO fixtures installed in exterior applications, except that the fixture should always be installed in combination with photocell or timeclock controls.

Exempt lighting for new construction. Some types of new construction lighting fixtures are exempt from inclusion in the interior lighting demand savings calculation, but they are still included in the total installed lighting power calculations for a project. Exempt fixtures are those that do not provide general/ambient/area lighting, have separate control devices, and are installed in one of the following applications:⁷

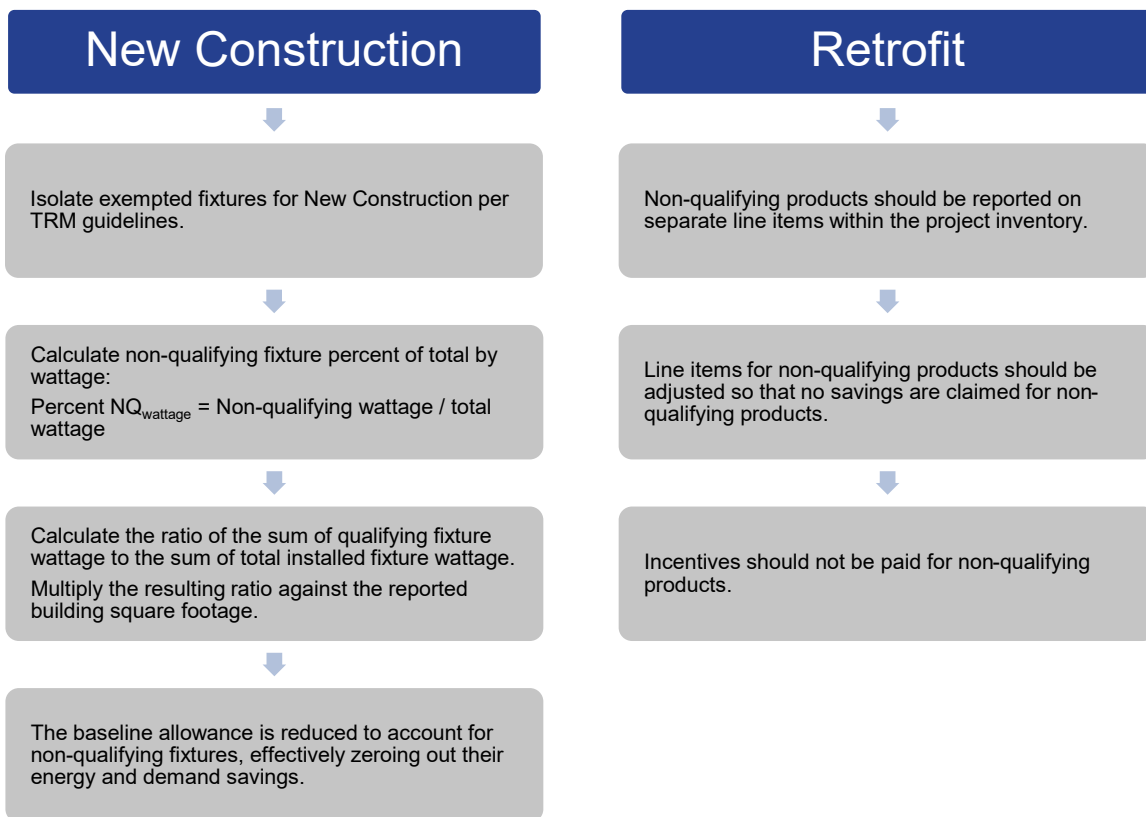
1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power
 - 1.1. Professional sports arena playing-field lighting
 - 1.2. Sleeping-unit lighting in hotels, motels, boarding houses, or similar buildings
 - 1.3. Emergency lighting automatically off during normal building operation
 - 1.4. Lighting in spaces specifically designed for use by occupants with special lighting needs including visual impairment and other medical and age-related issues
 - 1.5. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark
 - 1.6. Casino gaming areas
 - 1.7. Mirror lighting in dressing rooms
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device
 - 2.1. Task lighting for medical and dental purposes
 - 2.2. Display lighting for exhibits in galleries, museums, and monuments
3. Lighting for theatrical purposes, including performance, stage, film production, and video production
4. Lighting for photographic processes
5. Lighting integral to equipment or instrumentation and installed by the manufacturer
6. Task lighting for plant growth or maintenance
7. Advertising signage or directional signage
8. In restaurant building and areas, lighting for food warming or integral to food preparation equipment
9. Lighting equipment that is for sale
10. Lighting demonstration equipment in education facilities
11. Lighting approved because of safety or emergency considerations, inclusive of exit lights

⁷ IECC 2015, Section C405.4.1.

12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases
13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions
14. Furniture-mounted supplemental task lighting that is controlled by automatic shut off
15. Exit signs

Non-Qualifying LEDs. This section provides guidance to assess and calculate nonresidential lighting project savings that include non-qualifying LEDs. Figure 1 summarizes the recommended protocol for lighting system projects with non-qualifying LEDs when square footage cannot be isolated. Additional explanations and criteria for use follow.

Figure 1. Lamps & Fixtures—Non-Qualifying LED Process



Step 1: Qualify New Construction Projects. Calculate non-qualifying LED project percentage:

- Based as a percentage of demand (percent $NQ_{\text{wattage}} = \text{wattage of non-qualifying fixtures} / \text{wattage of total fixtures}$)

Step 2: New Construction Projects Only. Non-qualifying fixtures that pass Step 1 would follow all instructions for excluded fixtures.

- List non-qualifying LEDs on separate lines (e.g., separate on lighting inventory worksheet of deemed savings calculator). Non-qualifying fixtures are identified by a unique fixture code.
- Adjust code allowable baseline wattage so that non-qualifying fixture wattage is not included as part of the LPD code limit requirements. To do so, calculate the sum of the qualifying fixture wattage and the sum of the total installed fixture wattage. Take the ratio of qualifying fixture wattage to total fixture wattage and multiply the resulting ratio against the total treated square footage for space. The adjusted square footage is included as part of the overall LPD calculation and will decrease the total allowable baseline wattage for the project.
- **Fixture Isolation Method.** If non-qualifying fixtures are isolated to a section of the building whose square footage can be easily segmented from the total building square footage, the non-qualifying fixtures and affected square footage can be excluded from the lighting inventory. Excluded fixtures must be documented when using the fixture isolation method.

Step 3: Retrofit Projects. List non-qualifying LEDs on separate lines (e.g., separate on lighting inventory worksheet of deemed savings calculator).

- Include unique identifiers/markers for the non-qualifying LEDs within the inventory (e.g., fixture code, description, or another designator within the deemed savings tool).
- Adjust non-qualifying LED wattages, so their demand and energy savings are not included as part of the project savings. Demand and energy savings for non-qualifying LEDs shall result in zero-project savings.
- Adjust non-qualifying LED quantities so they are not included as part of the project incentive. Incentives shall not be paid on non-qualifying LEDs.
- Provide clear visibility for all changes within the savings calculation (e.g., deemed savings calculator), including changes to all input assumptions and calculation methodologies to implement the above procedure.
- All other savings procedures and requirements, as specified within the TRM for lighting measures apply to all fixtures of a lighting project.

Baseline Condition

The baseline condition or assumed baseline efficiency used in the savings calculations depends on the decision-type used for the measure. For new construction, the baseline will be based on an LPD in watts per square foot by building/space type, as specified by the relevant energy code/standard applied to a specific project. For retrofit applications, the baseline efficiency would typically reflect the in-situ, pre-existing equipment, except for linear fluorescent T12s and first-generation T8s, as explained below. All fixture types are eligible, and assigned wattages are specified in the Standard Fixture Wattages table.

Major renovation projects should use a new construction baseline (for the building type after the improvement) if either of the following conditions are met:

- Building type changes in combination with the renovation
- Renovation scope includes removing drywall and gutting existing building to the studs

Linear Fluorescent T12 Special Conditions

The US Energy Policy Act of 1992 (EPACT) set energy efficiency standards that preclude certain lamps and ballasts from being manufactured or imported into the US. The latest standards covering general service linear fluorescents went into full effect July 2014. Under this provision, almost all 4-foot and some 8-foot T12 lamps, as well as first-generation 4-foot, 700 series T8 lamps were prohibited from manufacture. Because all lighting equipment for Texas energy efficiency programs must be EPACT compliant, including existing or baseline equipment, adjustments were made to the T12 fixtures in the Standard Fixture Wattage table. Certain T12 lamp/ballast combinations which are non-EPACT compliant are assigned EPACT demand values.

As such, 4-foot and 8-foot T12s are no longer an approved baseline technology for Texas energy efficiency programs. 4-foot and 8-foot T12s are still eligible for lighting retrofit projects, but an assumed electronic T8 baseline will be used for estimating the energy and demand savings instead of the existing T12 equipment. T12 fixtures will remain in the Standard Fixture Wattage table, but the label for these records will be changed to “T12 (T8 baseline)” and the fixture wattage for these records will be adjusted to use the adjusted fixture wattages shown in Table 2.

Table 2. Lamps & Fixtures—Adjusted Baseline Wattages for T12 Equipment

T12 length	Lamp count	Revised lamp wattage	Revised system wattage
48-inch—std, HO, and VHO (4 feet)	1	32	31
	2	32	58
	3	32	85
	4	32	112
	6	32	170
	8	32	224
96-inch—std (8 feet) 60/75 W	1	59	69
	2	59	110
	3	59	179
	4	59	219
	6	59	330
	8	59	438*

T12 length	Lamp count	Revised lamp wattage	Revised system wattage
96-inch HO and VHO (8 feet) 95/110 W	1	86	101
	2	86	160
	3	86	261
	4	86	319
	6	86	481
	8	86	638
2-foot u-tube	1	32	32
	2	32	60
	3	32	89

*8 lamp fixture wattage approximated by doubling 4 lamp fixture wattage.

Key: HO = high output, VHO = very high output.

General Service Lamps

On May 8, 2022, the Department of Energy (DOE) issued two final rules relating to general service lamps (GSL):

- Energy Conservation Program: Definitions for General Service Lamps, effective July 8, 2022, which expanded the definition of a GSL.⁸
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens/watt efficacy.⁹

The baseline is assumed to be the second-tier Energy Independence and Security Act of 2007 (EISA)-mandated efficiency for a GSL (see Table 3). The EISA regulations dictate that GSLs must comply with a 45 lumen/watt efficacy standard at time of sale beginning January 1, 2023.

Table 3. Lamps & Fixtures—EISA 2007 Baseline Adjustment for GSLs^{10,11}

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	2 nd Tier EISA 2007 baseline wattage
250	309	25	Exempt

⁸ DOE Final Rule: Definitions for General Service Lamps. <https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022>.

⁹ DOE Final Rule: Energy Conservation Standards for General Service Lamps. <https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070>.

¹⁰ Federal standard for General Service Incandescent Lamps (GSILs): <https://www.energy.gov/eere/buildings/general-service-incandescent-lamps>.

¹¹ If exempt, refer to incandescent equivalent wattage.

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	2 nd Tier EISA 2007 baseline wattage
310	749	40	12
750	1,049	60	20
1,050	1,489	75	28
1,490	2,600	100	45
2,601	3,300	150	66

LED-to-LED Replacements

Replacement of existing LED fixtures is allowed if the existing LED wattage can be determined and is greater than the proposed LED wattage. If the existing LED wattage cannot be determined, program implementation staff should work with the evaluator to develop a strategy to estimate baseline wattage for individual products on a case-by-case basis.

High-Efficiency Condition

Eligible efficient fixture types and wattages are specified in the Standard Fixture Wattages table. In addition, some technologies such as LEDs must meet the additional requirements specified under Eligibility Criteria.

High-Efficiency/Performance Linear Fluorescent T8s

All 4-foot T8 post-retrofit technologies and new construction projects must use electronic ballasts manufactured after November 2014,¹² and high-performance T8 lamps that are on the T8 Replacement Lamp products list developed by the Consortium for Energy Efficiency (CEE) as published on its website.

If CEE does not have efficiency guidelines for a T8 system (such as for 8-foot, 3-foot, 2-foot, and U-bend T8 products), the product must have higher light output or reduced wattage than its standard equivalent product (minimum efficacy of 75 mean lumens per watt), while also providing a CRI (color rendering index) greater than 80, and an average rated life of 24,000 hours at three hours per start. In addition, 2-foot and 3-foot ballasts must also use electronic ballasts manufactured after November 2014.

Solar LEDs

Solar-powered LEDs are common in several commercial applications, primarily associated with pole-mounted fixtures. Solar lighting uses photovoltaic (PV) cells, which absorb solar energy to charge a battery and power the fixture. By default, solar fixtures should use an efficient wattage

¹² Changes to the DOE Federal standards for electronic ballasts effective November 2014 met both the CEE performance specification and the NEMA Premium requirements, so CEE discontinued their specification and qualifying product lists. A legacy ballast list from January 2015 is still available.

of 0. Because fixture performance relies on battery performance, the measure life for solar fixtures is capped at the expected battery life.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all lighting projects. Savings are calculated using separate methods for retrofit and new construction projects.

***Retrofit*^{13,14}**

$$\begin{aligned} \text{Energy Savings [kWh]} \\ = (kW_{pre} \times Hours_{pre} \times (1 - CAF_{pre}) - kW_{post} \times Hours_{post} \times (1 - CAF_{post})) \\ \times IEF_e \times ISR \end{aligned}$$

Equation 1

$$\begin{aligned} \text{Peak Demand Savings [kW]} \\ = (kW_{pre} \times CF_{pre} \times (1 - CAF_{pre}) - kW_{post} \times CF_{post} \times (1 - CAF_{post})) \times IEF_d \times ISR \end{aligned}$$

Equation 2

New Construction

$$\text{Energy Savings [kWh]} = \left(\frac{LPD \times FloorArea}{1,000} - kW_{post} \right) \times Hours \times (1 - CAF_{post}) \times IEF_e$$

Equation 3

$$\text{Peak Demand Savings [kW]} = \left(\frac{LPD \times FloorArea}{1,000} - kW_{post} \right) \times CF \times (1 - CAF_{post}) \times IEF_d$$

Equation 4

¹³ The number of non-operating fixtures will be limited to 10 percent of the total fixture count per facility. For projects exceeding this threshold, pre- and post-fixture count should be adjusted by multiplying fixture count against [1 - (% of non-operational fixtures - 0.1)]. No adjustment is applied to projects with less than 10 percent non-operational fixtures.

¹⁴ The energy and demand savings calculations should also account for lighting controls that are present on existing lighting systems. The CAF factors in the *Lighting Controls* measure section should be used for these calculations to adjust the deemed hours and coincidence factors on the pre-side of the equations.

Where:

kW_{pre} = Total kW of existing measure(s) (Approved baseline fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity)

$kW_{installed}$ = Total kW of retrofit measure(s) (Verified installed fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity)¹⁵

Note: wattage for installed LED fixtures may be rounded up or down to the nearest half watt; all other wattages should be rounded to the nearest watt.

LPD = Acceptable lighting power density based on building type from efficiency codes from Table 4 (W/ft²)

$Floor\ Area$ = Floor area of the treated space where the lights were installed

$Hours$ = Hours by building type from Table 7

CAF = Controls adjustment factor from Lighting Controls measure (set equal to 0 if no controls are installed on the existing fixture)

CF = Summer/winter seasonal peak coincidence factor by building type (see Table 8 or Table 9)

IEF_e = Energy HVAC interactive effects factor by building type (see Table 10)

IEF_d = Demand HVAC interactive effects factor by building type (see Table 10)

ISR = In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating = 1.0 unless otherwise specified for midstream/upstream applications (see Table 11)

¹⁵ Installed fixture wattage for fixtures defined by DLC as having “field-adjustable light output capability under the product features tab should be reported at the “default,” or maximum lumen output, setting. These fixtures may also utilize the Institutional Tuning control type. Field adjustments should be tracked in project inventories and verified with lumen measurements conducted during field inspections.

Each of the parameters in these equations, and the approach or their stipulated values, are discussed in detail below.

Lamp and Fixture Wattages (kW_{pre} , $kW_{installed}$)

Existing construction: standard fixture wattage table.¹⁶ Another example of standard fixture wattage can be found in the Fixture Codes tab of the latest version of the LSF. This table is used to assign identification codes and demand values (watts) to common fixture types (e.g., fluorescent, incandescent, HID, LED) used in commercial applications. The table is subdivided into lamp types (e.g., linear fluorescent, compact fluorescent, mercury vapor) with each subdivision sorted by fixture code. Each record (or row) in the table contains a fixture code, serving as a unique identifier. A legend explains the rules behind the fixture codes.

Each record also includes a description of the fixture, the number of lamps, the number of ballasts if applicable, and the fixture wattage. The table wattage values for each fixture type are averages of various manufacturers' laboratory tests performed to ANSI test standards. By using standardized demand values for each fixture type, the Table simplifies the accounting procedures for lighting equipment retrofits. The table is updated periodically as new fixtures are added.

The fixture codes and the demand values listed in the watt/fixture column in the Table of Standard Fixture Wattages are used to calculate energy and demand savings for any lighting efficiency project.

For implementers interested in adding new fixtures to EUMMOT's lighting table, a request should be submitted to Frontier. The request should include all information required to uniquely identify the fixture type and to fix its demand, as well as other contextual information needed for the table. If possible, the request should also be supported by manufacturer's ANSI test data. Frontier periodically releases updated versions of the LSF with new fixture codes.

New construction: LPD table. For new construction projects, the post-retrofit lighting wattages are determined as they are for the existing construction projects from the Standard Fixture Wattage table. However, the baseline wattage is determined from the treated floor area and an LPD value, which are the allowable watts per square foot of lit floor area as specified by the relevant energy code. The applicable baseline is determined by the energy code that was in effect at the time of building permit issuance. The code selected for energy savings calculations should match the code shown in the permit drawings. The current commercial energy code for the state of Texas is IECC 2015, but local jurisdictions may have adopted more recent versions.¹⁷ These values for interior space types for IECC 2015 are presented in Table 4.

¹⁶ Maintained by EUMMOT/Frontier Energy: <https://texasefficiency.com/dse/>.

¹⁷ Cities Adopted Code List: SPEER. <https://eepartnership.org/wp-content/uploads/2023/08/2023-Cities-Adopted-Code-updated-8.21.2023-1.xlsx>.

In Table 5, the lighting zones used for exterior space types are:

- Zone 1: Developed areas of national parks, state parks, forest lands, and rural areas
- Zone 2: Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited night-time use, and residential mixed-use areas
- Zone 3: All other areas
- Zone 4: High-activity commercial districts in major metropolitan areas as designated by the local land-use planning authority.

Projects should default to Zone 2. Other zones can be selected with documentation of the adjustment. Documentation includes a site aerial with a review of the neighboring properties to validate alternate selection. City zoning drawings may be used to validate a Zone 4 selection.

Table 4. Lamps & Fixtures—New Construction LPDs for Interior Space Types by Building Type¹⁸

Facility type	LPD (W/ft ²)	Facility type	LPD (W/ft ²)
Automotive facility	0.80	Multifamily	0.51
Convention center	1.01	Museum	1.02
Courthouse	1.01	Office	0.82
Dining: bar/lounge/leisure	1.01	Parking garage	0.21
Dining: cafeteria/fast food	0.90	Penitentiary	0.81
Dining: family	0.95	Performing arts	1.39
Dormitory	0.57	Police stations	0.87
Exercise center	0.84	Post office	0.87
Fire station	0.67	Religious buildings	1.00
Gymnasium	0.94	Retail	1.26
Health care/clinic	0.90	School/university	0.87
Hospital	1.05	Sports arena	0.91
Hotel/motel	0.87	Town hall	0.89
Library	1.19	Transportation	0.70
Manufacturing facility	1.17	Warehouse	0.66
Motion picture theater	0.76	Workshop	1.19

New construction agricultural buildings require a custom calculation for baseline wattage based on agricultural production requirements. Typically, the baseline is the quantity of metal halide

¹⁸ IECC 2015 Table C405.4.2(1) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.5.1.

lamps that are required for the agricultural production or the quantity that will fit in the space. Indoor vertical farming is not eligible because the lighting can only be completed by advanced LED fixtures. The total new construction exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table 5.

The reported square footage should represent the illuminated area. Each unique outdoor area should report a unique illuminated area specific to that application and should not be combined under a single space type. For example, a new construction convenience store project should have separate areas for fuel canopy, parking and drives, building facades, and any other applicable space types. Fuel canopies should reflect the area under the canopy rather than the entire exterior lot area. Building facades should reflect the total wall area where wall-mounted fixtures are installed rather than the floor area for any space type surrounding the illuminated wall.

Table 5. Lamps & Fixtures—New Construction LPDs for Exterior Space Types¹⁹

Space type	LPD (W/ft ²)			
	Exterior Zone 1	Exterior Zone 2	Exterior Zone 3	Exterior Zone 4
Base site allowance	500 W	600 W	750 W	1,300 W
Uncovered parking: Parking areas and drives	0.04	0.06	0.10	0.13
Building grounds: Walkways $\geq$ 10 ft. wide, plaza areas, and special feature areas	0.14	0.14	0.16	0.20
Building grounds: Stairways	0.75	1.00	1.00	1.00
Building grounds: Pedestrian tunnels	0.15	0.15	0.20	0.30
Building grounds: Landscaping (ASHRAE 90.1-2013 only) ²⁰	0.04	0.05	0.05	0.05
Building entrances and exits: Entry canopies	0.25	0.25	0.40	0.40
Building entrances, exits, and loading docks: Loading docks (ASHRAE 90.1-2013 specific) ²¹	0.50	0.50	0.50	0.50

¹⁹ IECC 2015 Table C405.5.1(2) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.4.2-2. Differences between the two standards are noted.

²⁰ In June 2016, the Texas Comptroller issued a state certification letter adopting ASHRAE 90.1-2013 as the energy code for state buildings while the Commercial building code remains IECC 2015. State-funded buildings are required to submit SECO compliance certificates as part of the NC/Renovation process. More details can be found at the Comptroller website: <https://comptroller.texas.gov/programs/seco/code/state-funded.php>. This space type is missing from the IECC 2015 LPD table, but the TRM authorizes the use of these LPDs for non-state-funded buildings.

²¹ Ibid.

Space type	LPD (W/ft ²)			
	Exterior Zone 1	Exterior Zone 2	Exterior Zone 3	Exterior Zone 4
Sales canopies: Free-standing and attached	0.60	0.60	0.80	1.00
Outdoor sales: Open areas	0.25	0.25	0.50	0.70
Building facades ²²	–	0.075	0.113	0.150
Entrances and gatehouse inspection stations	0.75	0.75	0.75	0.75
Loading areas for emergency vehicles	0.50	0.50	0.50	0.50

Default metal halide baseline wattage assumptions have been approved for exterior athletic fields and courts, which are not included in the above LPD table. For this application, use the upstream/midstream baseline wattages for exterior lamps from Table 11.

Operating Hours (Hours) and Coincidence Factors (CFs)

Operating hours and peak demand coincidence factors are assigned by building type, as shown in Table 7 through Table 9. The building types used in this table are based on Commercial Buildings Energy Consumption Survey (CBECS)²³ building types but have been modified for Texas. Refer to Volume 1, Section 4 for a description of the Texas peak demand methodology. Winter peak coincidence factors are only specified for outdoor fixtures, including for the “Parking Garage” building type.

The operating hours and coincidence factors specified in this section have been calculated at the facility level and should be applied to the entire facility. Outdoor fixtures that are not associated with the typical building lighting schedule may be claimed separately. These can include parking lot, walkway, wall pack, or another lighting, while building-mounted lighting with an operating schedule that more closely approximates the interior lighting schedule typically should not be claimed separately.

²² ASHRAE 90.1-2013 reflects a higher baseline. The TRM specifies the higher, more conservative, baseline to allow the same LPD to apply to all buildings, regardless of whether they are state-funded.

²³ DOE-EIA Commercial Building Energy Consumption Survey.

<https://www.eia.gov/consumption/commercial/>.

Table 6. Lamps & Fixtures—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Agriculture	General	Buildings used for support of agricultural operations.	1) Barns or workshops 2) Garage
	Custom	Buildings used for agricultural production to grow herbs, fruits, or vegetables under artificial lighting or animal housing lighting.	1) 24-hour grow house 2) Non-24-hour supplemented greenhouse 3) Animal housing
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center
Education	College/university	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	1) College or university 2) Career or vocational training 3) Adult education
	Primary school		1) Elementary or middle school (grade 8 or lower) 2) Preschool or daycare
	Secondary school ²⁵		1) High school (grade 9 or greater) 2) Religious education
Food sales	Convenience	Buildings used for retail or wholesale of food.	1) Gas station with a convenience store 2) Convenience store
	Supermarket		1) Grocery store or food market

²⁴ Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

²⁵ Individual middle and junior high schools may have a campus size and building activities that better align with secondary schools. Refer to Measure 2.2.2 for guidance on aligning subcategories.

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Food service	Full-service restaurant	Buildings used for the preparation and sale of food and beverages for consumption.	1) Restaurant or cafeteria
	Quick-service restaurant		1) Fast food
Healthcare	Hospital	Buildings used as diagnostic and treatment facilities for inpatient care.	1) Hospital 2) Inpatient rehabilitation
	Outpatient healthcare	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as office buildings).	1) Medical office 2) Clinic or outpatient health care 3) Veterinarian
Multifamily	Common area	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	1) Common area
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents.	1) Motel or inn 2) Hotel 3) Dormitory, fraternity, or sorority 4) Retirement home, nursing home, assisted living, or other residential care 5) Convent or monastery
	Nursing home		
	Small hotel/motel		

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Manufacturing	1 Shift (<70 hr/week)	Buildings used for manufacturing/industrial applications.	1) Apparel 2) Beverage, food, and tobacco products 3) Chemicals 4) Computer and electronic products 5) Appliances and components 6) Fabricated metal products 7) Furniture 8) Leather and allied products 9) Machinery 10) Nonmetallic mineral products 11) Paper 12) Petroleum and coal products 13) Plastics and rubber products 14) Primary metals 15) Printing and related support 16) Textile mills 17) Transportation equipment 18) Wood products
	2 Shift (70-120 hr/week)		
	3 Shift (>120 hr/week)		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	1) Retail store 2) Beer, wine, or liquor store 3) Rental center 4) Dealership or showroom for vehicles or boats 5) Studio or gallery
	Strip mall/enclosed mall	Shopping malls comprised of multiple connected establishments.	1) Strip shopping center 2) Enclosed malls

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Office	Large office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	1) Administrative or professional office 2) Government office 3) Mixed-use office 4) Bank or other financial institution 5) Medical office 6) Sales office 7) Contractor's office (e.g., construction, plumbing, HVAC) 8) Non-profit or social services 9) Research and development 10) City hall or city center 11) Religious office 12) Call center
	Medium office		
	Small office		
Parking	Parking garage	Buildings used for parking applications.	No sub-categories collected.

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Public order and safety	Jail and prison	Government establishments engaged in justice, public order, and safety.	1) Correctional institutions 2) Prison administration and operation
	Other		1) Police protection 2) Legal counsel and prosecution 3) Fire protection 4) Public order and safety, not elsewhere classified
Religious worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.

Building type	Principal building activity	Definition	Detailed business type examples ²⁴
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning salon 11) Copy center or printing shop 12) Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	1) Refrigerated warehouse 2) Non-refrigerated warehouse 3) Distribution or shipping center
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

Table 7. Lamps & Fixtures—Operating Hours by Building Type

Building type	Operating hours
Agriculture: General	2,638
Agriculture: Custom ²⁶	Custom
Data center	4,008
Education: K-12 with summer session, college, university, vocational, and day care	3,577
Education: K-12 with partial summer session ²⁷	3,177
Education: K-12 without summer session	2,777
Food Sales: Non-24-hour supermarket or convenience store	4,706
Food Sales: 24-hour supermarket or convenience store	6,900
Food service: Full-service restaurant	4,368
Food service: Quick-service restaurant	6,188
Food service: 24-hour restaurant	7,311
Healthcare: Inpatient	5,730
Healthcare: Outpatient	3,386
Lodging: Hotel/motel/dorm—common area	6,630
Lodging: Hotel/motel/dorm—room	3,055
Lodging: Nursing home	4,271
Manufacturing: 1 Shift (<70 hr/week)	2,786
Manufacturing: 2 Shift (70-120 hr/week)	5,188
Manufacturing: 3 Shift (>120 hr/week)	6,414
Mercantile: Non-24-hour stand-alone retail	3,668
Mercantile: Enclosed mall	4,813
Mercantile: Strip mall	3,965
Mercantile: 24-hour retail	6,900
Multifamily: Common area	4,772
Office	3,737
Outdoor: Athletic field and court ²⁸	767
Outdoor: Billboard ²⁹	3,470

²⁶ Document site-specific hours from lighting control setpoints based on agriculture production schedule.

²⁷ Assuming a partial summer session in June with no summer session in July.

²⁸ “2015 US Lighting Market Characterization,” US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours/year.

²⁹ Ibid.

Building type	Operating hours
Outdoor: Dusk-to-dawn ³⁰	4,161
Outdoor: Less than dusk-to-dawn ³¹	1,998
Parking garage	7,884
Public assembly	2,638
Public order and safety: Jail and prison	7,264
Public order and safety: Other	3,472
Religious worship	1,824
Service: Excluding food	3,406
Warehouse: Non-refrigerated	3,501
Warehouse: Refrigerated	3,798
Warehouse: 24-hour warehouse ³²	6,414
Other	2,638

³⁰ This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding ½ of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

³¹ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

³² Extended from Manufacturing: 3 Shift building type.

Table 8. Lamps & Fixtures—Summer Peak Coincidence Factors by Building Type³³

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture: General	0.65	0.65	0.65	0.65	0.65
Agriculture: Custom	1.00	1.00	1.00	1.00	1.00
Data center	0.85	0.85	0.85	0.85	0.85
Education: K-12 with summer session, college, university, vocational, and day care	0.90	0.90	0.90	0.90	0.90
Education: K-12 with partial summer session ³⁴	0.42	0.39	0.90	0.90	0.57
Education: K-12 without summer session	0.39	0.39	0.90	0.87	0.40
Food sales: Non-24-hour supermarket or convenience store	0.90	0.90	0.90	0.90	0.90
Food sales: 24-hour supermarket or convenience store	0.90	0.90	0.90	0.90	0.90
Food service: Full-service restaurant	0.90	0.90	0.90	0.90	0.90
Food service: Quick-service restaurant	0.90	0.90	0.90	0.90	0.90
Food service: 24-hour restaurant	0.90	0.90	0.90	0.90	0.90
Healthcare: Inpatient	0.80	0.83	0.81	0.80	0.90
Healthcare: Outpatient	0.70	0.75	0.72	0.71	0.90

³³ Building operating schedules are adapted from COMNET Appendix C – Schedules (Rev. 3). <https://comnet.org/appendix-c-schedules>. Updated 7/25/2016.

³⁴ Assuming a partial summer session in June with no summer session in July.

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Lodging: Hotel/motel/dorm, common area	0.90	0.90	0.90	0.90	0.90
Lodging: Hotel/motel/dorm, room	0.30	0.30	0.30	0.30	0.30
Lodging: Nursing home	0.70	0.75	0.72	0.71	0.90
Mercantile: Non-24-hour retail	0.90	0.90	0.90	0.90	0.90
Mercantile: Enclosed mall	0.90	0.90	0.90	0.90	0.90
Mercantile: Strip mall	0.90	0.90	0.90	0.90	0.90
Mercantile/food sales: 24-hour retail	0.90	0.90	0.90	0.90	0.90
Manufacturing: 1 Shift (<70 hr/week)	0.83	0.84	0.83	0.85	0.85
Manufacturing: 2 Shift (70-120 hr/week)	0.85	0.85	0.85	0.85	0.85
Manufacturing: 3 Shift (>120 hr/week)	0.85	0.85	0.85	0.85	0.85
Multifamily: Common area	0.90	0.90	0.90	0.90	0.90
Office	0.87	0.88	0.86	0.90	0.90
Outdoor: Athletic field and court	—	—	—	—	—
Outdoor: Billboard	—	—	—	—	—
Outdoor: Dusk-to-dawn	—	—	—	—	—
Outdoor: Less than dusk-to-dawn	—	—	—	—	—
Parking garage	1.00	1.00	1.00	1.00	1.00
Public assembly	0.65	0.65	0.65	0.65	0.65
Public order and safety: Jail and prison	0.90	0.90	0.90	0.90	0.90
Public order and safety: Other	0.70	0.75	0.72	0.71	0.90
Religious worship	0.65	0.65	0.65	0.65	0.65

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Service: Excluding food	0.90	0.90	0.90	0.90	0.90
Warehouse: Non-refrigerated	0.79	0.81	0.79	0.80	0.85
Warehouse: Refrigerated	0.79	0.81	0.79	0.80	0.85
Warehouse: 24-hour warehouse	0.85	0.85	0.85	0.85	0.85
Other	0.65	0.65	0.65	0.65	0.65

Table 9. Lamps & Fixtures—Winter Peak Coincidence Factors by Building Type³⁵

Space type	Winter peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Outdoor: Athletic field and court	0.26	0.27	0.24	0.29	0.38
Outdoor: Billboards	0.59	0.62	0.53	0.65	0.87
Outdoor: Dusk-to-dawn ³⁶	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn ³⁷	0.67	0.71	0.61	0.75	1.00
Parking garage	1.00	1.00	1.00	1.00	1.00

³⁵ Operating schedules are based on sunrise/sunset times for each climate-zone reference city, adjusted for compliance with IESNA-DG-13-96 and IESNA-DG-13-98 recommendations.

³⁶ This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule.

³⁷ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

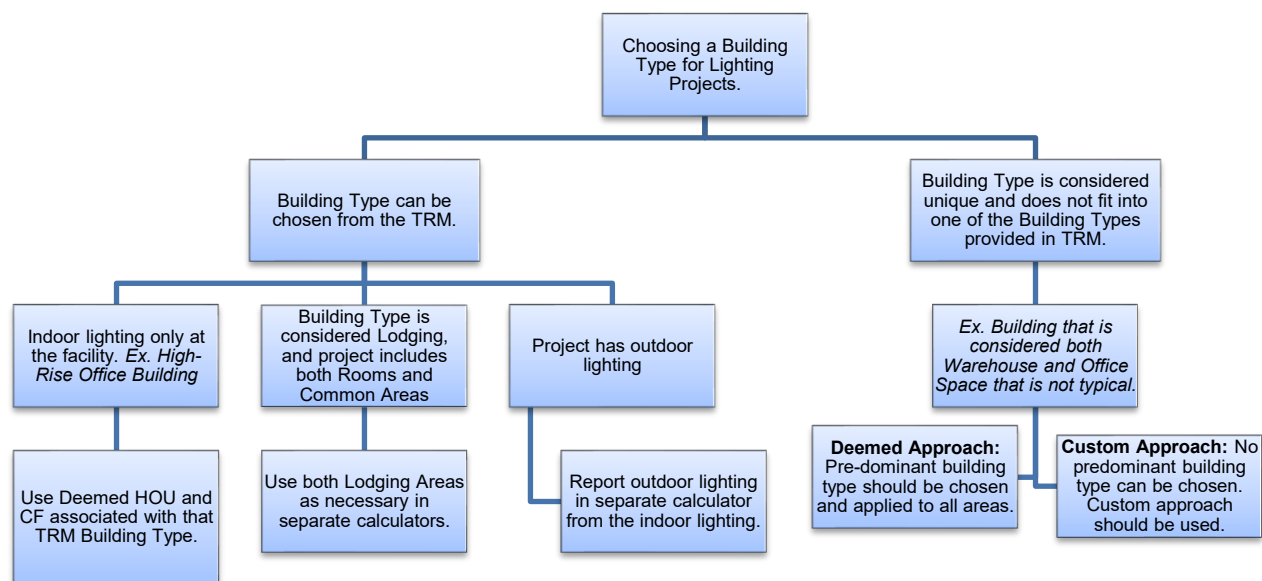
Building Type Selection

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.³⁸

The deemed lighting hours of use (HOU) and peak summer coincidence factors (CF) for utilities to use in calculating savings associated with lighting are broken down by building type and use. If the building type changes in combination with the retrofit, the selected building type should be consistent with the space condition after improvement. These values are provided in Table 7 through Table 9. For most building types listed in this table, the HOU and CFs were created based on weighted averages of lighting usage across all activity areas of the building.³⁹ Therefore, the deemed HOU and CFs are representative of an entire building type, across all activity areas that are in a “typical” building for this type.

The following flow chart, Figure 2, has been provided to assist utilities in understanding how they can use the deemed methods to calculate lighting savings based on HOU and CF provided in the TRM. Additionally, it provides guidance on how to treat lodging facilities and outdoor lighting projects as well as unique building types.

Figure 2. Lamps & Fixtures—Building Type Decision-Making



Lodging sites. Lodging facilities (Hotel/Motel/Dormitories) have been identified in the TRM by *Common* and *Rooms*, both with different HOU and CF. As two different values have been provided for these areas, it is acceptable for the utilities to use either or both building types for a single project.

³⁸ *Annual Statewide Portfolio Report for Program Year 2013 – Volume I.* Prepared for the Public Utility Commission of Texas. October 6, 2014.

³⁹ More information on how these values were created can be found in PUCT Docket #39146.

Exterior lighting. Projects involving outdoor lighting should be claimed in a separate calculator or separate inventory within the same calculator. The exception to this is walkway lighting that is more consistent with building operation. In this application, the utilities should use the primary building type as their HOU and CFs have been rolled up into the overall building type calculations (e.g., walkway lighting between two buildings that operates during business hours).

Combination building types. In most cases, buildings (except greenhouses and parking structures) should be classified based on the building type that represents the majority of the square footage. Greenhouses and parking garages should be treated separately from other indoor spaces intended for human occupancy.

In other situations where multiple TRM building types seem plausible, or a predominant TRM building type is unclear, the utilities have two choices:

- **Deemed approach.** The deemed approach is a simplified method where utilities should choose a TRM building type based on the “best fit” for the facility. For interior spaces, this is determined by the largest interior area for the potential building types. Although, if that is not best fit, the utilities will use their best judgment to make this decision and provide sufficient, defensible documentation for their decision.

The *manufacturing* building type is specified with 1-, 2-, and 3-shift options:

- Shift 1: Typical operation of 9.5-11.5 hours per day and 4-6 days per week (<70 hours per week)
- Shift 2: Typical operation of 18-20 hours per day and 5-6 days per week (70–120 hours per week)
- Shift 3: Typical operation of 24 hours per day and 5-6 days per week (>120 hours per week)

The following building type combinations are pre-authorized exceptions to this rule. For these combinations, individual fixtures can be reported as either specified building type based on location. All other interior space combinations should reference a single deemed building type unless authorized by the evaluator.

- Office: Warehouse (refrigerated or non-refrigerated)
- Office: Manufacturing (any shift number)
- Manufacturing (buildings with different shift designations by area)
- Inpatient healthcare: Outpatient healthcare
- Lodging, common areas: Lodging, rooms

The *other* building type can be used for business types that are not explicitly listed. The hours and CF values used for other are the most conservative from the explicitly listed building types (with the exception of the CF values specified for “Education: K-12 without Summer Session” and “Lodging: Hotel/Motel/Dorm, Common Areas”, which are associated with very specific operating schedules that experience low coincidence with the summer peak period). When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the lighting

schedule must be collected for the project site and stored in the utility tracking data system.

“Outdoor Dusk-to-Dawn” applies to outdoor fixtures controlled by a photocell or timer with dusk-to-dawn operation throughout the entire year. Outdoor fixtures controlled by timers with less than dusk-to-dawn operation (excluding athletic fields and courts) may be claimed separately using the “Outdoor Less than Dusk-to-Dawn” building type or using a custom timer schedule.

Exterior spaces may reference multiple outdoor building types differentiated based on typical operating schedules (Outdoor Dusk-to-Dawn, Less than Dusk-to-Dawn, Athletic, or Billboard).

- **Custom approach.** In more unique situations, utilities should consider projects “custom” where (1) the deemed building types in the TRM may not represent the project’s facility type, (2) the facility may represent multiple TRM building types without a clear predominant building type, or (3) the use of a predominant building type may be too conservative in the estimate of savings. The deemed methods only apply to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their HOU and CF values used in their savings calculations that the EM&V team can review.

HVAC Interactive Effects Factors

Basic lighting savings are adjusted to account for the lighting system interaction with HVAC systems in conditioned or refrigerated spaces. A reduced lighting load reduces the internal heat gain to the building, which reduces the air conditioning/cooling load while increasing the heating load. Currently, the TRM only considers additional cooling savings, and the heating penalty or increase in usage is ignored.

As Table 10 shows, four conditioned space types are used for the Texas programs: single air-conditioned space type, two options for commercial refrigeration, and refrigerated warehouses: medium and low temperature. Utility procedures state that if the actual application falls between these values, the higher temperature value should be used. The final space type is unconditioned (or more explicitly uncooled as the focus is on cooling). In the lighting calculators, these values are typically assigned at the line-item level based on the conditioning type for the space in which the fixtures are located.

Table 10. Lamps & Fixtures—Deemed Energy and Demand Interactive HVAC Factors⁴⁰

Space conditioning type	IEF _E	IEF _D
Refrigerated air	1.05	1.10
Evaporative cooling ⁴¹	1.02	1.04
Medium-temperature refrigeration (33 to 41°F)	1.25	1.25

⁴⁰ PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).

⁴¹ These factors are only applicable for projects in climate zones 1 and 5. They are derived by taking a ratio of total HVAC energy use for spaces with evaporative and refrigerated cooling then applying that ratio against the IEF factors specified for refrigerated air.

Low-temperature refrigeration (-10 to 32°F)	1.30	1.30
None (unconditioned/uncooled)	1.00	1.00

Upstream/Midstream Lighting

This section provides guidance on calculating and allocating savings at the sector-level for upstream/midstream lighting programs.

An increased number of utilities are offering or planning to offer upstream and/or midstream lighting programs in Texas. It is important that savings are calculated and reported consistently across utilities and in agreement with industry-standard practice and the Energy Efficiency Rule 16 TAC § 25.181.

Upstream/Midstream Program Assumptions

For upstream/midstream program delivery, use the following AOH and CF assumptions specified by lamp type. Assumed AOH and CF values have been weighted based on building type survey data from 2018 CBECS⁴² and 2018 MECS⁴³ as well as lamp density and lamp type distribution survey data from the DOE 2020 US Lighting Market Characterization (LMC)⁴⁴.

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed through upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining 5 percent of savings allocated to the commercial sector.⁴⁵ While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

Table 11. Lamps & Fixtures—Upstream/Midstream Input Assumptions by Lamp Type⁴⁶

Lamp type	AOH	Coincidence factors ⁴⁷					ISR
		Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso	
GSL/reflector	3,745	0.72	0.72	0.77	0.77	0.74	0.98

⁴² 2018 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>.

⁴³ 2018 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

⁴⁴ 2020 US Lighting Market Characterization, Department of Energy. April 2024.

https://www.energy.gov/sites/default/files/2024-08/ssl-lmc2020_apr24.pdf.

⁴⁵ Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs.

⁴⁶ 2018 CBECS and 2018 MECS. <https://www.eia.gov/consumption/commercial/data/2018/>.

<https://www.eia.gov/consumption/manufacturing/data/2018/>.

⁴⁷ Outdoor coincidence factors are specified for winter peak. All other values reference summer peak.

Lamp type	AOH	Coincidence factors ⁴⁷					ISR
		Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso	
LED tube	3,542	0.75	0.75	0.83	0.83	0.76	1.00
High-bay fixture	3,987	0.84	0.85	0.84	0.85	0.85	1.00
Garage ⁴⁸	7,884	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor ⁴⁹	4,161	0.67	0.71	0.61	0.75	1.00	1.00

Upstream/midstream lighting programs should use Table 12 below to determine baseline wattages for energy savings calculations.

Table 12. Lamps & Fixtures—Upstream/Midstream Baseline Wattages by Lamp Type⁵⁰

Lamp Type	Length	Lumens Range	Baseline Description	Baseline Watts
GSL/Reflector/ Downlight	N/A	250-309	A-lamps and other lamp shapes	Exempt ⁵¹
		310-3,300		Lumens/45
LED Tube	2-ft	≤ 1,200	F17T8	15
	4-ft	1,200-2,400	F32T8	29
		> 2,400	F32T8 high-output (HO)	34
LED Fixture, Linear	2-ft	≤ 3,500	F32T8 2-lamp	58
		3,501-5,000	F32T8 3-lamp	86
	4-ft	≤ 3,000	F32T8 1-lamp	29
		3,001-4,500	F32T8 2-lamp	58
		4,501-6,000	F32T8 3-lamp	86
		6,001-7,500	F32T8 4-lamp	115

⁴⁸ This category should only be used for products marketed for use in parking garage applications.

⁴⁹ This category should only be used for products marketed for use in outdoor applications.

⁵⁰ Baseline descriptions and lumens range are based on assumptions from Illinois TRM. Baseline wattages were pulled from the Standard Fixture Wattage Table found on the Texas Efficiency website and were determined by using the baseline description for the listed equipment.

⁵¹ If exempt, refer to incandescent equivalent wattage.

Lamp Type	Length	Lumens Range	Baseline Description	Baseline Watts
High-Bay Fixture	N/A	≤ 10,000	T5-HO 3-lamp	178
		10,001-15,000	T5-HO 4-lamp	238
		15,001-20,000	T5-HO 6-lamp	356
		20,001-30,000	T5-HO 8-lamp	462
		30,001-40,000	750W metal halide	812
		40,001-50,000	1,000W metal halide	1,078
		> 50,000	1,500W metal halide	1,605
Parking Garage/ Exterior	N/A	≤ 5,000	100W metal halide	124
		5,001-10,000	175W metal halide	208
		10,001-15,000	250W metal halide	288
		15,001-30,000	400W metal halide	453
		30,001-40,000	750W metal halide	812
		40,001-60,000	1,000W metal halide	1,078
		60,001-80,000	1,500W metal halide	1,605
		80,001-120,000	(2) 1,000W metal halides	2,156
		120,001-160,000	(3) 1,000W metal halides	3,234
		160,001-200,000	(4) 1,000W metal halides	4,312
		> 200,000	(5) 1,000W metal halides	5,390

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters related to lighting system operation.

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) values are defined for the following lamp/fixture types.⁵² A separate new construction EUL has been established due to account for the whole-building baseline.

- Halogen lamps: 1.5 years

⁵² PUCT Docket 36779.

- High-intensity discharge lamps: 15 years
- Integrated-ballast CCFL lamps: 4.5 years
- Integrated-ballast CFL lamps: 2.5 years
- Integral LED lamps: 9 years⁵³
- LED fixtures: 15 years
- LED corn cob lamps: 15 years
- LED tubes: 15 years
- Solar LEDs⁵⁴: 10 years
- Modular CFL and CCFL fixtures: 15 years
- T8 and T5 linear fluorescents: 15 years
- New construction interior fixtures/controls⁵⁵: 14 years
- New construction exterior fixtures⁵⁶: 15 years

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: retrofit or new construction
- Building or space type
- Optional: building or space funding source (state or private)
- **For new construction only:**
 - LPD factor
 - Interior and/or exterior lighting schedules and plans
 - Interior and/or exterior space areas and distances

⁵³ PUCT Docket 38023.

⁵⁴ The typical solar battery life is approximately 5–15 years. A typical product warranty for a solar LED fixture is 10 years. This deemed EUL aligns with the average product life expectancy and typical warranty period.

⁵⁵ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

⁵⁶ Ibid.

- If applicable, verify whether SECO compliance certification forms were filed⁵⁷
- Conditioned space type: cooling equipment type, refrigerated space temperature range, heating fuel type, percent heated/cooled for new construction only (specified per control)
- Baseline fixture configuration
- Baseline lamp wattage
- Baseline ballast type
- Baseline lighting controls
- Baseline counts of operating fixtures
- Baseline counts of inoperable fixtures
- Post-retrofit manufacturer and model number⁵⁸
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage⁵⁹
- Post-retrofit lamp specifications sheets: Post retrofit lamp product qualification information from DLC, ENERGY STAR®, or independent lab testing
- Post-retrofit ballast type
- Post-retrofit lighting controls
- Post-retrofit counts of operating fixtures
- **For FALO fixtures only:** isolate these fixtures by setting type and location within reported project inventories and track field adjustment settings; photos of the field-adjusted setpoints for a sample of fixtures
- Equipment operating hours
- Lighting measure group (from Measure Life groupings)

⁵⁷ State-funded buildings are required to submit SECO compliance forms as part of the NC/renovation process. Buildings that submit SECO compliance forms are considered state-funded and must meet the provisions of ASHRAE 90.1-2013 rather than IECC 2015. Previous tables in this section present the alternative compliance values where they are encountered in the codes.

⁵⁸ See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit model number.

⁵⁹ See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit fixture wattage.

- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; OR a photo of each model number on product packaging and installed fixture; OR as-built design drawings; OR lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach
- **For upstream/midstream only:** Qualified product list mapping efficient lighting products to baseline wattage assumptions
- **For Agricultural Custom:** provide the agricultural production requirements for lighting hours, lumens, and temperature. Identify the lighting specification that meet those requirements.

Lighting Measure Groups to be Used for Measure Summary Reports

The lighting measure groups, as defined in the Measure Life and Lifetime Savings list above, must be used for reporting summarized savings of lighting measures. Higher-level groupings of lighting technologies, such as “Non-LED” lighting, will not provide enough resolution for evaluation and cost-effectiveness analysis.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Describes EUL
- PUCT Docket 39146—Describes deemed values for energy and demand savings
- PUCT Docket 38023—Describes LED installation and efficiency standards for nonresidential LED products

Relevant Standards and Reference Sources

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

Document Revision History

Table 13. Lamps & Fixtures—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Measure Life section: Added additional energy efficiency measures for consistency with the EUMMOT maintained list. Calculator and Tools section: Eliminated description of calculator output comparisons. Tracking Data Requirements section: Added lighting category requirements for measure summary reports.

TRM version	Date	Description of change
v3.0	04/10/2015	Revised to eliminate T12 lamps as a valid baseline. Measure Description section: General clean-up of technology descriptions. Program Tracking Data section: Minor changes and clarifications.
v3.1	11/05/2015	Revised to eliminate T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. Eligibility Criteria: Adding sources for LED lamp and fixture eligibility.
v3.1	03/23/2016	Updated Linear Fluorescent T12 Special Conditions baseline table to include HO and VHO lamps. Updated criteria for miscellaneous length (e.g., 2-ft, 3-ft) T8s. Added footnote to explain how to account for non-rebated fixture lighting controls in savings calculations. Clarified some tracking data requirements.
v4.0	10/10/2016	Added LPD values and tracking data requirements for exterior space type climate zones used in Codes and Standards.
v5.0	10/2017	Added two new building types (i.e., Data Centers, 24-Hr Restaurants), and updated the Manufacturing building type to separate 1, 2 and 3 shift operations. Updated sources and references. Completed code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	Updated eligibility criteria to broaden the qualification paths for LED fixtures. Added rounding opt-in for LED wattages. Clarifications added for building type definitions, including the addition of an "Other" category for buildings that do not fit into the list of pre-defined building types. Updated peak coincident factors for the PDPF methodology outlined in Volume 1.
v7.0	10/2019	Merged relevant Volume 5 Implementation Guidance into the measure. Changed non-qualified lighting thresholds and accounting procedures for new construction projects. Added guidance for EISA baselines. Added Base Site Allowance for exterior new construction projects. Added equivalent metal halide guidance for exterior athletic fields and courts. Added new building types (Agriculture, Outdoor: Billboards, Education K-12 with partial summer session, Facility-Wide 24-Hour Lighting). Revised Outdoor: Athletic Field and Court factors. Added Midstream lighting guidance, assumptions, and calculations. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Updated EUL for new construction projects to apply to whole project. Updated dusk-to-dawn operating hours. Minor formula corrections. Updated DLC references to refer to v3.0 or later rather than explicit versions. Removed 10% nonqualified fixture threshold. Established lumens/watt assumptions for new construction baselines.

TRM version	Date	Description of change
v9.0	10/2021	General reference checks and text edits. Added guidance for certification of incremented length products. Added upstream clarification. Combined greater and less than 100 W GSLs and reflectors for upstream/midstream. Adjusted upstream/midstream residential vs. commercial split and ISRs. Updated upstream/midstream outdoor hours of use. Added guidance for LED model number, performance characteristics certification, and dates of certification. Changed LSF references to fixture wattage table.
v10.0	10/2022	Corrected DLC version requirements omitted from final TRM v8.0. Added guidance for field adjustable lights. Addressed savings path for solar fixtures. Added guidance for new construction exterior lighting zone selection. Added guidance for building type selection. Clarified midstream outdoor coincident factor is winter peak.
v11.0	10/2023	Added guidance for delisted lighting products and for new construction exterior lighting zone selection. Aligned building type names across all commercial measures.
v12.0	10/2024	Clarified exterior new construction code zone selection guidance, adjusted new construction savings algorithm, updated multiple control type, adjusted non-operational fixture footnote, in-service rate incorporated into retrofit savings algorithm, clarified building type section guidance, and updated midstream building type weighting assumptions.
v13.0	10/2025	Clarified agricultural building type application; added language to address LED to LED replacements; added 24-hour warehouse building type; updated baseline assumptions for upstream/midstream lighting measures.

2.1.2 Lighting Controls Measure Overview

TRM Measure ID: NR-LT-LC

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial, multifamily common areas

Fuels Affected: Electricity (interactive HVAC effects: electric/gas space heating)

Decision/Action Types: Retrofit, new construction

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls are typically installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, controls would be added where they are not already required by existing energy or building codes. Promoted technologies include occupancy sensors and daylight dimming controls. Energy and peak demand savings are calculated for these technologies with a controls adjustment factor (CAF).

Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 14. Savings may be claimed for control types that exceed the minimum code-required controls, mainly occupancy sensors for interior spaces.

New construction (NC) buildings designed after November 1, 2016 must be equipped with lighting controls unless specifically designated in the below exceptions. Most interior building spaces must have occupancy sensor controls or time-switch controls. Daylight responsive controls must be present in daylight zones. Exterior lighting must be installed with daylight sensors. Therefore, NC lighting controls savings can only be claimed in instances where the installed controls exceed energy code. Refer to IECC 2015, Section C405 for more information.

Networked lighting controls (NLC): An NLC system uses software control based on the outputs of the sensor equipment. The system requires commissioning to ensure proper operation. A plan detailing the inspection and recalibration frequency that identifies the actions necessary through the end of the EUL period is required to ensure continued operation in accordance with design conditions.

Baseline Condition

The retrofit baseline condition assumes no existing or code required automatic lighting controls are installed on the existing lighting fixtures (i.e., they are only manually switched).

For control types that exceed the minimum required control types (usually occupancy sensors or time switch controls), savings can be claimed with the minimum required controls as the baseline efficiency. In these cases, the applicable baseline CAFs are specified for occupancy sensors in Table 15.

For new construction projects, the baseline should be occupancy sensors in most cases unless a specific exception is allowed by code.⁶⁰

High-Efficiency Condition

The energy-efficient condition is properly installed (not bypassed or overridden) and calibrated lighting controls that control overhead lighting in a facility based on occupancy, daylighting, or tuning sensors.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The equations for lighting controls are similar to those used for lighting lamps and fixtures, with the addition of the control adjustment factor (CAF) multipliers, as shown below. Additionally, the pre/post kW difference is replaced by a single kW value (the total fixture wattage controlled by the device).

$$\text{Energy Savings [kWh]} = kW_{\text{controlled}} \times \text{CAF} \times \text{Hours} \times \text{HVAC}_{\text{energy}}$$

Equation 5

$$\text{Summer Peak Demand Savings [kW]} = kW_{\text{controlled}} \times \text{CAF} \times CF_S \times \text{HVAC}_{\text{demand}}$$

Equation 6

Where:

$kW_{\text{controlled}}$	=	Total kW of controlled fixtures (fixture wattage from Standard Wattage table multiplied by quantity of fixtures)
Hours	=	Hours by building type from Table 7
CAF	=	Controls adjustment factor (see Table 15)
CF_S	=	Summer peak coincidence factor by building type (see Table 8)

⁶⁰ Per IECC 2015, C405.2 lighting controls are mandatory.

$HVAC_{energy}$ = Energy Interactive HVAC factor by building type (see Table 10)

$HVAC_{demand}$ = Demand Interactive HVAC factor by building type (see Table 10)

See Section 2.1.1 of this volume for a full explanation of the non-control variables and their corresponding values. The lighting CAFs for different building types are presented in Table 15. The CAFs represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to 24 percent energy and demand savings. The same values from the referenced LBNL study are used for both energy and demand factors due to the lack of published data for coincidence factors.

Table 14. Lighting Controls—Control Definitions

Control type	Description
None	No control
Occupancy	Adjusting light levels according to the presence of occupants • Wall- or ceiling-mounted occupancy sensors • Wall- or ceiling-mounted occupancy sensors • Integrated fixture occupancy sensors • Time clocks • Energy management systems
Daylighting (indoor)	Adjusting light levels automatically in response to the presence of natural light • Photosensors
Outdoor	Outdoor on/off photosensor/time clock controls; no savings attributed because already required by code
Personal tuning	Adjusting individual light levels by occupants according to their personal preference; applies to private offices, workstation-specific lighting in open-plan offices, and classrooms • Dimmers • Wireless ON/OFF switches • Personal computer-based controls • Pre-set scene selection
Institutional tuning	Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants • Dimmable ballasts • ON/OFF or dimmer switches for non-personal tuning
Networked lighting control	Lighting systems with a combination of sensors, networked interfaces, software, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps. NLC systems can be installed with or without luminaire level lighting control (LLLC), referring to the capability to have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit.

Table 15. Lighting Controls—Energy and Power Adjustment Factors⁶¹

Control type	Control codes	CAF	
		Retrofit	NC ⁶²
None	None	–	–
Occupancy	OS	0.24	0.00
Continuous daylighting (indoor)	DL	0.28	0.04
Outdoor ⁶³	Outdoor	–	–
Personal tuning	PT	0.31	0.07
Institutional tuning	IT	0.36	0.12
Networked lighting control	NLC ⁶⁴	0.49	0.25

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.

⁶¹ Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”. Lawrence Berkeley National Laboratory. September 2011. Table 6, p. 14. Weighted average by number of “reviewed” and “non-reviewed” papers.

https://digital.library.unt.edu/ark:/67531/metadc840263/m2/1/high_res_d/1051271.pdf.

⁶² NC CAFs are derived by deducting the OS CAF from the equivalent retrofit CAF value.

⁶³ No control savings are allowed for outdoor controls because they are already required by code. ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

⁶⁴ “Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC,” Prepared by DesignLights Consortium for Northwest Energy Efficiency Alliance (NEEA). September 24, 2020. <https://www.designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/>. Savings range from 0.35 without LLLC to 0.63 with LLLC, with an overall average of 0.49. Average is selected because report concludes that additional study is needed to verify the impact of LLLC.

Measure Life and Lifetime Savings

Lighting controls savings for new interior construction projects should be claimed at the project level (combined fixture and controls savings) using the estimated useful life (EUL) matching the lighting equipment.⁶⁵

For retrofit applications, the EUL for lighting controls is provided by the 2007 GDS Associates Report.⁶⁶

- Retrofit sensors and controls: 10 years
- New construction interior fixtures/controls⁶⁷: 14 years

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: retrofit or new construction
- Building type
- Conditioned space type: cooling equipment type, refrigerated space temperature range (specified per control)
- Location of controlled lighting: interior or exterior (specified per control)
- Baseline and installed lighting control type code⁶⁸
- Lighting control mount type: wall, ceiling, integrated fixture, etc.
- Lighting control equipment specification sheets

⁶⁵ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

⁶⁶ GDS Associates. Measure Life Report—Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG). June 2007. This report only specifies an EUL for Occupancy Sensors and Photocells, so it is assumed that the same EUL was applied to time clocks. https://www.caetrm.com/media/reference-documents/HVAC_Ltg_measure_life_GDS_2007.pdf.

⁶⁷ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

⁶⁸ For a control type that combines multiple features (e.g., occupancy + daylighting) but does not qualify as an NLC system, specify the installed control type that corresponds to the highest control savings.

- For NLC systems:
 - Lighting control network specification sheets,
 - Lighting control commissioning report,
 - Lighting control network inspection and recalibration plan, or
 - other evaluator pre-approved documentation
- Controlled fixture lamp type
- Controlled fixture wattage
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; as-built design drawings; lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach

References and Efficiency Standards

Petitions and Rulings

- “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings.” Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, Lawrence Berkeley National Laboratory (LBNL). September 2011. Table 6, p. 14. Weighted average by the number of “reviewed” and “non-reviewed” papers.
- PUCT Docket 40668—Describes deemed values to be used in energy and demand savings calculations.
- PUCT Docket 36779—Describes EUL.

Relevant Standards and Reference Sources

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

Document Revision History

Table 16. Lighting Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v2.1	01/30/2015	Corrections to Equation 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for retrofit and new construction projects.

TRM version	Date	Description of change
v3.0	04/10/2015	Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a “controlled lighting watts” approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measures and added interior/exterior location.
v4.0	10/10/2016	No revision.
v5.0	10/2017	Completed source and code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	Revised multiple/combined control types EAF and PAF.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Added eligibility criteria for new construction applications.
v10.0	10/2022	Added guidance for field adjustable lights. Clarified baseline controls for new construction projects.
v11.0	10/2023	Clarified new construction controls eligibility. Updated control types. Consolidated EAF and PAF into CAF and added column for new construction CAF. Added documentation requirements for NLC systems.
v12.0	10/2024	Consolidated EAF and PAF coefficient label to CAF.
v13.0	10/2025	No revision.

2.1.3 Exterior Photocell and Time Clock Repair Measure Overview

TRM Measure ID: NR-LT-PR

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the repair of a photocell or time clock on an existing exterior light fixture. A photocell is designed to switch exterior light fixtures off during daylight hours. If broken, these fixtures may remain on as much as 8,760 hours per year.

Eligibility Criteria

This measure is only applicable to exterior retrofit applications where an existing photocell or time clock is not functioning as designed. New construction applications are not eligible.

The fixture must be manually controlled except for the photocell/time clock and may not be installed in combination with any supplemental controls.

Baseline Condition

The baseline condition is an exterior light fixture controlled by a photocell or time clock that is not functioning, allowing the fixture to operate continuously.

High-Efficiency Condition

The high-efficiency condition is a light fixture installed in combination with a functioning (repaired or new) photocell or time clock control.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all lighting projects. Savings are calculated using separate methods for retrofit and new construction projects.

$$\text{Energy Savings [kWh]} = kW_{\text{fixture}} \times (8,760 - AOH)$$

Equation 7

$$\text{Peak Demand Savings [kW]} = kW_{\text{fixture}} \times (1 - CF_{S/W})$$

Equation 8

Where:

kW_{fixture}	=	Total kW of controlled fixture (approved baseline fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity) ⁶⁹
AOH	=	Hours by outdoor application (see Table 17)
$CF_{S/W}$	=	Seasonal peak coincidence factor by outdoor application and climate zone (see Table 18)

Table 17. Exterior Photocell Repair—Annual Operating Hours by Outdoor Application

Building type	AOH
Outdoor: Athletic field and court ⁷⁰	767
Outdoor: Billboard ⁷¹	3,470
Outdoor: Dusk-to-dawn ⁷²	4,161
Outdoor: Less than dusk-to-dawn ⁷³	1,998

⁶⁹ Look up approved fixture wattage from the Standard Fixture Wattage Table.
<https://texasefficiency.com/dse/>.

⁷⁰ “2015 US Lighting Market Characterization,” US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours per year.

⁷¹ Ibid.

⁷² This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding one-half of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

⁷³ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

Table 18. Exterior Photocell Repair—Winter Peak Coincidence Factors by Outdoor Application^{74,75}

Building type	CF _s	CF _w				
	All climate zones	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Outdoor: Athletic field and court ⁷⁶	–	0.26	0.27	0.24	0.29	0.38
Outdoor: Billboard ⁷⁷	–	0.59	0.62	0.53	0.65	0.87
Outdoor: Dusk-to-dawn ⁷⁸	–	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn ⁷⁹	–	0.67	0.71	0.61	0.75	1.00

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters related to lighting system operation.

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 1 year for photocell repair based on the estimated remaining life of an exterior lamp operating 8,760 hours per year.⁸⁰ This value is further capped at 1 year based on the expectation that the photocell would be repaired in absence of utility program intervention beyond this point.

⁷⁴ Operating schedules are based on sunrise/sunset times for each climate-zone reference city, adjusted for compliance with IESNA-DG-13-96 and IESNA-DG-13-98 recommendations.

⁷⁵ Summer coincidence factor is set to zero for all exterior lighting applications.

⁷⁶ “2015 US Lighting Market Characterization,” US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours per year.

⁷⁷ Ibid.

⁷⁸ This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding one-half of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

⁷⁹ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

⁸⁰ Metal halide rated life expected between 6,000–15,000 hours. 10,500-hour midpoint divided by 8,760 hours yields 1.2 years.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Outdoor application
- Controlled fixture quantity
- Controlled fixture/lamp type
- Controlled fixture/lamp wattage
- Existing control type (photocell, time clock)
- Control intervention (repair, replacement)
- New control manufacturer and model number (replacement only)
- Photo of controlled light fixture nameplate, model number, or wattage stamp
- Photo demonstrating that fixture is operating during daytime hours
- Copy of project invoice detailing affected fixture quantity and control intervention
 - New photocell/time clock model number (replacement only)

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 19. Exterior Photocell Repair—Revision History

TRM version	Date	Description of change
v10.0	10/2022	Measure origin.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.1.4 LED Traffic Signals Measure Overview

TRM Measure ID: NR-LT-TS

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: Outdoor

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the installation of light emitting diode (LED) traffic signals (typically available in red, yellow, green, and pedestrian formats) at traffic lights serving any intersection, in retrofit applications.

Eligibility Criteria

New construction applications are not eligible for this measure, as incandescent traffic signals are not compliant with the current federal standard⁸¹, effective January 1, 2006.

Baseline Condition

For all retrofit applications, the baseline is a fixture with incandescent lamps.

High-Efficiency Condition

Due to the increased federal standard for traffic signals, the ENERGY STAR® Traffic Signal specification was suspended effective May 1, 2007. ENERGY STAR chose to suspend the specification rather than revise it due to minimal additional savings that would result from a revised specification. Because the ENERGY STAR specification no longer exists, the efficiency standard is an equivalent LED fixture for the same application. The equivalent LED fixture must be compliant with the current federal standard except for yellow “ball” or “arrow” fixtures where there is no federal standard.

⁸¹ Current federal standards for traffic and pedestrian signals can be found at the DOE website at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12.

Table 20. LED Traffic Signals—Federal Standard Maximum Wattages⁸² and Nominal Wattages⁸³

Module type	Maximum wattage	Nominal wattage
12" red ball	17	11
8" red ball	13	8
12" red arrow	12	9
12" green ball	15	15
8" green ball	12	12
12" green arrow	11	11
Combination walking man/hand	16	13
Walking man	12	9
Orange hand	16	13

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all LED traffic signal projects.

$$\text{Energy Savings [kWh]} = (kW_{pre} - kW_{installed}) \times \text{Hours}$$

Equation 9

$$\text{Summer Peak Demand Savings [kW]} = (kW_{pre} - kW_{installed}) \times CF_S$$

Equation 10

Where:

kW_{pre} = Total kW of existing measure (fixture wattage multiplied by quantity)

$kW_{installed}$ = Total kW of retrofit measure (fixture wattage multiplied by quantity)

Hours = Annual operating hours from Table 21

CF_S = Summer peak coincidence factor from Table 21

⁸² Maximum wattage is the wattage at which power consumed by the module after being operated for 60 minutes while mounted in a temperature testing chamber so that the lensed portion of the module is outside the chamber, all portions of the module behind the lens are within the chamber at a temperature of 74°C, and the air temperature in front of the lens is maintained at a minimum of 49°C.

⁸³ Nominal wattage is defined as power consumed by the module when it is operated within a chamber at a temperature of 25°C after the signal has been operated for 60 minutes.

Table 21. LED Traffic Signals—Savings Calculation Input Assumptions⁸⁴

Fixture type	Incandescent wattage	LED wattage	AOH	CF _s ⁸⁵
8" red ball	86	8	4,746	0.54
8" green ball		10	3,751	0.43
8" yellow ball		13	263	0.03
12" red ball	149	11	4,746	0.54
12" green ball		12	3,751	0.43
12" yellow ball		10	263	0.03
8" red arrow	69	8	6,570	0.75
8" green arrow		8	1,825	0.21
8" yellow arrow	128	10	263	0.03
12" red arrow		7.5	7,771	0.89
12" green arrow		10	726	0.08
12" yellow arrow		10	263	0.03
Large (16"x18") pedestrian signal	149	9	8,642	0.99
Small (12"x12") pedestrian signal	107	9	8,642	0.99

Deemed Energy and Demand Savings Tables

Table 22. LED Traffic Signals—Energy and Peak Demand Savings per Fixture

Fixture type	kWh savings	kW savings
8" red ball	370	0.042
8" green ball	285	0.033
8" yellow ball	19	0.002
12" red ball	655	0.075
12" green ball	514	0.059
12" yellow ball	37	0.004
8" red arrow	401	0.046
8" green arrow	111	0.013
8" yellow arrow	31	0.004
12" red arrow	936	0.107
12" green arrow	86	0.010
12" yellow arrow	31	0.004
Large (16"x18") pedestrian signal	1,210	0.138
Small (12"x12") pedestrian signal	847	0.097

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

According to the Northwest Power and Conservation Council Regional Technical Forum, the EUL is 5 to 6 years depending on the installed fixture type, as shown in the following table.

Table 23. LED Traffic Signals—EULs by Fixture Type⁸⁶

Fixture type	EUL (years)
8" and 12" red, green, and yellow ball	6
8" and 12" red, green, and yellow arrow	
Large (16"x18") pedestrian signal	5
Small (12"x12") pedestrian signal	

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: retrofit or NC (NC not eligible)
- Fixture type
- Quantity of installed fixtures
- Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach

References and Efficiency Standards

Petitions and Rulings

Not applicable.

⁸⁴ Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. <https://rtf.nwcouncil.org/deactivated-measures/>.

⁸⁵ Traffic signals operate consistently during each hour of the year. Therefore, CFs are calculated by dividing the assumed AOH value by 8,760 hours/year.

⁸⁶ Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. <http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37>.

Relevant Standards and Reference Sources

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

Document Revision History

Table 24. LED Traffic Signals—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	No revision.
v10.0	10/2022	General reference checks and text edits.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.2 NONRESIDENTIAL: HVAC

2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview

TRM Measure ID: NR-HV-TU

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure applies to direct expansion central air conditioners (AC) and heat pumps (HP) of any configuration where all applicable actions from the checklist below are completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions to restore operating efficiencies, closer to as-new performance. This measure applies to all commercial applications.

For this measure, the service technician must complete the following tasks according to industry best practices. To properly assess and adjust the refrigerant charge level, the unit must be operating under significant (normal) cooling load conditions. Therefore, this measure may only be performed for energy savings reporting purposes when the outdoor ambient dry bulb temperature is above 75°F and the indoor return air dry bulb temperature is above 70°F.

HVAC Inspection and tune-up checklist:⁸⁷

- Check thermostat settings
- Tighten all electrical connections, measure motor voltage and current
- Lubricate all moving parts, including motor and fan bearings
- Inspect and clean condensate drain

⁸⁷ Based on ENERGY STAR HVAC Maintenance Checklist.

<https://www.energystar.gov/saveathome/heating-cooling/maintenance-checklist>.

- Inspect controls of the system to ensure proper and safe operation; check startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly
- Clean evaporator and condenser coils
- Check refrigerant level and adjust to manufacturer specifications
- Clean indoor blower fan components and adjust to provide proper system airflow
- Inspect and clean (or change) air filters; replacement preferred best practice
- Measure airflow via static pressure across the cooling coil and adjust to manufacturers specifications
- Check capacitor functionality and capacitance; compare to OEM specifications

Eligibility Criteria

HVAC systems must be manufactured before January 1, 2023, to be eligible for this measure.⁸⁸ All commercial customers are eligible for this measure if they have direct expansion refrigerated air conditioning that has not been serviced through a utility program in the last 5 years.

This measure also applies to packaged terminal air conditioners and heat pumps (PTAC/PTHP), but chillers are ineligible.

Baseline Condition

The baseline is a system with all or some of the following issues:

- Dirty condenser coil
- Dirty evaporator coil
- Dirty blower wheel
- Dirty filter
- Improper airflow
- Incorrect refrigerant charge

⁸⁸ The current federal standard became effective on January 1, 2023, with full manufacturing compliance of the new SEER2 testing procedure being enforced as of April 24, 2023. This measure will be updated in the future to address the new efficiency ratings. <https://www.regulations.gov/document/EERE-2021-BT-TP-0030-0027>.

The baseline system efficiency should be calculated using the following formulas:

$$EER_{pre} = (1 - EL) \times EER_{post}$$

Equation 11

$$HSPF_{pre} = (1 - EL) \times HSPF_{post}$$

Equation 12

Where:

EER_{pre}	=	Efficiency of the cooling equipment before tune-up [Btuh/W]
EL	=	Efficiency loss due to dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05
EER_{post}	=	Deemed cooling efficiency of the equipment after tune-up [Btuh/W] (see Table 25)
$HSPF_{pre}$	=	Heating efficiency of the air source heat pump before tune-up [Btuh/W]
$HSPF_{post}$	=	Deemed heating efficiency of air source heat pumps after tune-up [Btuh/W] (see Table 25)

Table 25. AC/HP Tune-Ups—Default EER and HSPF per Size Category⁸⁹

Size category (Btuh/hr)	AC only default EER	Heat pump default EER	Default HSPF
< 65,000	11.2	11.2	7.7
≥ 65,000 and < 135,000	10.1	9.9	10.9
≥ 135,000 and < 240,000	9.5	9.1	10.6
≥ 240,000 and < 760,000	9.3	8.8	10.6
≥ 760,000	9.0	8.8	10.6

High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above. Additionally, refrigerant charge adjustments must be within ± 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and ± 5 degrees of target super heat for units with fixed orifices or capillary tubes.

⁸⁹ Code specified EER and HSPF value from ASHRAE 90.1-2010 (efficiency value effective January 23, 2006 for units < 65,000 Btu/hr and prior to January 1, 2010 for units ≥ 65,000 Btu/hr). HSPF = COP x 3.412.

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the majority of existing, functioning units were installed under the federal standard in place between January 23, 2006 and January 1, 2015 for units less than 65,000 Btuh, which set a baseline of 13 SEER and 7.7 HSPF⁹⁰, and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER⁹¹ using the conversion developed by Lawrence Berkeley Lab and US DOE: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. A 3.2 and 3.1 COP is equivalent to approximately 10.9 and 10.6 HSPF, respectively, using the conversion of $HSPF = 3.412 \times COP$.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of five percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.⁹²

Heating energy savings are only applicable to heat pumps.

$$Total\ Energy\ Savings\ [kWh] = kWh_C + kWh_H$$

Equation 13

$$Cooling\ Energy\ Savings\ [kWh_C] = Cap_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}} \right) \times EFLH_C \times \frac{1\ kW}{1,000\ W}$$

Equation 14

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}} \right) \times EFLH_H \times \frac{1\ kW}{1,000\ W}$$

Equation 15

Where:

Cap_C = Rated cooling/heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)

$EFLH_{C/H}$ = Cooling/heating equivalent full-load hours for appropriate climate zone [hours]; see Table 35 through Table 39 in Section 2.2.2

⁹⁰ Code specified HSPF from federal standard effective January 23, 2006, through January 1, 2015.

⁹¹ Code specified 13 SEER from federal standard effective January 23, 2006, through January 1, 2015, converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." US Department of Energy. Revised October 2010. <http://www.nrel.gov/docs/fy11osti/49246.pdf>.

⁹² Energy Center of Wisconsin, May 2008; "Central Air-Conditioning in Wisconsin, A Compilation of Recent Field Research."

Demand Savings Algorithms

Summer and winter demand savings are determined by applying a coincidence factor for each season. Winter peak demand savings are only applicable to heat pumps.

$$\text{Summer Peak Demand Savings [kW]} = \text{Cap}_C \times \left(\frac{1}{\text{EER}_{pre}} - \frac{1}{\text{EER}_{post}} \right) \times CF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 16

$$\text{Winter Peak Demand Savings [kW]} = \text{Cap}_H \times \left(\frac{1}{\text{HSPF}_{pre}} - \frac{1}{\text{HSPF}_{post}} \right) \times CF_W \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 17

Where:

$CF_{S/W}$ = Summer/winter seasonal peak coincidence factor; see Table 35 through Table 39 in Section 2.2.2

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is 5 years.⁹³

⁹³ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

Program Tracking Data and Evaluation Requirements

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

- The most recent tune-up service date or confirmation that system has not been serviced within the previous five years
- Climate zone or county
- Equipment type (split AC, split HP, packaged AC, packaged HP, PTAC, PTHP)
- Manufacturer and model number
- Cooling capacity of the serviced unit (tons)
- Heating capacity of the serviced unit, if applicable (tons)
- Before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment nameplates are useful).
- Recommended:
 - Serial number
 - Refrigerant type
 - Amount of refrigerant added or removed
 - Target superheat or subcooling
 - Post-tune-up superheat or subcooling
 - Static pressures before and after a tune-up
 - Return and supply dry bulb and wet bulb temperatures

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Efficiency Sources

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

Document Revision History

Table 26. AC/HP Tune-Ups—Revision History

TRM version	Date	Description of change
v4.0	10/10/2016	Measure origin.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	Clarified eligibility criteria.
v12.0	10/2024	Updated tune-up checklist to match ENERGY STAR HVAC Maintenance Checklist.
v13.0	10/2025	No revision.

2.2.2 Split and Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: NR-HV-SP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of air-cooled split system and single packaged air conditioning (AC) and heat pump (HP) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and for replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types include:

- Packaged and split direct expansion (DX) ACs
- Packaged and split DX HPs

Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment is electric.
- The building falls into one of the categories listed in Table 35 through Table 39. Building type descriptions and examples are provided in Table 33 and Table 34.

- For ER projects: ER projects involve the replacement of a working system. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- If these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of Air-Conditioning, Heating, and Refrigeration Institute (AHRI) or DOE CCMS certification must be provided.^{94,95}

Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and replace-on-burnout/new construction are as follows:

Early Retirement

Early Retirement (ER) systems involve the replacement of a working system, prior to natural burnout. The ER baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 27 through Table 31 according to the capacity, system type, and age (based on year manufactured) of the replaced system.⁹⁶ When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in Table 27 through Table 31 should be used. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years.⁹⁷ A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via ER.

⁹⁴ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

⁹⁵ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

⁹⁶ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

⁹⁷ As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the system was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010 and 2018, coinciding with the IECC 2009 and IECC 2015 code increases. The baseline efficiency levels shown in Table 27 through Table 31 are based on assumptions of the predominant heating types expected in the state. For air conditioners, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For HPs, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type.

For units < 65,000 Btuh (approximately 5.42 tons), EER, SEER, and HSPF values are converted to EER2, SEER2, and HSPF2 for consistency with the current federal standard. Unspecified EER2 are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER. Unspecified SEER2 values are calculated by multiplying average SEER/SEER2 ratios, referencing SEER2 values specified for 14, 14.5, 15, and 16 SEER. Unspecified HSPF2 values are calculated by multiplying average HSPF/HSPF2 ratios, referencing HSPF2 values specified for 8.0 and 8.8 HSPF.

For $\geq 65,000$ Btuh units, baseline EER values shown from ASHRAE/IECC assume natural gas heating for the predominant heating section type expected for commercial facilities in Texas. For units installed from 2002 to present, 0.2 EER may be added for “Electric Resistance (or None)” heating types. For units installed before 2002 and $\geq 135,000$ Btuh (approximately 11.3 tons), 0.2 EER may be added for no heating.

Table 27. DX HVAC—ER Baseline Full-Load Efficiency for ACs

Year installed (replaced system)	Split < 3.75 tons (EER2)	Split 3.75 to 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2009	10.1	10.1	10.1	10.1	9.5	9.3	9.0
2010–2017	10.1	10.1	10.1	11.0	10.8	9.8	9.5
2018–2022	10.1	10.1	10.9	11.0	10.8	9.8	9.5
≥ 2023	11.7	11.2	10.9	11.0	10.8	9.8	9.5

Table 28. DX HVAC—ER Baseline Part-Load Efficiency for ACs⁹⁸

Year installed (replaced system)	Split < 3.75 tons (SEER2)	Split 3.75 to < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2009	12.4	12.4	12.4	10.3	9.7	9.4	9.1
2010–2017	12.4	12.4	12.4	11.2	11.0	9.9	9.6
2018–2022	12.4	12.4	13.4	12.6	12.2	11.4	11.0
≥ 2023	14.3	13.8	13.4	14.6	14.0	13.0	11.0

Table 29. DX HVAC—ER Baseline Full-Load Cooling Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2009	10.1	10.1	10.1	9.3	9.0	9.0
2010–2017	10.1	10.1	11.0	10.6	9.5	9.5
2018–2022	10.9	10.9	11.0	10.6	9.5	9.5
≥ 2023	11.7	10.9	11.0	10.6	9.5	9.5

Table 30. DX HVAC—ER Baseline Part-Load Cooling Efficiency for HPs⁹⁹

Year installed (replaced system)	Split < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2009	12.4	12.4	10.3	9.5	9.1	9.1
2010–2017	12.4	12.4	11.2	10.7	9.6	9.6
2018–2022	13.4	13.4	12.0	11.6	10.6	10.6
≥ 2023	14.3	13.4	14.1	13.5	12.5	10.6

⁹⁸ IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

⁹⁹ IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

Table 31. DX HVAC—ER Baseline Heating Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (HSPF2)	Packaged < 5.42 tons (HSPF2)	All 5.42 to < 11.3 tons (COP)	All 11.3 to < 20 tons (COP)	All ≥ 20 tons (COP)
≤ 2009	6.5	6.5	3.2	3.1	3.1
2010–2017	6.5	6.5	3.3	3.2	3.2
2018–2022	6.9	6.7	3.3	3.2	3.2
≥ 2023	7.5	6.7	3.4	3.3	3.2

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for package and split DX ACs and HPs are provided in Table 32. The baseline part-load efficiency levels reflect the latest minimum efficiency requirements from the current federal standard, effective January 1, 2023, for units with a rated cooling capacity of < 65,000 Btu/hour (Btuh) (5.42 tons)¹⁰⁰ and for units rated between 65,000-759,999 Btuh.¹⁰¹ Full-load efficiency levels are estimated for < 65,000 Btuh systems using a comparison of AHRI SEER2 and EER2 efficiency ratings. Part-load efficiency for ≥ 760,000 Btuh systems and full-load efficiency for ≥ 65,000 Btuh systems are specified in the IECC codes. The current statewide energy code is IECC 2015, but local jurisdictions may have adopted more recent codes with higher efficiencies, such as IECC 2021.^{102,103}

An updated federal standard¹⁰⁴, effective September 17, 2024, with a manufacturing compliance date of January 1, 2029, will establish new integrated ventilation, economizing, and cooling (IVEC) and integrated ventilation and heating efficiency (IVHE) minimum efficiency requirements. After the compliance date, IVEC will replace IEER, and IVHE will replace COP.

For ACs, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For HPs, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type. For all other heating section types, or for no heating section type, the baseline efficiencies may need to be adjusted as specified by the footnotes in the tables.

¹⁰⁰ US Department of Energy (DOE) federal minimum efficiency standard for < 65,000 btuh systems, 10 CFR 430.32. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32>.

¹⁰¹ US DOE federal minimum efficiency standard for 65,000-759,999 btuh systems, 10 CFR 431.97. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97>.

¹⁰² IECC 2015 Table C403.2.3(1) and C403.2.3(2). <https://codes.iccsafe.org/content/IECC2015>.

¹⁰³ Cities Adopted Code List: 2012 or Newer IECC. SPEER. <https://eepartnership.org/wp-content/uploads/2024/05/2024-Cities-Adopted-Code-5.28.24.xlsx>.

¹⁰⁴ US DOE federal minimum efficiency standard for air-cooled commercial package air conditioners and heat pumps. <https://www.regulations.gov/document/EERE-2022-BT-STD-0015-0100>.

Table 32. DX HVAC—NC/ROB Baseline Efficiency Levels¹⁰⁵

System type	Capacity (tons)	Baseline efficiencies	Source ¹⁰⁶
Air conditioner	Split < 3.75	11.7 EER2 14.3 SEER2	DOE Standards
	Split ≥ 3.75	11.2 EER2 13.8 SEER2	
	Split < 5.42 tons rated at ≥ 15.2 SEER2	9.8 EER2 ¹⁰⁷	
	Packaged < 5.42 tons	10.6 EER2 13.4 SEER2	
	5.42 to < 11.3	11.0 EER 14.6 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.8 EER 14.0 IEER	
	20 to < 63.3	9.8 EER 13.0 IEER	
	≥ 63.3	9.5 EER 11.0 IEER	IECC 2015

¹⁰⁵ IECC 2015 Table C403.2.3(1) and C403.2.3(2).

¹⁰⁶ The baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 430.32 for < 65,000 Btu/h and 10 CFR 431.97 for 65,000-759,999 Btu/h.

¹⁰⁷ When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

System type	Capacity (tons)	Baseline efficiencies	Source ¹⁰⁶
Heat pump (cooling) ¹⁰⁸	Split < 5.42	11.7 EER2 14.3 SEER2	DOE Standards
	Split < 5.42 tons rated at ≥ 15.2 SEER2	9.8 EER2 ¹⁰⁹	
	Packaged < 5.42	10.9 EER2 ¹¹⁰ 13.4 SEER2	
	5.42 to < 11.3	11.0 EER 14.1 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.6 EER 13.5 IEER	
	20 to < 63.3	9.5 EER 12.5 IEER	
	≥ 63.3	9.5 EER 10.6 IEER	IECC 2015
Heat pump (heating) ¹¹¹	Split < 5.42	7.5 HSPF2	DOE Standards
	Packaged < 5.42	6.7 HSPF2	
	5.42 to < 11.3	3.4 COP	DOE Standards
	11.3 to < 20	3.3 COP	
	≥ 20	3.2 COP	DOE Standards IECC 2015
Heat pump (heating) – replacement of electric resistance furnace	≤ 5.42	3.412 HSPF2	Standard assumption
	≥ 5.42	1.0 COP	

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 32. Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired

¹⁰⁸ ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type “No Heating or Electric Resistance Heating”, excluding systems with “All Other Types of Heating”.

¹⁰⁹ When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

¹¹⁰ Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing values specified in the current federal standard for 12.2 and 11.7 EER.

¹¹¹ Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

For reference, both ENERGY STAR¹¹² and the Consortium for Energy Efficiency (CEE)¹¹³ offer suggested guidelines for high-efficiency equipment. Additional conditions for replace-on-burnout, ER and new construction are in the sections below.

New Construction and Replace-on-Burnout

This scenario includes equipment used for new construction and retrofit/replacements that are not covered by ER, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:¹¹⁴

- For ER projects only, when downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no limit on upsizing because the savings are calculated using the lower pre-installed capacity.
- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, full and part-load baseline efficiency, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}} \right) \times CF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 18

¹¹² ENERGY STAR Heating & Cooling, <http://www.energystar.gov/newhomes/features-benefits/heating-cooling>.

¹¹³ CEE Program Resources, <https://cee1.org/program-resources/>.

¹¹⁴ From PUCT Docket #41070.

$$\text{Winter Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times CF_W \times \frac{1 \text{ kW}}{3,412 \text{ Btuh}}$$

Equation 19

$$\text{Total Energy Savings [kWh]} = kWh_C + kWh_H$$

Equation 20

$$\text{Cooling Energy Savings [kWh}_C] = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 21

$$\text{Heating Energy Savings [kWh}_H] = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times EFLH_H \times \frac{1 \text{ kWh}}{3,412 \text{ Btu}}$$

Equation 22

Where:

$\text{Cap}_{C/H,pre}$ = For ER and ROB, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$\text{Cap}_{C/H,post}$ = Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh

Note: The capacity in the equations may not always match the capacity of the units.

$\eta_{baseline,C}$ = Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]

$\eta_{installed,C}$ = Rated cooling efficiency of the newly installed equipment (Must exceed ROB/NC baseline efficiency standards in Table 32) [Btuh/W]

$\eta_{baseline,H}$ = Heating efficiency of existing equipment (ER) or standard equipment (ROB/NC) [COP]

$\eta_{installed,H}$ = Rated heating efficiency of the newly installed equipment (Must exceed baseline efficiency standards in Table 32) [COP]

Note: Use EER2/EER for summer kilowatt, SEER2/IEER for cooling kilowatt-hour, and COP for heating kilowatt-hour and winter kilowatt savings calculations. The COP expressed for units ≥ 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$COP = \frac{HSPF}{3.412}$$

Equation 23

$CF_{S/W}$ = Summer/winter seasonal peak coincidence factor (see Table 35 through Table 39)

$EFLH_{C/H}$ = Cooling/heating equivalent full-load hours [hours] (see Table 35 through Table 39)

Early Retirement Savings

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require weighted savings calculated over both the ER and ROB periods, accounting for both the EUL and RUL. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A.

System Type Conversion

Chiller to AC: Conversions from chiller-based systems to a packaged/split AC system are covered under this measure. See the reference tables in the HVAC Chillers measure for the savings.

AC to HP: Conversions from AC to HP are acceptable in commercial applications. Use CAP_H , $\eta_{baseline,H}$, CF_W , and $EFLH_H$ values for the new HP as a proxy for the baseline AC heating savings coefficients.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 33 and Table 34. These building types are derived from the EIA Commercial Building Energy Consumption Survey (CBECS).¹¹⁵

The CF and EFLH values for packaged and split AC and HP units are presented in Table 35 through Table 39.

A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

¹¹⁵ CBECS, implemented by the US Energy Information Administration, includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type—large multifamily—included.
<https://www.eia.gov/consumption/commercial/>.

Combination building types. In situations where multiple TRM building types seem plausible or a predominant TRM building type is unclear, the utilities have two choices:

- **Deemed approach.** The deemed approach is a simplified method where utilities should choose a TRM building type based on the “best fit” for the facility. This is determined by the largest interior area for the potential building types. Although, if that is not best fit, the utilities will use their best judgment to make this decision and provide sufficient, defensible documentation for their decision.

The following building type combinations are pre-authorized exceptions to this rule. For these combinations, individual fixtures can be reported as either specified building type based on location. All other interior space combinations should reference a single deemed building type unless authorized by the evaluator.

- Office (any size): Warehouse
- Hospital: Outpatient healthcare

The *other* building type can be used for business types that are not explicitly listed. The CF and EFLH values used for *other* are the most conservative from the explicitly listed building types. When the *other* building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

For those combinations of technology, climate zone, and building type with no values, a project with that specific combination should use the *other* building type.

- **Custom approach.** In more unique situations, utilities should consider projects “custom” where (1) the deemed building types in the TRM may not represent the project’s facility type, (2) the facility may represent multiple TRM building types without a clear predominant building type, or (3) the use of a predominant building type may be too conservative in the estimate of savings. The deemed methods only apply to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their EFLH and CF values used in their savings calculations that the EM&V team can review.

Table 33. DX HVAC—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples ¹¹⁶
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

¹¹⁶ Principal Building Activities are based on sub-categories from CBECS
<https://www.eia.gov/consumption/commercial/building-type-definitions.php>.

Building type	Principal building activity	Definition	Detailed business type examples ¹¹⁶
Education	College/university	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	1) College or university 2) Career or vocational training 3) Adult education
	Primary school		1) Elementary or middle school (grade 8 or lower) 2) Preschool or daycare
	Secondary school ¹¹⁷		1) High school (grade 9 or greater) 2) Religious education
Food sales	Convenience store	Buildings used for retail or wholesale of food.	1) Gas station with a convenience store 2) Convenience store
	Supermarket		1) Grocery store or food market
Food service	Full-service restaurant	Buildings used for the preparation and sale of food and beverages for consumption.	1) Restaurant or cafeteria
	Quick-service restaurant		1) Fast food
Healthcare	Inpatient	Buildings used as diagnostic and treatment facilities for inpatient care.	1) Hospital 2) Inpatient rehabilitation
	Outpatient	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	1) Medical office 2) Clinic or outpatient health care 3) Veterinarian

¹¹⁷ Individual middle and junior high schools may have a campus size and building activities that better align with secondary schools (see Table 34). The use of secondary school assumptions in lieu of primary school assumptions is subject to evaluator pre-approval. Otherwise, the *education* subcategory should be determined by lowest grade.

Building type	Principal building activity	Definition	Detailed business type examples ¹¹⁶
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	1) Motel or inn 2) Hotel 3) Dormitory, fraternity, or sorority 4) Retirement home, nursing home, assisted living, or other residential care 5) Convent or monastery
	Nursing home		
	Small hotel/motel		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	1) Retail store 2) Beer, wine, or liquor store 3) Rental center 4) Dealership or showroom for vehicles or boats 5) Studio or gallery
	Strip and enclosed mall	Shopping malls comprised of multiple connected establishments.	1) Strip shopping center 2) Enclosed malls
Office	Large office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	1) Administrative or professional office 2) Government office 3) Mixed-use office 4) Bank or other financial institution 5) Medical office 6) Sales office 7) Contractor's office (e.g., construction, plumbing, HVAC) 8) Non-profit or social services 9) Research and development 10) City hall or city center 11) Religious office 12) Call center
	Medium office		
	Small office		

Building type	Principal building activity	Definition	Detailed business type examples ¹¹⁶
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Religious worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.
Service	Service: Excluding food	Buildings in which some type of service is provided, other than food service or retail sales of goods.	1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning salon 11) Copy center or printing shop 12) Kennel

Building type	Principal building activity	Definition	Detailed business type examples ¹¹⁶
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	1) Refrigerated warehouse 2) Non-refrigerated warehouse 3) Distribution or shipping center
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

Table 34. DX HVAC—Building Type Floor Area and Number of Floors¹¹⁸

Building type	Principal building activity	Average floor area (ft ²)	Average number of floors
Data center	Data center	Not specified	Not specified
Education	College/university	Not specified	Not specified
	Primary school	73,960	1
	Secondary school	210,887	2
Food sales	Convenience store	Not specified	1
	Supermarket	45,000	1
Food service	Full-service restaurant	5,500	1
	Quick-service restaurant	2,500	1
Healthcare	Inpatient	241,351	5
	Outpatient	40,946	3
Large multifamily	Midrise apartment	33,740	4
Lodging	Large hotel	122,120	6
	Nursing home	Not specified	Not specified
	Small hotel/motel	43,200	4
Mercantile	Stand-alone retail	24,962	1
	Strip and enclosed mall	22,500	1
Office	Large office	498,588	12
	Medium office	53,628	3
	Small office	5,500	1
Public assembly	Public assembly	Not specified	Not specified

¹¹⁸ Building prototype information from DOE Commercial Reference Buildings, “Not specified” means that a building prototype is not defined for that building type. <http://energy.gov/eere/buildings/Commercial-reference-buildings>.

Building type	Principal building activity	Average floor area (ft ²)	Average number of floors
Religious worship	Religious worship	Not specified	Not specified
Service	Service: Excluding food	Not specified	Not specified
Warehouse	Warehouse	52,045	1

Table 35. DX HVAC—CF and EFLH Values for Climate Zone 1: Amarillo

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹¹⁹			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	0.89	2,048	0.89	2,048	–	–
Education	College/university	0.69	787	0.69	787	–	–
	Primary school	0.64	740	0.64	740	0.43	701
	Secondary school	0.69	535	0.69	535	0.43	736
Food sales	Convenience store	0.73	884	0.73	884	–	–
	Supermarket	0.29	219	0.29	219	–	–
Food service	Full-service restaurant	0.83	1,020	0.83	1,020	0.43	1,123
	24-hour full-service restaurant	0.81	1,093	0.81	1,093	0.43	1,346
	Quick-service restaurant	0.73	765	0.73	765	0.48	1,029
	24-hour quick-service restaurant	0.74	817	0.74	817	0.48	1,300
Healthcare	Inpatient	0.72	2,185	0.72	2,185	–	–
	Outpatient	0.71	2,036	0.71	2,036	0.27	579
Large multifamily	Midrise apartment	0.68	674	0.68	674	–	–
Lodging	Large hotel	0.58	1,345	0.58	1,345	0.86	1,095
	Nursing home	0.68	685	0.68	685	–	–
	Small hotel/motel	0.57	1,554	0.57	1,554	0.36	475
Mercantile	Stand-alone retail	0.68	623	0.68	623	0.99	907
	24-hour retail	0.80	820	0.80	820	0.43	1,277
	Strip and enclosed mall	0.75	687	0.75	687	0.39	753

¹¹⁹ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹¹⁹			
		CF _s	EFLH _C	CF _s	EFLH _C	CF _w	EFLH _H
Office	Large office	0.90	2,058	0.90	2,058	–	–
	Medium office	0.64	925	0.64	925	0.72	576
	Small office	0.72	711	0.72	711	0.29	340
Public assembly	Public assembly	0.64	995	0.64	995	–	–
Religious worship	Religious worship	0.57	387	0.57	387	–	–
Service	Service: Excluding food	0.83	790	0.83	790	–	–
Warehouse	Warehouse	0.34	173	0.34	173	–	–
Other	Other	0.29	173	0.29	173	0.27	340

Table 36. DX HVAC—CF and EFLH Values for Climate Zone 2: Dallas

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump ¹²⁰			
		CF _s	EFLH _C	CF _s	EFLH _C	CF _w	EFLH _H
Data center	Data center	1.00	3,401	1.00	3,401	–	–
Education	College/university	1.00	1,595	1.00	1,595	–	–
	Primary school	0.88	1,208	0.88	1,208	0.66	397
	Secondary school	1.00	1,084	1.00	1,084	0.59	489
Food sales	Convenience store	1.00	1,835	1.00	1,835	–	–
	Supermarket	0.58	615	0.58	615	–	–
Food service	Full-service restaurant	1.00	1,823	1.00	1,823	0.50	688
	24-hour full-service restaurant	1.00	2,061	1.00	2,061	0.49	873
	Quick-service restaurant	1.00	1,588	1.00	1,588	0.61	631
	24-hour quick-service restaurant	1.00	1,765	1.00	1,765	0.60	794
Healthcare	Inpatient	0.92	3,097	0.92	3,097	–	–
	Outpatient	0.80	2,532	0.80	2,532	0.28	310
Large	Midrise apartment	1.00	1,709	1.00	1,709	–	–

¹²⁰ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump ¹²⁰			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
multifamily							
Lodging	Large hotel	0.70	2,079	0.70	2,079	0.82	464
	Nursing home	1.00	1,736	1.00	1,736	–	–
	Small hotel/motel	0.55	2,281	0.55	2,281	0.42	249
Mercantile	Stand-alone retail	0.95	1,157	0.95	1,157	0.55	352
	24-hour retail	1.00	1,539	1.00	1,539	0.57	632
	Strip and enclosed mall	0.91	1,100	0.91	1,100	0.55	376
Office	Large office	1.00	2,379	1.00	2,379	–	–
	Medium office	0.76	1,236	0.76	1,236	0.66	262
	Small office	0.92	1,203	0.92	1,203	0.40	153
Public assembly	Public assembly	0.88	1,624	0.88	1,624	–	–
Religious worship	Religious worship	0.55	567	0.55	567	–	–
Service	Service: Excluding food	1.00	1,412	1.00	1,412	–	–
Warehouse	Warehouse	0.84	597	0.84	597	–	–
Other	Other	0.55	567	0.55	567	0.28	153

Table 37. DX HVAC—CF and EFLH Values for Climate Zone 3: Houston

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²¹			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	1.00	4,022	1.00	4,022	–	–
Education	College/university	0.98	1,843	0.98	1,843	–	–
	Primary school	0.88	1,443	0.88	1,443	0.50	239
	Secondary school	0.98	1,253	0.98	1,253	0.54	293
Food sales	Convenience store	1.00	2,142	1.00	2,142	–	–
	Supermarket	0.60	744	0.60	744	–	–

¹²¹ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²¹			
		CF _s	EFLH _C	CF _s	EFLH _C	CF _w	EFLH _H
Food service	Full-service restaurant	1.00	2,135	1.00	2,135	0.44	429
	24-hour full-service restaurant	1.00	2,426	1.00	2,426	0.44	559
	Quick-service restaurant	1.00	1,853	1.00	1,853	0.51	372
	24-hour quick-service restaurant	1.00	2,059	1.00	2,059	0.50	483
Healthcare	Inpatient	0.90	3,490	0.90	3,490	–	–
	Outpatient	0.80	2,844	0.80	2,844	0.29	196
Large multifamily	Midrise apartment	1.00	2,031	1.00	2,031	–	–
Lodging	Large hotel	0.70	2,531	0.70	2,531	0.33	250
	Nursing home	1.00	2,063	1.00	2,063	–	–
	Small hotel/motel	0.65	2,316	0.65	2,316	0.19	147
Mercantile	Stand-alone retail	0.95	1,399	0.95	1,399	0.43	204
	24-hour retail	0.97	1,804	0.97	1,804	0.41	374
	Strip and enclosed mall	0.92	1,330	0.92	1,330	0.42	218
Office	Large office	1.00	2,619	1.00	2,619	–	–
	Medium office	0.75	1,387	0.75	1,387	0.42	149
	Small office	0.88	1,338	0.88	1,338	0.28	69
Public assembly	Public assembly	0.88	1,940	0.88	1,940	–	–
Religious worship	Religious worship	0.65	576	0.65	576	–	–
Service	Service: Excluding food	1.00	1,653	1.00	1,653	–	–
Warehouse	Warehouse	0.84	633	0.84	633	–	–
Other	Other	0.60	576	0.60	576	0.19	69

Table 38. DX HVAC—CF and EFLH Values for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²²			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	0.97	4,499	0.97	4,499	–	–
Education	College/university	0.96	2,211	0.96	2,211	–	–
	Primary school	0.88	1,680	0.88	1,680	0.30	156
	Secondary school	0.96	1,503	0.96	1,503	0.35	196
Food sales	Convenience store	0.94	2,510	0.94	2,510	–	–
	Supermarket	0.54	894	0.54	894	–	–
Food service	Full-service restaurant	0.98	2,530	0.98	2,530	0.35	292
	24-hour full-service restaurant	0.97	2,897	0.97	2,897	0.36	377
	Quick-service restaurant	0.94	2,172	0.94	2,172	0.34	232
	24-hour quick-service restaurant	0.93	2,440	0.93	2,440	0.34	296
Healthcare	Inpatient	0.86	3,819	0.86	3,819	–	–
	Outpatient	0.78	3,092	0.78	3,092	0.08	122
Large multifamily	Midrise apartment	0.92	2,236	0.92	2,236	–	–
Lodging	Large hotel	0.65	2,981	0.65	2,981	0.21	131
	Nursing home	0.92	2,271	0.92	2,271	–	–
	Small hotel/motel	0.58	2,530	0.58	2,530	0.10	82
Mercantile	Stand-alone retail	0.84	1,582	0.84	1,582	0.22	131
	24-hour retail	0.86	2,118	0.86	2,118	0.25	255
	Strip and enclosed mall	0.82	1,510	0.82	1,510	0.21	141
Office	Large office	0.91	2,778	0.91	2,778	–	–
	Medium office	0.66	1,523	0.66	1,523	0.24	83
	Small office	0.80	1,504	0.80	1,504	0.14	39
Public assembly	Public assembly	0.88	2,259	0.88	2,259	–	–
Religious worship	Religious worship	0.58	629	0.58	629	–	–

¹²² For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²²			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Service	Service: Excluding food	0.98	1,959	0.98	1,959	–	–
Warehouse	Warehouse	0.73	665	0.73	665	–	–
Other	Other	0.54	629	0.54	629	0.08	39

Table 39. DX HVAC—CF and EFLH Values for Climate Zone 5: El Paso

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²³			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Data center	Data center	0.88	2,547	0.88	2,547	–	–
Education	College/university	0.87	1,092	0.87	1,092	–	–
	Primary school	0.91	996	0.91	996	0.37	408
	Secondary school	0.87	742	0.87	742	0.43	431
Food sales	Convenience store	0.76	1,251	0.76	1,251	–	–
	Supermarket	0.38	347	0.38	347	–	–
Food service	Full-service restaurant	0.76	1,276	0.76	1,276	0.28	613
	24-hour full-service restaurant	0.74	1,413	0.74	1,413	0.27	809
	Quick-service restaurant	0.76	1,082	0.76	1,082	0.26	522
	24-hour quick-service restaurant	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Inpatient	0.81	2,555	0.81	2,555	–	–
	Outpatient	0.81	2,377	0.81	2,377	0.04	320
Large multifamily	Midrise apartment	0.88	1,209	0.88	1,209	–	–
Lodging	Large hotel	0.63	1,701	0.63	1,701	0.21	440
	Nursing home	0.88	1,228	0.88	1,228	–	–
	Small hotel/motel	0.63	1,921	0.63	1,921	0.06	185
Mercantile	Stand-alone retail	0.80	904	0.80	904	0.26	384
	24-hour retail	0.86	1,228	0.86	1,228	0.28	808

¹²³ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²³			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
	Strip and enclosed mall	0.83	931	0.83	931	0.27	448
Office	Large office	0.98	2,423	0.98	2,423	–	–
	Medium office	0.77	1,173	0.77	1,173	0.27	256
	Small office	0.84	1,037	0.84	1,037	0.15	146
Public assembly	Public assembly	0.91	1,339	0.91	1,339	–	–
Religious worship	Religious worship	0.63	478	0.63	478	–	–
Service	Service: Excluding food	0.76	988	0.76	988	–	–
Warehouse	Warehouse	0.75	324	0.75	324	–	–
Other	Other	0.38	324	0.38	324	0.04	146

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream Delivery

For upstream/midstream program delivery, use the EFLH and CF assumptions outlined in Table 40. Assumed values have been weighted based on building-type survey data from 2018 CBECS¹²⁴ Manufacturing Energy Consumption Survey (MECS).¹²⁵

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 35 through Table 39. For program designs where the building type is unknown, you may use the savings coefficients from Table 40. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

¹²⁴ 2018 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>.

¹²⁵ 2018 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

Table 40. DX HVAC—Upstream/Midstream Input Assumptions¹²⁶

Savings coefficient	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
EFLH _C	1,042	1,517	1,723	1,918	1,314
EFLH _H	524	260	139	85	259
CF _S	0.68	0.92	0.91	0.84	0.84
CF _W	0.36	0.40	0.28	0.15	0.13

Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below. The reader should refer to the definitions of estimated useful life (EUL) and remaining useful life in the glossary in Volume 1 for guidance on how to determine the decision type for system installations.

Estimated Useful Life

The EUL for split and packaged ACs and HPs is 15 years.¹²⁷

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 41. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL – RUL). The calculations for ER projects are extensive, and as such, are provided in Appendix A.

¹²⁶ 2018 CBECS and MECS.

¹²⁷ The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

Table 41. DX HVAC—RUL of Early Retirement Systems^{128,129}

Age of replaced system (years)	Split/package AC/HP systems RUL (years)	Age of replaced system (years)	Split/package AC/HP systems RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18 ¹³⁰	0.0

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.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone or county
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- **For ER only:** Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)

¹²⁸ PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹²⁹ Current new construction baseline matches the baseline for existing systems manufactured in 2023. Existing systems manufactured after 1/1/2023 are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are grayed out in the table and displayed for informational purposes only.

¹³⁰ RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
 - Photograph of retired heating unit nameplate, utility inspection, recording nameplate information, or other evaluator-approved approach. Sampling is allowed for multifamily complexes
- Installed number of units
- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
 - For exempted HPs < 5.4 tons referencing the previous federal standard, a copy of the AHRI certificate or manufacturer specification sheet with date corresponding to time of application or purchase demonstrating that unit does not have a SEER2 efficiency rating is required.
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building types only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of ER savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.

- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
- Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, room air conditioners, and chilled water systems.
- Approved estimates of RUL of working chilled water systems.
- Updated demand and energy coefficients for all commercial HVAC systems.
- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the ER concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A

Relevant Standards and Reference Sources

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

Document Revision History

Table 42. DX HVAC—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Modified ER savings calculations and added references to Appendix A, which details those calculations. Added heat pump minimum required heating efficiencies for reference. Revised baseline efficiency standards based on updates to federal standards.
v2.1	01/30/2015	Minor text updates and clarification of ER requirements.
v3.0	04/10/2015	Updated savings method to allow for part-load efficiency calculations. For heat pumps: Added heating efficiencies and split EFLH into cooling and heating components.
v3.1	11/05/2015	Updated the building type definitions and descriptions. Added "Other" building type for when building type is not explicitly listed.

TRM version	Date	Description of change
v4.0	10/10/2016	Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for split and packaged units less than 5.4 tons to be consistent with updated federal standards.
v5.0	10/2017	Updated baseline efficiency values for IECC 2015 and added 24-hour building load shapes. Updated RUL table based on DOE survival curves. Updated baseline efficiency tables to include “Electric Resistance (or None)” heating section type EER/IEER values. Modified baseline cooling efficiency tables for heat pumps to assume Electric Resistance supplemental; corrected an error on the 11.3 to 20 tons category for the EER to IEER conversion.
v6.0	10/2018	Revised ER criteria for systems with an overall capacity change. Added Data Center as a new building type. Created methodology for heat pump projects without explicitly building type modeling.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Clarified use of post capacity for ROB baselines. Verify M&V plan requirement for VRF and documentation requirements. Added unknown age defaults for ER.
v9.0	10/2021	General reference checks and text edits. Removed baseline efficiency splits between heating section types for air conditioners and defaulted to “All Other” efficiencies. Clarified approach for system types conversion to split/package AC systems. Updated EUL methodology. Incorporated building type weighted savings coefficients for upstream/midstream. Incremented RUL table for code compliance.
v10.0	10/2022	Added additional guidance for selection of building types for complex projects. Incremented RUL table for code compliance.
v11.0	10/2023	Removed < 5.4 ton HP sell-through exception. Updated ER baselines for compliance with updated federal standard. Updated NC/ROB 5.4+ ton baselines to incorporate current federal standard. Clarified pre- and post-capacity limits. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
v12.0	10/2024	Updated midstream building type weighting assumptions, defined grade levels for primary and secondary schools, updated early retirement age eligibility and criteria related to downsizing, and noted new federal standard and compliance date.
v13.0	10/2025	Updated evaluation requirements to support a reduced heating baseline for ER heat; capped all CFs at 1.

2.2.3 HVAC Chillers Measure Overview

TRM Measure ID: NR-HV-CH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 56 through Table 60.

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This document presents the deemed savings methodology for the installation of chillers. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards.

Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation, whenever possible. Default values are provided for when the actual age of the unit is unknown. Minimum efficiencies are defined in units of kW/ton, the ratio of input power in kW to the cooling capacity in tons, or EER, the ratio of cooling capacity in Btu/h to input power in Watts.

Two paths are currently available for chiller compliance through the IECC and ASHRAE rating standards. Path A requires higher efficiency ratings for full-load operation, with lower ratings for part-load efficiency, and is most applicable to units that are expected to operate at or near full-load conditions. Path B requires higher efficiency ratings for part-load operation, with lower ratings for full-load efficiency, and is most applicable to units that are expected to operate primarily at part-load conditions with variable frequency drives. Either Path can be used for compliance on any particular chiller, but the chiller must meet the minimum requirements for both full and part-load efficiency that are set forth in the following sections.

Applicable efficient measure types include:¹³¹

- Compressor types: centrifugal or positive-displacement (screw, scroll, or reciprocating)
- Condenser/heat rejection type: air-cooled or water-cooled system type conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. If this type of retrofit is performed, reference the tables from the split/single packaged air conditioners and heat pumps measure.
- Chiller type conversions: from an air-cooled chiller system to a water-cooled chiller system is also addressed in this measure. An additional adjustment is made to the basic chiller savings to account for the auxiliary equipment associated with a water-cooled chiller.

Eligibility Criteria

For a measure to be eligible for this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment is electric.
- The building falls into one of the categories listed in Table 56 through Table 60. Building type descriptions and examples are provided in Table 33 and Table 34.
- For early retirement projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- For redundant chiller configurations, the installed chiller must not be exclusively sequenced as a standby chiller. As an example, for N+1 configurations where the redundant chiller is rotated, the deemed savings approach should only be used for N chillers, where N is the total number of chillers in the redundant chiller configuration minus one. Multiple chillers sequenced in a lead-lag or base-trim configuration are eligible to use the deemed savings.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.^{132, 133}

¹³¹ Savings can also be claimed by a retrofit involving a change in equipment type (e.g., air-cooled packaged DX system to a water-cooled centrifugal chiller, or a split system air-cooled heat pump to an air-cooled non-centrifugal chiller). If this type of retrofit is performed, reference the tables from the following HVAC measure templates: HVAC-Chillers, Split System/Single Packaged Heat Pumps, and Air Conditioners

¹³² Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

¹³³ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

Baseline Condition

Early Retirement

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 43 through Table 54 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.¹³⁴ When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 43 through Table 54 should be used. When the system age is unknown, assume a default value equal to the EUL. This corresponds to 20 years for non-centrifugal chillers and 25 years for centrifugal chillers. A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the chiller was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010 and 2018,¹³⁵ coinciding with the IECC 2009 and IECC 2015 code increases.

PUCT Docket 40885 provided baseline efficiencies for chillers replaced via early retirement programs and included a category for 1990-2001. However, the common practice for energy efficiency programs in Texas is to allow systems older than 1990 to use the same baseline efficiencies as those listed for 1990-2001. This practice is reflected in the baseline efficiency tables, by showing the Year Installed as ≤ 2001 rather than 1990-2001.

¹³⁴ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

¹³⁵ IECC 2015 not enforced in Texas until program year 2018.

ER Baseline: Air-Cooled Chillers

Table 43. Chillers—Air-Cooled Path A ER Baseline Full-Load Efficiency¹³⁶

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	9.212	9.212	8.530	8.530	8.530
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	10.100	10.100	10.100	10.100	10.100

Table 44. Chillers—Air-Cooled Path B ER Baseline Full-Load Efficiency¹³⁷

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	9.212	9.212	8.530	8.530	8.530
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	9.700	9.700	9.700	9.700	9.700

Table 45. Chillers—Air-Cooled Path A ER Baseline Part-Load Efficiency (IPLV)¹³⁸

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	9.554	9.554	8.530	8.530	8.530
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	13.700	13.700	14.000	14.000	14.000

Table 46. Chillers—Air-Cooled Path B ER Baseline Part-Load Efficiency (IPLV)¹³⁹

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	9.554	9.554	8.530	8.530	8.530
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	15.800	15.800	16.100	16.100	16.100

¹³⁶ Code-specified efficiencies in effect prior to 2002 were given in COP and have been converted to EER using $EER = COP \times 3.412$. Values in the “≤ 2001” row have been converted and are expressed in italics.

¹³⁷ Ibid.

¹³⁸ Ibid.

¹³⁹ Ibid.

ER Baseline: Centrifugal Water-Cooled Chillers

Table 47. Chillers—Water-Cooled Centrifugal Path A ER Baseline Full-Load Efficiency¹⁴⁰

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748	0.748
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.634	0.634	0.634	0.576	0.576	0.570
≥ 2018	0.610	0.610	0.610	0.560	0.560	0.560

Table 48. Chillers—Water-Cooled Centrifugal Path B ER Baseline Full-Load Efficiency¹⁴¹

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748	0.748
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.639	0.639	0.639	0.600	0.600	0.590
≥ 2018	0.695	0.695	0.635	0.595	0.585	0.585

Table 49. Chillers—Water-Cooled Centrifugal Path A ER Baseline Part-Load Efficiency (IPLV)¹⁴²

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733	0.733
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.596	0.596	0.596	0.549	0.549	0.539
≥ 2018	0.550	0.550	0.550	0.520	0.500	0.500

¹⁴⁰ Ibid.

¹⁴¹ Ibid.

¹⁴² Ibid.

Table 50. Chillers—Water-Cooled Centrifugal Path B ER Baseline Part-Load Efficiency (IPLV)¹⁴³

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733	0.733
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.450	0.450	0.450	0.400	0.400	0.400
≥ 2018	0.440	0.440	0.400	0.390	0.380	0.380

ER Baseline: Positive-Displacement (Screw, Scroll, or Reciprocating) Water-Cooled Chillers

Table 51. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Full-Load Efficiency¹⁴⁴

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002–2009	0.790	0.790	0.718	0.639	0.639
2010–2017	0.780	0.775	0.680	0.620	0.620
≥ 2018	0.750	0.720	0.660	0.610	0.560

Table 52. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Full-Load Efficiency¹⁴⁵

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002–2009	0.790	0.790	0.718	0.639	0.639
2010–2017	0.800	0.790	0.718	0.639	0.639
≥ 2018	0.780	0.750	0.680	0.625	0.585

¹⁴³ Ibid.¹⁴⁴ Ibid.¹⁴⁵ Ibid.

Table 53. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Part-Load Efficiency (IPLV)¹⁴⁶

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.630	0.615	0.580	0.540	0.540
≥ 2018	0.600	0.560	0.540	0.520	0.500

Table 54. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Part-Load Efficiency (IPLV)¹⁴⁷

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.600	0.586	0.540	0.490	0.490
≥ 2018	0.500	0.490	0.440	0.410	0.380

Replace-on-Burnout and New Construction

New baseline efficiency levels for chillers are provided in Table 55, which includes both full load and integrated part load value (IPLV) ratings. The IPLV accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard ASHRAE 90.1-2010. This standard contains two paths for compliance, Path A or Path B. According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller). Path A chillers are eligible to claim savings using the full-load efficiency conditions in the energy and demand savings algorithms.¹⁴⁸ Path B chillers are eligible to claim savings using the Path B chiller part-load baseline efficiencies with the demand and energy coefficients defined in this measure.

¹⁴⁶ Ibid.

¹⁴⁷ Ibid.

¹⁴⁸ According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for water-cooled chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller).

Table 55. Chillers—NC/ROB Baseline Efficiencies¹⁴⁹

System type (efficiency units)		Efficiency type	Capacity (tons)	Path A		Path B	
				Full- load	IPLV	Full- load	IPLV
Air-cooled chiller		EER	< 150	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
			≥ 150	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water- cooled chiller	Screw/ scroll/ recip.	kW/ton	< 75	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
			≥ 75 and < 150	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
			≥ 150 and < 300	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
			≥ 300 and < 600	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
			≥ 600	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
	Centrifugal		< 150	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
			≥ 150 and < 300	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.400
			≥ 300 and < 400	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
			≥ 400	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380

High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 55 for either Path A or Path B. For whichever path is used, the chiller must exceed the minimum baseline efficiency for both full-load and IPLV of that path to qualify. Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace-on-Burnout

This scenario includes chillers used for new construction and retrofit/replacements that are not covered by early retirement, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:¹⁵⁰

- For early retirement projects only, when downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no cap on upsizing because the savings are calculated using the lower pre-capacity.
- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement portion of the savings calculation: manufacturer year, EUL,

¹⁴⁹ IECC 2015 Table C403.2.3(7).

¹⁵⁰ From PUCT Docket #41070.

RUL, path A/B full and part-load baseline efficiency, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Path A and B Air and Water-Cooled Chillers

$$\text{Summer Peak Demand Savings [kW]} = (Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}) \times DF_S$$

Equation 24

$$\text{Energy Savings [kWh]} = (Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}) \times EFLH_C$$

Equation 25

Where:

$Cap_{C,pre}$ = For ER and ROB, rated equipment cooling capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [tons]

$Cap_{C,post}$ = Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [tons]

Note: The capacity in the equations may not always match the capacity of the units.

$\eta_{baseline}$ = Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/ton] – default values, based on system type, are given in Table 43 through Table 55; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]

$\eta_{installed}$ = Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 55; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]

Note: Use full-load efficiency (kW/ton) for kW demand savings calculations and part-load efficiency (IPLV) for kWh energy savings calculations.

$$\frac{kW}{Ton} = \frac{12}{EER}$$

Equation 26

CF_s	=	Summer peak coincidence factor (see Table 56 through Table 60)
$EFLH_c$	=	Cooling equivalent full-load hours [hours] (see Table 56 through Table 60)

Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment¹⁵¹

The equipment efficiency for an air-cooled chiller includes condenser fans, but the equipment efficiency for a water-cooled chiller does not include the condenser water pump and cooling tower (auxiliary equipment). Therefore, when an air-cooled chiller is replaced with a water-cooled chiller, the savings must be reduced to account for the impact of the water-cooled system's additional equipment. This type of retrofit is only applicable for ER situations. The following equations are used:

$$kW_{adjust} = (HP_{CW\ pump} + HP_{CT\ fan}) \times \frac{0.746}{0.86} \times 0.80$$

Equation 27

$$kWh_{adjust} = kW \times 8,760$$

Equation 28

Where:

$HP_{CW\ pump}$	=	Horsepower of the condenser water pump
$HP_{CT\ fan}$	=	Horsepower of the cooling tower fan
0.746	=	Conversion from HP to kW [kW/HP]
0.86	=	Assumed equipment efficiency
0.80	=	Assumed load factor
8,760	=	Annual run-time hours

The energy and demand of the condenser water pump and cooling tower fans are subtracted from the final savings, to reach the net savings:

$$kW_{savings,net} = kW_{chiller} - kW_{adjust}$$

Equation 29

$$kWh_{savings,net} = kWh_{chiller} - kWh_{adjust}$$

Equation 30

Early Retirement Savings

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require weighted savings calculated over both the ER period and the ROB period, accounting for the EUL and the RUL. The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings

¹⁵¹ This extra adjustment is noted in PUCT Docket No. 41070.

over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A. Table 56 through Table 60 present the demand and energy coefficients as well as the Part Load Factor. These HVAC coefficients vary by climate zone, building type, and equipment type. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 33 and Table 34. These building types are derived from the EIA CBECS study.¹⁵²

Deemed peak CF and EFLH values are presented by building type and climate zone for chillers in Table 56 through Table 60. These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The CF and EFLH values used for Other are the most conservative values from the explicitly listed building types. Alternately, with evaluator pre-approval, a deemed building type specified in Table 56 through Table 60 can be used in lieu of *other* if it has a similar building type activity or operating schedule. For example, *healthcare outpatient* is not listed in the deemed tables, but the *office* building could be used if its typical operating schedule aligns closely with that of an office building. When the *other* building type is used, or if a non-listed building type is mapped to another deemed option, a description of the actual building type, the primary business activity, the business operating hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination cannot use the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Table 56. Chillers—CF and EFLH for Climate Zone 1: Amarillo

Building type	Principal building activity	Chiller ¹⁵³			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.56	2,807	0.73	5,100
Education	College/university	0.87	1,115	0.68	1,243
	Primary school	0.44	576	0.53	971

¹⁵² The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines Commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type—Large Multifamily—included. <https://www.eia.gov/consumption/commercial/>.

¹⁵³ Coefficient values are derived from the petitions filed in Docket 40885 and Docket 30331. Coefficients were updated with Docket 40885, but not all building types (herein “principal building activities,” or PBAs) that were originally available in Docket 30331 were updated in Docket 40885. Coefficient values for those PBAs that were not updated in Docket 40885 remain valid.

Building type	Principal building activity	Chiller ¹⁵³			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
	Secondary school	0.70	802	0.58	1,772
Food Sales	Supermarket	0.52	489	0.54	719
Healthcare	Inpatient	0.70	2,006	0.65	2,711
	Outpatient	0.70	1,208	0.61	1,506
Large multifamily	Midrise apartment	0.41	421	0.50	1,098
Lodging	Large hotel	0.58	1,283	0.59	1,553
	Nursing home	0.41	428	0.50	1,115
Manufacturing	Manufacturing	0.70	1,208	0.61	1,506
Mercantile	Stand-alone retail	0.52	489	0.54	719
	24-hour retail	0.67	681	0.62	974
Office	Office	0.70	1,208	0.61	1,506
Public assembly	Public assembly	0.44	774	0.53	1,306
Religious worship	Religious worship	0.52	294	0.54	433
Other	Other	0.41	294	0.50	433

Table 57. Chillers—CF and EFLH for Climate Zone 2: Dallas

Building type	Principal building activity	Chiller ¹⁵⁴			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.54	2,791	0.77	4,906
Education	College/university	0.89	1,587	0.81	1,761
	Primary school	0.48	726	0.60	1,412
	Secondary school	0.84	1,170	0.54	2,234
Food Sales	Supermarket	0.79	936	0.72	1,328
Healthcare	Inpatient	0.90	2,784	0.81	3,683
	Outpatient	0.92	1,711	0.70	2,062
Large multifamily	Midrise apartment	0.68	1,060	0.66	2,053
Lodging	Large hotel	0.80	2,086	0.71	2,627
	Nursing home	0.68	1,077	0.66	2,085
Manufacturing	Manufacturing	0.92	1,711	0.70	2,062
Mercantile	Stand-alone retail	0.79	936	0.72	1,328
	24-hour retail	0.89	1,307	0.79	1,975
Office	Office	0.92	1,711	0.70	2,062
Public assembly	Public assembly	0.48	976	0.60	1,898
Religious worship	Religious worship	0.79	563	0.72	799
Other	Other	0.48	563	0.54	799

¹⁵⁴ Ibid.

Table 58. Chillers—CF and EFLH for Climate Zone 3: Houston

Building type	Principal building activity	Chiller ¹⁵⁵			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.53	2,824	0.76	5,075
Education	College/university	0.80	1,858	0.84	2,099
	Primary school	0.45	818	0.60	1,627
	Secondary school	0.77	1,306	0.55	2,404
Food Sales	Supermarket	0.83	1,224	0.78	1,712
Healthcare	Inpatient	0.85	3,116	0.79	4,171
	Outpatient	0.92	1,820	0.71	2,312
Large multifamily	Midrise apartment	0.65	1,295	0.66	2,467
Lodging	Large hotel	0.71	2,499	0.73	3,201
	Nursing home	0.65	1,315	0.66	2,506
Manufacturing	Manufacturing	0.92	1,820	0.71	2,312
Mercantile	Stand-alone retail	0.83	1,224	0.78	1,712
	24-hour retail	0.80	1,513	0.74	2,427
Office	Office	0.92	1,820	0.71	2,312
Public assembly	Public assembly	0.45	1,100	0.60	2,188
Religious worship	Religious worship	0.83	737	0.78	1,031
Other	Other	0.45	737	0.55	1,031

Table 59. Chillers—CF and EFLH for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Chiller ¹⁵⁶			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.48	2,881	0.77	5,266
Education	College/university	0.80	2,340	0.87	2,583
	Primary school	0.45	937	0.61	1,845
	Secondary school	0.68	1,503	0.55	2,577
Food Sales	Supermarket	0.75	1,394	0.76	1,953
Healthcare	Inpatient	0.79	3,455	0.82	4,637
	Outpatient	0.82	2,027	0.72	2,570
Large multifamily	Midrise apartment	0.61	1,534	0.67	2,840
Lodging	Large hotel	0.74	2,908	0.73	3,713
	Nursing home	0.61	1,558	0.67	2,884
Manufacturing	Manufacturing	0.82	2,027	0.72	2,570
Mercantile	Stand-alone retail	0.75	1,394	0.76	1,953
	24-hour retail	0.70	1,725	0.73	2,768
Office	Office	0.82	2,027	0.72	2,570
Public assembly	Public assembly	0.45	1,260	0.61	2,481

¹⁵⁵ Ibid.

¹⁵⁶ Ibid.

Building type	Principal building activity	Chiller ¹⁵⁶			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Religious worship	Religious worship	0.75	839	0.76	1,176
Other	Other	0.45	839	0.55	1,176

Table 60. Chillers—CF and EFLH for Climate Zone 5: El Paso

Building type	Principal building activity	Chiller ¹⁵⁷			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.56	2,950	0.71	5,137
Education	College/university	0.93	1,278	0.96	1,458
	Primary school	0.61	751	0.53	1,113
	Secondary school	0.77	1,039	0.54	2,196
Food Sales	Supermarket	0.64	722	0.55	948
Healthcare	Inpatient	0.71	2,355	0.59	2,992
	Outpatient	0.77	1,442	0.60	1,683
Large multifamily	Midrise apartment	0.56	841	0.52	1,553
Lodging	Large hotel	0.63	1,815	0.58	2,038
	Nursing home	0.56	854	0.52	1,577
Manufacturing	Manufacturing	0.77	1,442	0.60	1,683
Mercantile	Stand-alone retail	0.64	722	0.55	948
	24-hour retail	0.61	884	0.60	1,371
Office	Office	0.77	1,442	0.60	1,683
Public assembly	Public assembly	0.61	1,010	0.53	1,496
Religious worship	Religious worship	0.64	435	0.55	571
Other	Other	0.56	435	0.52	571

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

¹⁵⁷ Ibid.

Upstream/Midstream

For upstream/midstream program delivery, use the EFLH and CF assumptions outlined in Table 59 and Table 60. Assumed values have been weighted based on building type survey data from 2012 CBECS¹⁵⁸ and 2014 MECS¹⁵⁹.

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 56 through Table 60. For program designs where building type is unknown, you may use the savings coefficients from Table 61 and Table 62. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 61. Chillers—Air-Cooled Upstream/Midstream Input Assumptions¹⁶⁰

Savings coefficient	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
EFLH _c	982	1,440	1,605	1,820	1,234
CF _s	0.63	0.82	0.79	0.72	0.71

Table 62. Chillers—Water-Cooled Upstream/Midstream Input Assumptions¹⁶¹

Savings coefficient	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
EFLH _c	1,405	2,013	2,303	2,578	1,661
CF _s	0.59	0.67	0.69	0.69	0.58

¹⁵⁸ 2012 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

¹⁵⁹ 2014 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

¹⁶⁰ 2012 CBECS and 2014 MECS.

¹⁶¹ Ibid.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years¹⁶²
- Centrifugal chillers: 25 years.¹⁶³

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 63. For ER units of unknown age, a default value of 20 years for non-centrifugal chillers and 25 years for centrifugal chillers should be used (equal to the EUL). This corresponds to a default RUL of 3.6 years for non-centrifugal chillers and 5.4 years for centrifugal chillers. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for early retirement projects for two distinct periods: The ER period (RUL) and the ROB period (EUL-RUL). The calculations for early retirement projects are extensive, and as such, are provided in Appendix A.

Table 63. Chillers—RUL of Early Retirement Systems^{164,165}

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)	Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
1	18.7	23.9	17	5.0	8.7
2	17.7	22.9	18	4.5	8.1
3	16.7	21.9	19	4.0	7.5
4	15.7	20.9	20	3.6	7.1
5	14.7	19.9	21	3.0	6.6
6	13.7	18.9	22	2.0	6.3
7	12.7	17.9	23	1.0	5.9

¹⁶² PUCT Docket No. 36779. The original source was DEER 2008, but DEER 2014 provides the same value of 20 years for “High Efficiency Chillers”. DEER does not differentiate between centrifugal and non-centrifugal chillers.

¹⁶³ PUCT Docket No. 40885, review of multiple studies looking at the lifetime of centrifugal chillers as detailed in petition workpapers.

¹⁶⁴ PUCT Docket No. 40885, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹⁶⁵ Current New Construction baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)	Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
8	11.8	16.9	24 ¹⁶⁶	0.0	5.6
9	10.9	15.9	25	–	5.4
10	10.0	14.9	26	–	5.0
11	9.1	13.9	27	–	4.0
12	8.3	12.9	28	–	3.0
13	7.5	11.9	29	–	2.0
14	6.8	10.9	30	–	1.0
15	6.2	10.1	31 ¹⁶⁷	–	0.0
16	5.5	9.3			

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.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone or county
- Baseline number of units
- Baseline equipment type (compressor/condenser type)
- Baseline equipment rated cooling capacity
- **For ER only:** Baseline age of system and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)

¹⁶⁶ RULs are capped at the 75th percentile of non-centrifugal equipment age, 24 years, as determined based on DOE survival curves. Non-centrifugal systems older than 24 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

¹⁶⁷ Ibid.

- Installed number of units
- Installed equipment type (compressor/condenser type)
- Installed path (Path A or Path B)
- Is the installed chiller a standby unit in a redundant chiller configuration? (yes, no)
- Installed rated cooling capacity
- Installed cooling efficiency rating
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For retrofit only:** Proof of purchase: invoice showing model number; photos of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For chiller type conversion only:** Condenser water pump HP and cooling tower fan HP
- **For other building type only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 30331—Established rules for energy efficiency programs, including factors for principal building activities (PBAs). Most PBA values were superseded by Docket 40885; however, some values from this docket remain valid.
- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
 - Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, room air conditioners, and chilled water systems.
 - Approved estimates of RUL of working chilled water systems.
 - Updated demand and energy coefficients for all commercial HVAC systems.

- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Previously these savings were taken from the Dallas-Fort Worth area, which has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

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

Document Revision History

Table 64. Chillers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Modified savings calculations surrounding early retirement programs, and revised details surrounding RUL and Measure Life. Added references to Appendix A for EUL and RUL discussion, and Net Present Value (NPV) equations.
v2.1	01/30/2015	Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	Updated savings method to allow for part-load efficiency calculations.
v3.1	11/05/2015	Updated table references to clarify building types and RUL references. Added “Other” building type for when building type is not explicitly listed. Added Religious Worship building type to Climate Zone 5 for consistency with other zones.
v4.0	10/10/2016	Updated coincidence factors and EFLH for applicable building types and climate zones.
v5.0	10/2017	Included Path A and Path B compliance options for chillers. Added 24-hour Retail load shape. Updated RUL table based on DOE survival curves.
v6.0	10/2018	Revised Path A and B savings methodology for mid-year guidance memo. Added Data Center as a new building type. Updated early retirement guidance for projects with a total capacity change.
v7.0	10/2019	Updated program tracking requirements.

TRM version	Date	Description of change
v8.0	10/2020	General reference checks and text edits. Clarified use of post capacity for ROB baselines. Added unknown age defaults for early retirement.
v9.0	10/2021	General reference checks and text edits. Updated default age of system to match EUL. Incorporated upstream/midstream building-type weighting for savings coefficients. Incremented RUL table for code compliance.
v10.0	10/2022	Added guidance for redundant chiller configurations. Incremented RUL table for code compliance.
v11.0	10/2023	Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
v12.0	10/2024	Updated early retirement age eligibility and criteria related to downsizing, updated midstream building type weighting assumptions, and provided guidance for building types.
v13.0	10/2025	Expanded building types.

2.2.4 Packaged Terminal Air Conditioners/Heat Pumps, Single Package Vertical Air Conditioners/Heat Pumps, and Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-PT

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See All commercial

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal air conditioners (PTAC), packaged terminal heat pumps (PTHP), single package vertical air conditioners (SPVAC), single package vertical heat pumps (SPVHP), and room AC (RAC) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) of PTAC/PTHPs, replace-on-burnout (ROB), and new construction (NC) situations based current and previous on efficiency standards. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types include:

Packaged Terminal Air Conditioners and Heat Pumps. Both standard and non-standard size equipment types are covered. Standard size refers to equipment with wall sleeve dimensions having an external wall opening greater than or equal to 16 inches high or greater than or equal to 42 inches wide and a cross-sectional area greater than 670 in². Non-standard size refers to equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide and a cross-sectional area less than 670 in².

Single Package Vertical Air Conditioners and Heat Pumps. All cooling capacities less than 240,000 Btu/hr are covered.

Room Air Conditioners include all equipment configurations covered by the federal appliance standards, including with or without a reverse cycle, louvered or non-louvered sides, casement-only, and casement-slide.

Eligibility Criteria

For a measure to be eligible for this deemed savings approach, the following conditions will be met:

- The existing and proposed cooling equipment is electric.
- The PTAC, PTHP, SPVAC, SPVHP, or RAC must be the primary cooling source for the space.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.^{168,169}

Baseline Condition

Early Retirement for PTAC/PTHP Systems

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC or PTHP), and age (based on year manufactured) of the replaced system.¹⁷⁰ When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 65, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

¹⁶⁸ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

¹⁶⁹ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

¹⁷⁰ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years.¹⁷¹ A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing standard size PTAC systems manufactured as of January 1, 2017 and standard size PTHP systems manufactured as of October 8, 2012, are not eligible for early retirement. All non-standard size PTAC/PTHPs are not eligible for early retirement.

Table 65. PTAC/PTHPs—ER Baseline Efficiency Levels for Standard Size Units¹⁷²

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (no built-in ER heat)	Baseline heating efficiency (COP) (with built-in ER heat)
PTAC	<7,000	11.0	–	1.0
	7,000-15,000	$12.5 - (0.213 \times \text{Cap}/1,000)$		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	–
	7,000-15,000	$12.3 - (0.213 \times \text{Cap}/1,000)$	$3.2 - (0.026 \times \text{Cap}/1,000)$	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 66 provides federal minimum efficiency standards for PTAC/PTHP units reflected in 10 CFR 431. The effective date for standard size PTACs is January 1, 2017, and the effective date for standard size PTHPs is October 8, 2012. The effective date for all non-standard PTAC/PTHPs is October 7, 2010.

¹⁷¹ As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

¹⁷² ER only applies to standard size units because the minimum efficiency requirements for non-standard systems have never changed, making the ER baseline efficiency the same as for ROB.

Table 66. PTAC/PTHPs—NC/ROB Baseline Efficiency Levels^{173,174}

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTAC	Standard size	<7,000	11.9	—
		7,000-15,000	14.0 – (0.300 x Cap/1,000)	—
		>15,000	9.5	—
	Non-standard size	<7,000	9.4	—
		7,000-15,000	10.9 – (0.213 x Cap/1,000)	—
		>15,000	7.7	—
PTHP	Standard size	<7,000	11.9	3.3
		7,000-15,000	14.0 – (0.300 x Cap/1,000)	3.7 – (0.052 x Cap/1,000)
		>15,000	9.5	2.9
	Non-standard size	<7,000	9.3	2.7
		7,000-15,000	10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)
		>15,000	7.6	2.5

Table 67 provides federal minimum efficiency standards for SPVAC/SPVHP units reflected in 10 CFR 431. The effective date for the Final Rule was November 23, 2015. Compliance with the standards for SPVAC/SPVHPs with cooling capacities less than 65,000 Btu/hr was September 23, 2019; compliance with the standard for SPVAC/SPVHPs with cooling capacities between 65,000 and 135,000 Btu/hr was October 9, 2015; and compliance with the standard for SPVAC/SPVHPs with cooling capacities between 135,000 and 240,000 Btu/hr was October 9, 2016.

Table 67. SPVAC/SPVHPs—NC/ROB Baseline Efficiency Levels¹⁷⁵

Equipment Type	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
Single package vertical air conditioners	< 65,000	11.0	—
	≥ 65,000 and <240,000	10.0	—
Single package vertical air heat pumps	< 65,000	11.0	3.3
	≥ 65,000 and <240,000	10.0	3.0

¹⁷³ IECC 2015 Table C403.2.3(3).

¹⁷⁴ Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

¹⁷⁵ Table 11 to 10 CFR 431.97.

Table 68 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b). A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.¹⁷⁶

Table 68. Room ACs—NC/ROB Baseline Efficiency Levels¹⁷⁷

Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)
Without reverse cycle, with louvered sides	< 8,000	11.0
	≥ 8,000 and < 14,000	10.9
	≥ 14,000 and < 20,000	10.7
	≥ 20,000 and < 25,000	9.4
	≥ 25,000	9.0
Without reverse cycle, without louvered sides	< 8,000	10.0
	≥ 8,000 and < 11,000	9.6
	≥ 11,000 and < 14,000	9.5
	≥ 14,000 and < 20,000	9.3
	≥ 20,000	9.4
With reverse cycle, with louvered sides	< 20,000	9.8
	≥ 20,000	9.3
With reverse cycle, without louvered sides	< 14,000	9.3
	≥ 14,000	8.7
Casement-only	All capacities	9.5
Casement-slider	All capacities	10.4

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 66 through Table 68.

The high-efficiency retrofits must also meet the following criteria:¹⁷⁸

- For early retirement projects only, when downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no cap on upsizing because the savings are calculated using the lower pre-capacity.

¹⁷⁶ Current DOE minimum efficiency standard for residential room air conditioners. <https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057>.

¹⁷⁷ Direct final rule for new Room Air Conditioner Standards was published on April 21st, 2011 (76 FR 22454), effective August 19th, 2011, and are required starting June 1st, 2014. These are found in 10 CFR Part 430.

¹⁷⁸ Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend Early Retirement to cover PTAC/PTHP.

- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement portion of the savings calculation: manufacturer year, EUL, RUL, full and part-load baseline, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.
- Non-standard size PTAC/PTHPs cannot be used for new construction
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times DF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 31

$$\text{Winter Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times DF_W \times \frac{1 \text{ kW}}{3,412 \text{ Btuh}}$$

Equation 32

$$\text{Total Energy Savings [kWh]} = \text{kWh}_C + \text{kWh}_H$$

Equation 33

$$\text{Cooling Energy Savings [kWh}_C] = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 34

$$\text{Heating Energy Savings [kWh}_H] = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times EFLH_H \times \frac{1 \text{ kW}}{3,412 \text{ Btu}}$$

Equation 35

Where:

$\text{Cap}_{C/H,pre}$	=	For ER and ROB, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [BTUH]; 1 ton = 12,000 Btuh
$\text{Cap}_{C/H,post}$	=	Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh

Note: The capacity in the equations may not always match the capacity of the units.

$\eta_{baseline,C}$	=	Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 65 through Table 68)
$\eta_{baseline,H}$	=	Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 65 and Table 66) ¹⁷⁹
$\eta_{installed,C}$	=	Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]—(Must exceed minimum federal standards found in Table 66 and Table 68) ¹⁸⁰
$\eta_{installed,H}$	=	Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 66)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 35 through Table 39)
$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours [hours] (see Table 69 through Table 73)

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A.

Deemed Energy and Demand Savings Tables

Table 69 through Table 73 present the deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs, SPVAC/SPVHPs, and RACs. These values are calculated by climate zone, building type, and equipment type. A description of the calculation method can also be found in Docket No. 40885, Attachment B.

These tables also include an *other* building type, which can be used for business types that are not explicitly listed. The CF and EFLH values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system. For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination should use the “Other” building type.

¹⁷⁹ Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.

¹⁸⁰ Ibid.

Table 69. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 1: Amarillo

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.56	686	0.56	686	0.43	322
	Secondary school	0.61	496	0.61	496	0.43	338
Food sales	Convenience store	0.64	820	0.64	820	0.48	410
Food service	Full-service restaurant	0.73	946	0.73	946	0.43	516
	24-hour full-service restaurant	0.71	1,014	0.71	1,014	0.43	619
	Quick-service restaurant	0.64	710	0.64	710	0.48	473
	24-hour quick-service restaurant	0.65	758	0.65	758	0.48	598
Lodging	Large hotel	0.51	1,248	0.51	1,248	0.86	504
	Nursing home	0.60	635	0.60	635	0.50	256
	Small hotel	0.50	1,442	0.50	1,442	0.36	218
Mercantile	Strip mall	0.66	637	0.66	637	0.39	346
Office	Small office	0.63	660	0.63	660	0.29	156
Other	Other	0.50	496	0.50	496	0.29	156

Table 70. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 2: Dallas

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.85	1,016	0.85	1,016	0.66	231
	Secondary school	0.99	912	0.99	912	0.59	285
Food sales	Convenience store	1.05	1,544	1.05	1,544	0.61	318
Food service	Full-service restaurant	1.06	1,534	1.06	1,534	0.50	401
	24-hour full-service restaurant	1.06	1,734	1.06	1,734	0.49	509
	Quick-service restaurant	1.05	1,336	1.05	1,336	0.61	368
	24-hour quick-service restaurant	1.05	1,485	1.05	1,485	0.60	463

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _C	CF _s	EFLH _C	CF _W	EFLH _H
Lodging	Large hotel	0.68	1,749	0.68	1,749	0.82	270
	Nursing home	1.01	1,460	1.01	1,460	0.61	226
	Small hotel	0.53	1,919	0.53	1,919	0.42	145
Mercantile	Strip mall	0.88	925	0.88	925	0.55	219
Office	Small office	0.89	1,012	0.89	1,012	0.40	89
Other	Other	0.53	912	0.53	912	0.40	89

Table 71. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 3: Houston

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _C	CF _s	EFLH _C	CF _W	EFLH _H
Education	Primary school	0.71	1,186	0.71	1,186	0.50	52
	Secondary school	0.79	1,030	0.79	1,030	0.54	63
Food sales	Convenience store	0.83	1,760	0.83	1,760	0.51	70
Food service	Full-service restaurant	0.85	1,755	0.85	1,755	0.44	93
	24-hour full-service restaurant	0.86	1,994	0.86	1,994	0.44	121
	Quick-service restaurant	0.83	1,523	0.83	1,523	0.51	80
	24-hour quick-service restaurant	0.85	1,692	0.85	1,692	0.50	104
Lodging	Large hotel	0.57	2,080	0.57	2,080	0.33	54
	Nursing home	0.81	1,695	0.81	1,695	0.24	44
	Small hotel	0.53	1,903	0.53	1,903	0.19	32
Mercantile	Strip mall	0.74	1,093	0.74	1,093	0.42	47
Office	Small office	0.71	1,100	0.71	1,100	0.28	15
Other	Other	0.53	1,030	0.53	1,030	0.28	15

Table 72. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 4: Corpus Christi

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.70	1,355	0.70	1,355	0.30	73
	Secondary school	0.76	1,212	0.76	1,212	0.35	92
Food sales	Convenience store	0.74	2,025	0.74	2,025	0.34	94
Food service	Full-service restaurant	0.77	2,041	0.77	2,041	0.35	136
	24-hour full-service restaurant	0.77	2,337	0.77	2,337	0.36	176
	Quick-service restaurant	0.74	1,752	0.74	1,752	0.34	108
	24-hour quick-service restaurant	0.74	1,968	0.74	1,968	0.34	138
Lodging	Large hotel	0.51	2,404	0.51	2,404	0.21	61
	Nursing home	0.73	1,832	0.73	1,832	0.15	47
	Small hotel	0.46	2,041	0.46	2,041	0.10	38
Mercantile	Strip mall	0.65	1,218	0.65	1,218	0.21	66
Office	Small office	0.63	1,213	0.63	1,213	0.14	18
Other	Other	0.46	1,212	0.46	1,212	0.14	18

Table 73. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 5: El Paso

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.88	1,009	0.88	1,009	0.37	271
	Secondary school	0.84	751	0.84	751	0.43	286
Food sales	Convenience store	0.74	1,267	0.74	1,267	0.26	300
Food service	Full-service restaurant	0.74	1,292	0.74	1,292	0.28	407
	24-hour full-service restaurant	0.72	1,431	0.72	1,431	0.27	538
	Quick-service restaurant	0.74	1,096	0.74	1,096	0.26	347
	24-hour quick-service restaurant	0.75	1,186	0.75	1,186	0.26	463

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Lodging	Large hotel	0.61	1,723	0.61	1,723	0.21	292
	Nursing home	0.85	1,244	0.85	1,244	0.15	211
	Small hotel	0.61	1,945	0.61	1,945	0.06	123
Mercantile	Strip mall	0.80	943	0.80	943	0.27	298
Office	Small office	0.81	1,050	0.81	1,050	0.15	97
Other	Other	0.61	751	0.61	751	0.15	97

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream

For upstream/midstream program delivery, use the EFLH and CF assumptions from Table 74. Assumed values have been weighted based on building type survey data from 2012 CBECS¹⁸¹ and 2014 MECS¹⁸².

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 69 through Table 73. For program designs where building type is unknown, you may use the savings coefficients from Table 74. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 74. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—Upstream/Midstream Input Assumptions¹⁸³

Savings coefficient	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
EFLH _c	1,033	1,681	1,791	1,929	1,586
EFLH _H	238	186	38	43	168
CF _s	0.55	0.77	0.67	0.60	0.73
CF _w	0.43	0.52	0.22	0.13	0.11

¹⁸¹ 2012 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

¹⁸² 2014 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

¹⁸³ 2012 CBECS and 2014 MECS.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of PTAC/PTHP units is 8 years, as determined by the DOE in its 2023 final rule.¹⁸⁴

The EUL of SPVAC/SPVHP units is 15 years, as determined by the DOE in its September 2015 final rule.¹⁸⁵

The EUL of RAC units is 10 years based on current DOE Final Rule standards for room air conditioners. This value is consistent with the EUL reported in the Department of Energy Technical Support Document for Room Air conditioners.¹⁸⁶

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 75.

For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for early retirement projects for two distinct periods: The ER period (RUL) and the ROB period (EUL-RUL). The calculations for early retirement projects are extensive, and as such, are provided in Appendix A.

Table 75. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement
Standard Size PTAC/PTHPs^{187,188}

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	RUL (years)
1	14.0	9	6.5
2	13.0	10	5.7
3	12.0	11	5.0
4	11.0	12	4.0

¹⁸⁴ Department of Energy, Energy Conservation Program: Energy Conservation Standards for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps, Final Determination <https://www.regulations.gov/document/EERE-2019-BT-STD-0035-0023>.

¹⁸⁵ Department of Energy, Energy Conservation Program: Energy Conservation Standards for Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps, 80 FR 57467 <https://www.federalregister.gov/documents/2015/09/23/2015-23029/energy-conservation-program-energy-conservation-standards-for-single-package-vertical-air>.

¹⁸⁶ Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. <https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013>.

¹⁸⁷ PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹⁸⁸ Current federal standard effective date is 1/1/2017. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	RUL (years)
5	10.0	13	3.0
6	9.1	14	2.0
7	8.2	15	1.0
8	7.3	16 ¹⁸⁹	0.0

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.

- Decision/action type: ROB, NC, ER, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone or county
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- **For ER only:** Baseline age and method of determination (e.g., nameplate, blueprints, Customer reported, not available)
- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Installed number of units
- Installed equipment type (PTAC, PTHP, SPVAC, SPVHP, RAC)
- Equipment configuration category: Standard/non-standard or room AC
- Installed rated heating and cooling capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number

¹⁸⁹ RULs are capped at the maximum age of the product lifetime range specified in the current DOE federal standard for PTAC/PTHPs. <https://www.regulations.gov/document/EERE-2019-BT-STD-0035-0023>.

- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building type only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. This petition updated demand and energy coefficients for all commercial HVAC systems.

Relevant Standards and Reference Sources

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

Document Revision History

Table 76. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Updated EUL value for DX units, based on PUCT Docket No. 36779. Updated the minimum baseline efficiencies for Standard PTAC and PTHP based on new federal standards, 10 CFR 431.97, and updated the minimum efficiencies for Room AC units and added specifications for new Casement-only and Casement-slider equipment. Expanded application to “Hotel—Large” business type for PTAC/PTHP equipment and changed the RAC energy and demand coefficients to reference those for DX systems, rather than those for PTAC/PTHP systems.
v2.1	01/30/2015	Corrections to energy and demand coefficients for heat pumps in Climate Zone 3 (Houston).
v3.0	04/10/2015	Added energy and demand coefficients for RAC units. Included text to allow for early retirement changes. For PTHPs: Added heating efficiencies and split EFLH into cooling and heating components.

TRM version	Date	Description of change
v3.1	11/05/2015	Added updated building type definitions and descriptions, minor updates to text for clarification and consistency.
v4.0	10/10/2016	No revision.
v5.0	10/2017	Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for IECC 2015 and added 24-hour building load shapes. Updated RUL table based on DOE survival curves. Added several new building types.
v6.0	10/2018	Revised early retirement criteria for systems with an overall capacity change.
v7.0	10/2019	Revised early retirement criteria for systems with an overall capacity change. Added clarification for PTHPs replacing PTACs with electric resistance heating. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Clarified use of post capacity for ROB baselines. Added unknown age defaults for early retirement.
v9.0	10/2021	General reference checks and text edits. Incorporated upstream/midstream building type weighted savings coefficients. Clarified default age and RUL. Incremented RUL table for code compliance.
v10.0	10/2022	Incremented RUL table for code compliance.
v11.0	10/2023	Added SPVAC and SPVHP units to measure. Corrected current federal standard effective date. Added separate RUL table for PTHP. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
v12.0	10/2024	Updated early retirement age eligibility and criteria related to downsizing and updated midstream building type weighting assumptions.
v13.0	10/2025	Updated EUL to align with current PTAC federal standard.

2.2.5 Computer Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-CR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Data centers

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Calculator

Measure Description

This section summarizes the deemed savings methodology for the installation of computer room air conditioning (CRAC) systems. A CRAC unit is a device that monitors and maintains the temperature, air distribution, and humidity in a network room or data center. This measure covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of only part-load efficiency values, as these types of units are only rated in units of sensible coefficient of performance (SCOP) for units manufactured before May 28, 2024, and net sensible coefficient of performance (NSenCOP) for units manufactured as of May 28, 2024. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. If the actual age of the unit is unknown, default values are provided.

Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment is electric.
- The building type is a network room or data center.
- For early retirement projects: ER projects involve the replacement of a working system. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- In the event that these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.^{190,191}

Baseline Condition

The baseline conditions related to efficiency and system capacity for early retirement and replace-on-burnout/new construction are as follows:

Early Retirement

Early retirement baseline efficiency levels for CRACs are provided in Table 77. These baseline efficiency levels reflect the minimum efficiency requirements from IECC 2015, which uses the SCOP as the standard efficiency metric.

Table 77. CRACs—ER Baseline Efficiency Levels¹⁹²

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)
Air conditioners, air-cooled	< 65,000	2.20 / 2.09
	≥ 65,000 and < 240,000	2.10 / 1.99
	≥ 240,000	1.90 / 1.79
Air conditioners, water-cooled	< 65,000	2.60 / 2.49
	≥ 65,000 and < 240,000	2.50 / 2.39
	≥ 240,000	2.40 / 2.29
Air conditioners, water-cooled with fluid economizer	< 65,000	2.55 / 2.44
	≥ 65,000 and < 240,000	2.45 / 2.34
	≥ 240,000	2.35 / 2.24
Air conditioners, glycol cooled (rated at 40 percent propylene glycol)	< 65,000	2.50 / 2.39
	≥ 65,000 and < 240,000	2.15 / 2.04
	≥ 240,000	2.10 / 1.99

¹⁹⁰ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

¹⁹¹ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

¹⁹² IECC 2015 Table C403.2.3(9).

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)
Air conditioners, glycol cooled (rated at 40 percent propylene glycol) with fluid economizer	< 65,000	2.45 / 2.34
	≥ 65,000 and < 240,000	2.10 / 1.99
	≥ 240,000	2.05 / 1.94

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for CRACs are provided in Table 78. These baseline efficiency levels reflect the minimum efficiency requirements from Department of Energy (DOE) 10 CFR 431, referencing ASHRAE 90.1-2019. This standard updates the standard efficiency metric from SCOP to NSenCOP. The current federal standard is effective May 28, 2024.

Table 78. CRACs—NC/ROB Baseline Efficiency Levels¹⁹³

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Floor-mounted CRACs			
Air cooled	Downflow	< 80,000	2.70
		≥ 80,000 and < 295,000	2.58
		≥ 295,000 and < 930,000	2.36
	Upflow ducted	< 80,000	2.67
		≥ 80,000 and < 295,000	2.55
		≥ 295,000 and < 930,000	2.33
	Upflow non-ducted	< 65,000	2.16
		≥ 65,000 and < 240,000	2.04
		≥ 240,000 and < 760,000	1.89
	Horizontal	< 65,000	2.65
		≥ 65,000 and < 240,000	2.55
		≥ 240,000 and < 760,000	2.47

¹⁹³ DOE 10 CFR 431: Table I-1 & I-2. <https://www.federalregister.gov/documents/2022/03/07/2022-04151/energy-conservation-program-energy-conservation-standards-for-computer-room-air-conditioners>.

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Air-cooled with fluid economizer	Downflow	< 80,000	2.70
		≥ 80,000 and < 295,000	2.58
		≥ 295,000 and < 930,000	2.36
	Upflow ducted	< 80,000	2.67
		≥ 80,000 and < 295,000	2.55
		≥ 295,000 and < 930,000	2.33
	Upflow non-ducted	< 65,000	2.09
		≥ 65,000 and < 240,000	1.99
		≥ 240,000 and < 760,000	1.81
	Horizontal	< 65,000	2.65
		≥ 65,000 and < 240,000	2.55
		≥ 240,000 and < 760,000	2.47
Water-cooled	Downflow	< 80,000	2.82
		≥ 80,000 and < 295,000	2.73
		≥ 295,000 and < 930,000	2.67
	Upflow ducted	< 80,000	2.79
		≥ 80,000 and < 295,000	2.70
		≥ 295,000 and < 930,000	2.64
	Upflow non-ducted	< 65,000	2.43
		≥ 65,000 and < 240,000	2.32
		≥ 240,000 and < 760,000	2.20
	Horizontal	< 65,000	2.79
		≥ 65,000 and < 240,000	2.68
		≥ 240,000 and < 760,000	2.60

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Water-cooled with fluid economizer	Downflow	< 80,000	2.77
		≥ 80,000 and < 295,000	2.68
		≥ 295,000 and < 930,000	2.61
	Upflow ducted	< 80,000	2.74
		≥ 80,000 and < 295,000	2.65
		≥ 295,000 and < 930,000	2.58
	Upflow non-ducted	< 65,000	2.35
		≥ 65,000 and < 240,000	2.24
		≥ 240,000 and < 760,000	2.12
	Horizontal	< 65,000	2.71
		≥ 65,000 and < 240,000	2.60
		≥ 240,000 and < 760,000	2.54
Glycol cooled	Downflow	< 80,000	2.56
		≥ 80,000 and < 295,000	2.24
		≥ 295,000 and < 930,000	2.21
	Upflow ducted	< 80,000	2.53
		≥ 80,000 and < 295,000	2.21
		≥ 295,000 and < 930,000	2.18
	Upflow non-ducted	< 65,000	2.08
		≥ 65,000 and < 240,000	1.90
		≥ 240,000 and < 760,000	1.81
	Horizontal	< 65,000	2.48
		≥ 65,000 and < 240,000	2.18
		≥ 240,000 and < 760,000	2.18

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Glycol-cooled with fluid economizer	Downflow	< 80,000	2.51
		≥ 80,000 and < 295,000	2.19
		≥ 295,000 and < 930,000	2.15
	Upflow ducted	< 80,000	2.48
		≥ 80,000 and < 295,000	2.16
		≥ 295,000 and < 930,000	2.12
	Upflow non-ducted	< 65,000	2.00
		≥ 65,000 and < 240,000	1.82
		≥ 240,000 and < 760,000	1.73
	Horizontal	< 65,000	2.44
		≥ 65,000 and < 240,000	2.10
		≥ 240,000 and < 760,000	2.10
Ceiling-mounted CRACs			
Air-cooled with free air discharge condenser	Ducted	< 29,000	2.05
		≥ 29,000 and < 65,000	2.02
		≥ 65,000 and < 760,000	1.92
	Non-ducted	< 29,000	2.08
		≥ 29,000 and < 65,000	2.05
		≥ 65,000 and < 760,000	1.94
Air-cooled with free air discharge condenser and fluid economizer	Ducted	< 29,000	2.01
		≥ 29,000 and < 65,000	1.97
		≥ 65,000 and < 760,000	1.87
	Non-ducted	< 29,000	2.04
		≥ 29,000 and < 65,000	2.00
		≥ 65,000 and < 760,000	1.89
Air-cooled with ducted condenser	Ducted	< 29,000	1.86
		≥ 29,000 and < 65,000	1.83
		≥ 65,000 and < 760,000	1.73
	Non-ducted	< 29,000	1.89
		≥ 29,000 and < 65,000	1.86
		≥ 65,000 and < 760,000	1.75

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Air-cooled with ducted condenser and fluid economizer	Ducted	< 29,000	1.82
		≥ 29,000 and < 65,000	1.78
		≥ 65,000 and < 760,000	1.68
	Non-ducted	< 29,000	1.85
		≥ 29,000 and < 65,000	1.81
		≥ 65,000 and < 760,000	1.70
Water-cooled	Ducted	< 29,000	2.38
		≥ 29,000 and < 65,000	2.28
		≥ 65,000 and < 760,000	2.18
	Non-ducted	< 29,000	2.41
		≥ 29,000 and < 65,000	2.31
		≥ 65,000 and < 760,000	2.20
Water-cooled with fluid economizer	Ducted	< 29,000	2.33
		≥ 29,000 and < 65,000	2.23
		≥ 65,000 and < 760,000	2.13
	Non-ducted	< 29,000	2.36
		≥ 29,000 and < 65,000	2.26
		≥ 65,000 and < 760,000	2.16
Glycol-cooled	Ducted	< 29,000	1.97
		≥ 29,000 and < 65,000	1.93
		≥ 65,000 and < 760,000	1.78
	Non-ducted	< 29,000	2.00
		≥ 29,000 and < 65,000	1.98
		≥ 65,000 and < 760,000	1.81
Glycol-cooled with fluid economizer	Ducted	< 29,000	1.92
		≥ 29,000 and < 65,000	1.88
		≥ 65,000 and < 760,000	1.73
	Non-ducted	< 29,000	1.95
		≥ 29,000 and < 65,000	1.93
		≥ 65,000 and < 760,000	1.76

High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 78. Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace on Burnout

This scenario includes equipment used for new construction and retrofit/replacements that are not covered by early retirement, such as units that are replaced after natural failure.

Early Retirement

When downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no cap when upsizing because the savings are calculated using the lower pre-capacity. For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the above guidance. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, baseline efficiency, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}} \right) \times DF_S \times \frac{1 \text{ kW}}{3,412 \text{ Btu/h}}$$

Equation 36

$$\text{Energy Savings [kWh]} = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}} \right) \times EFLH_C \times \frac{1 \text{ kWh}}{3,412 \text{ Btu}}$$

Equation 37

Where:

$Cap_{C,pre}$	=	For ER and ROB, rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [Btu/h]; 1 ton = 12,000 Btu/h
$Cap_{C,post}$	=	Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btu/h]; 1 ton = 12,000 Btu/h

Note: The capacity in the equations may not always match the capacity of the units. AHRI may rate cooling capacity in kW. In these cases, convert from kW to Btuh by multiplying kW by 3,412.

$\eta_{baseline,C}$ = Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [SCOP for ER, NSenCOP for ROB/NC]

$\eta_{installed,C}$ = Rated cooling efficiency of the newly installed equipment (SCOP)—(Must exceed ROB/NC baseline efficiency standards in Table 78) [NSenCOP]

Note: Use NSenCOP/SCOP for both kW and kWh savings calculations.

DF_S = Summer peak demand factor (see Table 80)

$EFLH_C$ = Cooling equivalent full-load hours [hours] (see Table 80)

Early Retirement Savings

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require weighted savings calculated over both the ER and ROB periods, accounting for both the EUL and RUL. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. This measure is restricted to the data center building types, derived from the EIA CBECS study.¹⁹⁴

The DF and EFLH values for CRAC units are presented in Table 80. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

¹⁹⁴ The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those *buildings greater than 1,000 square feet that devote more than half of their floor space to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type - Large Multifamily – included.*

Table 79. CRACs—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples ¹⁹⁵
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

Table 80. CRACs—DF and EFLH Values

Climate zone	Building type and principal building activity	DF _s	EFLH _c
Climate Zone 1: Amarillo	Data center	0.89	2,048
Climate Zone 2: Dallas		1.08	3,401
Climate Zone 3: Houston		1.05	4,022
Climate Zone 4: Corpus Christi		0.97	4,499
Climate Zone 5: El Paso		0.88	2,547

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below. The reader should refer to the definitions of effective useful life and remaining useful life in the glossary in Volume 1 for guidance on how to determine the decision type for system installations.

Effective Useful Life (EUL)

The EUL for CRACs is 15 years, consistent with the EUL specified for split and packaged air conditioners and heat pumps.¹⁹⁶

¹⁹⁵ Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

¹⁹⁶ The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 81. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL – RUL). The calculations for ER projects are extensive, and as such, are provided in Appendix A.

Table 81. CRACs—Remaining Useful Life Early Retirement Systems^{197,198}

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18 ¹⁹⁹	0.0

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.

- Decision/action type: ER, ROB, NC, system type conversion
- Climate zone
- Baseline number of units

¹⁹⁷ PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹⁹⁸ Existing CRAC systems manufactured after May 28, 2024, are subject to the current federal standard. They are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are grayed out in the table and displayed for informational purposes only.

¹⁹⁹ RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, “Considerations for Early Replacement of Residential Equipment,” for further detail.

- Baseline equipment type
- Baseline equipment rated cooling capacity
- **For ER only:** Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- New manufacturer, model, and manufacturing date
- New number of units
- New equipment type, duct location, and mounting location
- New equipment rated cooling capacity
- New rated cooling efficiency rating (NSenCOP)
- New unit AHRI/DOE CCMS certificate or reference number

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083— Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition include the following:
 - Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, Room Air Conditioners, and chilled water systems.
 - Approved estimates of RUL of working chilled water systems.
 - Updated demand and energy coefficients for all commercial HVAC systems.
 - Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
 - Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for Packaged and Split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.

- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, TX. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a net present value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

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

Document Revision History

Table 82. CRACs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits. Removed text referring to building types other than data centers.
v9.0	10/2021	Updated baseline table citation. Added capacity conversion from kW to Btu/hr.
v10.0	10/2022	No revision.
v11.0	10/2023	Added reference to new standard and plan to incorporate in PY2025.
v12.0	10/2024	Added early retirement criteria related to downsizing, updated early retirement and new construction/ROB baseline efficiency levels.
v13.0	10/2025	No revision.

2.2.6 Computer Room Air Handler Motor Efficiency Measure Overview

TRM Measure ID: NS-HV-CM

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Data centers

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 measure involves improving the operational efficiency of a computer room air handler (CRAH) through the installation of a variable frequency drive (VFD) or electronically commutated motor (ECM). Savings for this measure include fan motor savings resulting from the ability to modulate the fan speed. Any associated cooling energy savings are not captured.

Eligibility Criteria

Eligible equipment includes fan motors and VFDs, 15 horsepower and smaller used to distribute conditioned air throughout a data center.²⁰⁰

Baseline Condition

The CRAH baseline is a conventional AC motor driven, constant speed fan.

High-Efficiency Condition

The high-efficiency condition is the installation of a variable frequency drive (VFD) and/or electronically commutated motor (ECM).

²⁰⁰ The existing associated computer room air conditioning (CRAC) unit condenser and evaporator are expected to remain in place for this measure. If those units are also replaced, reference the CRAC measure TRM entry.

Savings Algorithms and Input Variables

Energy and demand savings are estimated using input assumptions taken from site measured motor kW and operating hours for 243 CRAH units.²⁰¹

Energy Savings Algorithms

$$Energy\ Savings\ [kWh] = \left(kW_{pre} - kW / hp_{post} \times hp_{post} \right) \times hours$$

Equation 38

$$kW_{pre} = 0.746 \times HP_{pre} \times \frac{LF}{\eta}$$

Equation 39

Where:

- HP_{pre}

=

Rated horsepower of the existing motor
- LF

=

Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent at the fan or pump design 100 percent per DEER
- η

=

Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013

Table 83. CRAHs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM²⁰²

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.91
10	0.917
15	0.93

²⁰¹ Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.

²⁰² For unlisted motor horsepower values, round down to the next lowest horsepower value.

<i>0.746</i>	=	<i>Constant to convert from hp to kW</i>
<i>kW/hp_{post}</i>	=	<i>Efficient kW per motor hp²⁰³ = 0.27</i>
<i>hp_{post}</i>	=	<i>Total efficient motor horsepower</i>
<i>hours</i>	=	<i>Annual operating hours = 8,760</i>

Demand Savings Algorithms

$$\text{Peak Demand Savings [kW]} = \frac{\text{Annual Energy Savings (kWh)}}{\text{hours}} \times DF_{S/W}$$

Equation 40

Where:

$$CF_{S/W} = \text{Summer/winter seasonal peak coincidence factor} = 0.11^{204}$$

Deemed Energy and Demand Savings Tables

There are no deemed 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 median estimated useful life (EUL) for premium efficiency motors is 15 years.²⁰⁵

The EUL for HVAC VFD measure is 15 years.

²⁰³ Oncor site data. Average kW/hp values are weighted by measure count.

²⁰⁴ Peak coincidence factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using average hourly kW trends from Oncor site data. Summer and winter CF ranged from 0.10 to 0.12 across all climate zones, and the average value of 0.11 is used as the default input assumption for calculating demand savings.

²⁰⁵ US DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors", Median of "Table 8.2.23 Average Application Lifetime". Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

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.

- Motor quantity, type, horsepower, and control; pre-installation
- Motor quantity, type, horsepower, and control; post-installation
- Climate zone or county

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 84. CRAHs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	No revision.
v10.0	10/2022	Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.2.7 HVAC Variable Frequency Drives Measure Overview

TRM Measure ID: NR-HV-VF

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the installation of a variable frequency drive (VFD) or equivalent motor control in a commercial HVAC application. Eligible applications include:

- AHU supply fan on a split or packaged HVAC system. The fan is in a variable air volume (VAV) system with terminal VAV boxes or constant air volume (CAV) unit with no control device.
- Hot water distribution pumps
- Chilled water distribution and condenser pumps
- Cooling tower fans

This measure does not apply to controls installed on the HVAC compressor. This measure accounts for the interactive air conditioning demand savings during the utility defined summer peak period. The savings are on a per-control basis, and the lookup tables show the total savings for eligible scenarios.

Eligibility Criteria

AHU supply fans may not have variable pitch blades. VFD-controlled motors must be less than or equal to 100 hp. Custom applications are more appropriate for applications above 100 hp.

Equivalent motor controls must vary the speed of AHU fan blades based on environmental sensor readings similar to VFD control of HVAC fans. One example is electrically-commutated motors (ECM's) controlled by a central building automation system.

New construction systems and equipment used for process loads are ineligible.

Baseline Condition

The AHU supply fan baseline is a centrifugal supply fan with a single-speed motor on a direct expansion (DX) VAV or CAV air conditioning (AC) unit. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2013, which are provided by horsepower. The AC unit has standard cooling efficiency based on IECC 2015. The part-load fan control is an outlet damper, inlet damper, inlet guide vane, or no control (constant volume systems).

The HVAC pump baseline is a constant speed pump with a standard-efficiency motor. This measure is applicable to both primary and secondary hot or chilled water pumping systems, as well as chiller condenser pumps.

The cooling tower fan baseline control is either fan cycling or any fan design that enables two-speed operation.

High-Efficiency Condition

The high-efficiency condition is the installation of a VFD on an AHU supply fan, cooling tower fan, condenser water pump, hot water pump, or chilled water pump.

For AHU supply fans, when applicable, the existing damper or inlet guide vane will be removed or set completely open permanently after installation. The VFD or equivalent will maintain the design airflow and/or environmental conditions by adjusting the fan speed based on pressure and other sensor readings.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

For AHUs:

$$\%CFM_i = m \times t_{db,i} + b$$

Equation 41

Where:

$t_{db,i}$	=	<i>The hourly dry bulb temperature (DBT) using TMY3²⁰⁶ data</i>
m	=	<i>The slope of the relationship between DBT and CFM (see Table 85)</i>
b	=	<i>The intercept of the relationship between DSBT and CFM</i>

²⁰⁶ National Renewable Energy Laboratory's (NREL) National Solar Radiation Data Base: 1991- 2005 Update for Typical Meteorological Year 3 (TMY3). Available at <https://sam.nrel.gov/weather-data.html>.

(see Table 85)

The minimum flow rate is set to 60 percent cfm based on common design practice.²⁰⁷ Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.²⁰⁸

Table 85. HVAC VFDs—AHU Supply Fan VFD Percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (<i>m</i>)	Intercept (<i>b</i>)
Climate Zone 1: Amarillo	Flow rate (%cfm)	60	100	1.18	16.92
	Dry bulb T (°F)	65	98.8		
Climate Zone 2: Dallas	Flow rate (%cfm)	60	100	1.10	-11.43
	Dry bulb T (°F)	65	101.4		
Climate Zone 3: Houston	Flow rate (%cfm)	60	100	1.23	19.75
	Dry bulb T (°F)	65	97.6		
Climate Zone 4: Corpus Christi	Flow rate (%cfm)	60	100	1.25	-21.50
	Dry bulb T (°F)	65	96.9		
Climate Zone 5: El Paso	Flow rate (%cfm)	60	100	1.10	11.82
	Dry bulb T (°F)	65	101.2		

For cooling towers:

$$\%CFM_i = m \times t_{wb\_i} + b$$

Equation 42

Where:

t_{wb_i} = the hourly wet bulb temperature (WBT) based on TMY3 data²⁰⁹

m = the slope of the relationship between WBT and cfm (see

²⁰⁷ For AHU, a 60% minimum setpoint strategy is assumed, so any results below 60% are set to 60%. Similarly, any results greater than 100% are set to 100%.

²⁰⁸ ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

²⁰⁹ TMY3 data does not include WBT. WBT was calculated from TMY3 data using the empirical formula from “Wet-bulb temperature from relative humidity and air temperature”, *Journal of Applied Meteorology and Climatology*, <https://doi.org/10.1175/JAMC-D-11-0143.1>.

Table 86)

b = the intercept of the relationship between WBT and cfm (see

Table 86)

Table 86. HVAC VFDs—Cooling Tower VFD Percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (<i>m</i>)	Intercept (<i>b</i>)
Climate Zone 1: Amarillo	Flow rate (%cfm)	40	100	3.98	-184.25
	Wet bulb T (°F)	56.3	71.4		
Climate Zone 2: Dallas	Flow rate (%cfm)	40	100	2.99	-135.13
	Wet bulb T (°F)	58.5	78.6		
Climate Zone 3: Houston	Flow rate (%cfm)	40	100	2.95	-136.58
	Wet bulb T (°F)	59.9	80.2		
Climate Zone 4: Corpus Christi	Flow rate (%cfm)	40	100	2.92	-137.43
	Wet bulb T (°F)	60.8	81.3		
Climate Zone 5: El Paso	Flow rate (%cfm)	40	100	3.31	-130.71
	Wet bulb T (°F)	51.6	69.8		

The minimum flow rate is set to 40 percent cfm based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.²¹⁰ Determination of the minimum WBT assumes that the cooling tower will only operate above the cooling reference temperature of 65°F dry bulb. The minimum WBT is calculated using TMY3 data as the average WBT when the DBT is between 64°F and 65°F dry bulb. The maximum WBT is the ASHRAE wet bulb design temperature.²¹¹

For chilled water and condenser water pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 43

Where:

m = The slope of the relationship between DBT and GPM (see Table 87)

b = The intercept of the relationship between DSBT and GPM (see Table 87)

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.²¹² Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference

²¹⁰ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.240, cooling tower minimum speed default.

²¹¹ ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Evaporation WB

²¹² PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.²¹³

Table 87. HVAC VFDs—Chilled Water and Condenser Water Pumps VFD Percentage of GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (<i>m</i>)	Intercept (<i>b</i>)
Climate Zone 1: Amarillo	Flow rate (%GPM)	10	100	2.66	-163.08
	Dry bulb T (°F)	65	98.8		
Climate Zone 2: Dallas	Flow rate (%GPM)	10	100	2.47	-150.71
	Dry bulb T (°F)	65	101.4		
Climate Zone 3: Houston	Flow rate (%GPM)	10	100	2.77	-169.45
	Dry bulb T (°F)	65	97.6		
Climate Zone 4: Corpus Christi	Flow rate (%GPM)	10	100	2.82	-173.39
	Dry bulb T (°F)	65	96.9		
Climate Zone 5: El Paso	Flow rate (%GPM)	10	100	2.49	-151.60
	Dry bulb T (°F)	65	101.2		

For hot water pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 44

Where:

m = The slope of the relationship between DBT and GPM (see Table 88)

b = The intercept of the relationship between DSBT and GPM (see Table 88)

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.²¹⁴ Determination of the minimum dry bulb temperature assumes that heating will only operate below the heating reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.²¹⁵

²¹³ ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

²¹⁴ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

²¹⁵ ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

Table 88. HVAC VFDs—Hot Water Pump VFD %GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (m)	Intercept (b)
Climate Zone 1: Amarillo	Flow rate (%GPM)	10	100	-1.66	117.93
	Dry bulb T (°F)	65	10.8		
Climate Zone 2: Dallas	Flow rate (%GPM)	10	100	-2.16	150.63
	Dry bulb T (°F)	65	23.4		
Climate Zone 3: Houston	Flow rate (%GPM)	10	100	-2.68	184.11
	Dry bulb T (°F)	65	31.4		
Climate Zone 4: Corpus Christi	Flow rate (%GPM)	10	100	2.96	202.43
	Dry bulb T (°F)	65	34.6		
Climate Zone 5: El Paso	Flow rate (%GPM)	10	100	-2.29	158.86
	Dry bulb T (°F)	65	25.7		

Step 2 - Calculate the percentage of power (%power) for the applicable baseline and the new VFD technology:

Baseline Technologies

For AHU supply fan:²¹⁶

$$\%power_{i,OutletDamper} = 0.00745 \times \%CFM_i^2 + 0.10983 \times \%CFM_i + 20.41905$$

Equation 45

$$\begin{aligned} \%power_{i,InletDamper} \\ = 0.00013 \times \%CFM_i^3 - 0.01452 \times \%CFM_i^2 + 0.71648 \times \%CFM_i + 50.25833 \end{aligned}$$

Equation 46

$$\%power_{i,InletGuideVane} = 0.00009 \times \%CFM_i^3 - 0.00128 \times \%CFM_i^2 + 0.06808 \times \%CFM_i + 20$$

Equation 47

Note: %power for constant volume baseline technologies with no fan control is set equal to 100% for each hour where %power is less than 100% for the other baseline control types. When %power exceeds 100% for the other baseline control types, %power for no fan control is set equal to the maximum value from the other baseline control types.

²¹⁶ https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225. Please note, the CFM² coefficients in Equation 38 and Equation 39 have the wrong sign in the reference document.

For cooling tower:

$$\%power_{i,fan\ cycling} = \text{if } t_{wb\_i} > t_{wb\_min}, \text{ then } 1, \text{ otherwise } 0$$

Equation 48

For chilled, hot, and condenser water pumps²¹⁷:

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

Equation 49

VFD Technology

For AHU supply fan²¹⁸:

$$\%power_{VFD} = 0.00004 \times \%CFM_i^3 + 0.00766 \times \%CFM_i^2 - 0.19567 \times \%CFM_i + 5.9$$

Equation 50

For cooling tower²¹⁹:

$$\text{if } t_{wb\_i} > t_{wb\_min}, \text{ then } \%power_{VFD} = 0.9484823 \times \%CFM_i^3 + 0.60556507 \times \%CFM_i^2 - 0.88567609 \times \%CFM_i + 0.33162901, \text{ otherwise } 0$$

Equation 51

For chilled water, hot water, and condenser pumps²²⁰:

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

Equation 52

Note: for all applications, baseline %power should use a minimum of zero.

Step 3 - Calculate kW_{full} using the hp from the motor nameplate, load factor, and the applicable motor efficiency from ASHRAE 2013, Table 10.8-1 Minimum Nominal Efficiency for General Purpose Electric Motors; Use that result and the %power results to determine power consumption at each hour:

²¹⁷ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

²¹⁸ https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225.

²¹⁹ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 85 Default Efficiency TWR-FAN-PLR Coefficients – VSD on Cooling Tower Fan.

²²⁰ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

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

Equation 53

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

Equation 54

Where:

$\%power_i$	=	Percentage of full load pump power at the i^{th} hour calculated by an equation based on the control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD) ²²¹
kW_{full}	=	Motor power demand operating at the fan design 100 percent CFM or pump design 100 percent GPM
kW_i	=	Fan or Pump real-time power at the i^{th} hour of a year
HP	=	Rated horsepower of the motor
LF	=	Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent
η	=	Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013
0.746	=	Constant to convert from HP to kW

Table 89. HVAC VFDs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM²²²

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.91
10	0.917
15	0.93
20	0.93
25	0.936
30	0.941

²²¹ Fan curves by control type are provided in the BPA ASD Calculator, <https://www.bpa.gov/-/media/Aep/energy-efficiency/industrial/Industrial-files/ASDCalculators>.

²²² For unlisted motor horsepower values, round down to the next lowest horsepower value.

Motor horsepower	Full load efficiency
40	0.941
50	0.945
60	0.95
75	0.95
100	0.954

Step 4 - Calculate the kW savings for each of the top 20 hours (excluding weekends, assuming a calendar year of 2026) within the applicable peak probability analysis for the building's climate zone from Volume 1. Sum the kW savings for each hour multiplied by the peak demand probability factor from the 20 individual hourly calculations, then divide by the sum of the PDPF for the 20 hours to get the average peak demand impact, and then calculate the total peak demand saved by adding peak demand interactive effects:

Hourly Savings Calculations

$$(kW_i)_{Saved} = [(kW_i)_{Baseline} - (kW_i)_{VFD}]$$

Equation 55

Average Peak Demand Saved Calculation, excluding interactive effects

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

Equation 56

Where:

$$PDPF_i = \text{Peak demand probability factor from the applicable climate zone table in Volume 1}$$

Total Peak Demand Saved Calculation, including interactive effects. This applies only to AHU supply fans during summer cooling. Total peak demand savings for pumps are found using Equation 56 above:

$$kW_{TotalSaved} = kW_{PDPF,Saved} \times \left(1 + \frac{3.412}{Cooling_{EER}}\right)$$

Equation 57

Where:

$$Cooling_{EER} = \text{Air conditioner full-load cooling efficiency, assumed at 11.2, based on IECC 2015 minimum efficiency of a unitary AC system between 5 and 11.3 tons}$$

Energy Savings are calculated in the following manner:

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

$$\text{Energy Savings [kWh]} = \sum_{i=1}^{8,760} (kW_i \times \text{schedule}_i)$$

Equation 58

Where:

8,760 = Total of hours per year

schedule_i = 1 when building is occupied, 0.2 when building is unoccupied (see Table 90).

Table 90. HVAC VFDs—Yearly Motor Operation Hours by Building Type^{223,224}

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Assembly, worship	9am–11pm	9am–11pm	5,840
Convenience store, service, strip mall	9am–10pm	9am–8pm (Saturday) 10am–7pm (Sunday)	5,298
Education	8am–11pm	closed	4,884
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	24-hr	24-hr	8,760
Office—large, medium	7am–11pm	7am–7pm (Saturday)	5,592
Office—small	7am–8pm	closed	4,466
Restaurants	6am–2am	6am–2am	7,592
Stand-alone retail, supermarket	8am–10pm	8am–11pm (Saturday) 10am–7pm (Sunday)	5,674
Warehouse	7am–7pm	closed	4,258

²²³ Hours for all building types except for Assembly come from the Department of Energy Commercial Building Prototype Models, Scorecards, HVAC Operation Schedule. Motor hours are set to equal 1 when the HVAC Operation Schedule is “on” and 0.2 when the HVAC Operation Schedule is “off.” https://www.energycodes.gov/development/commercial/prototype_models. Assembly occupied hours come from COMNET Appendix C—Schedules (Rev 3) <https://comnet.org/appendix-c-schedules>, updated 07/25/2016.

²²⁴ Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Other ²²⁵	7am–7pm	closed	4,258

Step 2 - Subtract the Annual kWh_{new} from the Annual kWh_{baseline} to get the Energy Savings:

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

Equation 59

The deemed energy savings below utilize an hourly model with TMY3 data and assigning weekends and weekdays based on the 2026 calendar year.

Deemed Energy and Demand Savings Tables²²⁶

Table 91. HVAC VFDs—AHU Supply Fan Outlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	751	707	684	668	720
Convenience store, service, strip mall	671	631	609	594	643
Education	631	594	575	563	606
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,160	1,101	1,071	1,047	1,122
Office—large, medium	723	681	659	643	695
Office—small	573	541	521	509	553
Restaurants	995	941	913	892	959
Stand-alone retail, supermarket	728	685	661	645	698
Warehouse	546	515	495	483	526
Other	546	515	495	483	526
Summer kW savings (kW per motor HP)					
All building types	0.047	0.021	0.008	0.056	0.042
Winter kW savings (kW per motor HP)					
All building types	0.143				

²²⁵ The *other* building type may be used when none of the listed building types apply. The values used for Other are the most conservative of the listed building types.

²²⁶ Data centers are covered in Section 2.2.6 Computer Room Air Handler Motor Efficiency.

Table 92. HVAC VFDs—AHU Supply Fan Inlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	1,164	1,057	1,003	961	1,086
Convenience store, service, strip mall	1,038	942	889	853	968
Education	979	891	846	815	916
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,825	1,672	1,598	1,535	1,723
Office—large, medium	1,124	1,021	966	928	1,052
Office—small	889	809	762	733	835
Restaurants	1,556	1,420	1,352	1,298	1,462
Stand-alone retail, supermarket	1,127	1,024	967	927	1,052
Warehouse	846	770	723	695	795
Other	846	770	723	695	795
Summer kW Savings (kW per Motor HP)					
All building types	0.052	0.023	0.009	0.061	0.047
Winter kW savings (kW per motor HP)					
All building types	0.235				

Table 93. HVAC VFDs—AHU Supply Fan Inlet Guide Vane Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	245	216	201	189	223
Convenience store, service, strip mall	218	192	177	168	198
Education	206	182	170	161	189
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388	345	325	307	359
Office—large, medium	237	209	193	183	217

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Office—small	187	165	152	144	172
Restaurants	329	292	273	258	303
Stand-alone retail, supermarket	237	209	193	182	216
Warehouse	178	157	144	137	164
Other	178	157	144	137	164
Summer kW savings (kW per motor HP)					
All building types	0.010	0.006	0.002	0.011	0.012
Winter kW savings (kW per motor HP)					
All building types	0.052				

Table 94. HVAC VFDs—AHU Supply Fan No Control Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	2,106	1,916	1,819	1,745	1,969
Convenience store, service, strip mall	1,877	1,705	1,612	1,546	1,753
Education	1,772	1,615	1,535	1,479	1,662
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	3,302	3,034	2,905	2,794	3,125
Office—large, medium	2,033	1,852	1,754	1,686	1,908
Office—small	1,608	1,466	1,383	1,330	1,514
Restaurants	2,817	2,577	2,457	2,360	2,651
Stand-alone retail, supermarket	2,040	1,855	1,754	1,681	1,908
Warehouse	1,530	1,395	1,312	1,260	1,441
Other	1,530	1,395	1,312	1,260	1,441
Summer kW savings (kW per motor HP)					
All building types	0.047	0.009	0.004	0.067	0.026
Winter kW savings (kW per motor HP)					
All building types	0.423				

Table 95. HVAC VFDs—Cooling Tower Fans Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	736	1,023	1,270	1,385	946
Convenience store, service, strip mall	664	918	1,142	1,248	851
Education	628	820	1,053	1,140	800
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,124	1,528	1,883	2,070	1,389
Office—large, medium	708	973	1,203	1,325	898
Office—small	568	764	953	1,059	728
Restaurants	968	1,325	1,635	1,790	1,219
Stand-alone retail, supermarket	713	992	1,229	1,346	920
Warehouse	541	726	904	1,007	692
Other	541	726	904	1,007	692
Summer kW savings (kW per motor HP)					
All building types	0.087	0.010	0.082	0.149	0.164

Table 96. HVAC VFDs—Chilled Water Pump Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	601	818	933	1,011	773
Convenience store, service, strip mall	550	741	848	908	700
Education	499	664	765	830	640
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	778	1,154	1,339	1,482	1,050
Office—large, medium	560	776	900	963	728
Office—small	452	616	718	768	578
Restaurants	723	1,030	1,183	1,297	960
Stand-alone retail, supermarket	587	796	913	981	753

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Warehouse	430	586	682	731	551
Other	430	586	682	731	551
Summer kW savings (kW per motor HP)					
All building types	0.060	0.021	0.008	0.076	0.045

Table 97. HVAC VFDs—Hot Water Pump Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	791	544	426	351	630
Convenience store, service, strip mall	698	478	369	304	556
Education	669	467	369	308	538
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,298	912	721	610	1,038
Office—large, medium	769	528	409	342	613
Office—small	605	417	321	266	486
Restaurants	1,086	756	598	500	863
Stand-alone retail, supermarket	764	525	406	333	608
Warehouse	575	396	303	251	460
Other	575	396	303	251	460
Winter kW savings (kW per motor HP)					
All building types	0.069	0.014	0.009	0.055	0.233

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.²²⁷

²²⁷ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

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
- Application type (AHU supply fan, hot water pump, chilled water pump, cooling tower fans)
- Climate zone or county
- Motor horsepower
- Drive type: variable speed drive or equivalent control
- **For equivalent control only:** Motor and sensor control type (e.g. ECM motor with BAS control) and description of control variables.
- **For AHU supply fans only:** Baseline part-load control type (e.g., outlet damper, inlet damper, inlet guide vane, constant volume/no control).

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for VFD equipment
- PUCT Docket 40668—Provides details on deemed savings calculations for VFDs.

Relevant Standards and Reference Sources

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

Document Revision History

Table 98. HVAC VFDs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	Corrected ASHRAE 0.4 percent Dry Bulb Design Temperature references for three climate zone reference cities: DFW, El Paso, and Houston. Updated Valley climate zone reference city to Corpus Christi to be consistent with TRM guidance. Corrected Motor Load Factor to 75 percent.
v4.0	10/10/2016	Added reference for percent power and corrected signs for variables in Equation 50.
v5.0	10/2017	Updated deemed energy/demand tables for revised peak demand definition.

TRM version	Date	Description of change
v6.0	10/2018	Added no control device option for constant volume systems. Corrected error in previous kW and kWh deemed savings calculations for Outlet Damper baseline control.
v7.0	10/2019	Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
v8.0	10/2020	General reference checks and text edits. Added motor efficiency default assumptions.
v9.0	10/2021	Expanded eligible building types and updated occupancy schedules.
v10.0	10/2022	Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	Added cooling tower fan and condenser water pump applications. Updated maximum temperatures for linear regression equations to correspond with ASHRAE design conditions. Aligned building type names across all commercial measures.
v12.0	10/2024	Savings calculations moved to Excel. Reviewed hours of operation and using same fan and pump hours referenced in the existing measure.
v13.0	10/2025	Added an equivalent option for alternate motor control systems that react to environmental sensors. Added winter kW savings for all applications, and updated summer kW savings to align with Volume 1 updates. Adjusted model year parameters.

2.2.8 Condenser Air Evaporative Pre-Cooling Measure Overview

TRM Measure ID: NR-HV-EP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of an evaporative pre-cooling system onto HVAC equipment. This process reduces the temperature of the outside air before it is used to cool the condenser coil for direct expansion (DX) units or air-cooled chillers. The temperature reduction is achieved by having the incoming air pass through a saturated media or mist wall, which will increase the humidity ratio under adiabatic conditions. This allows the dry bulb temperature to decrease while the wet bulb temperature remains constant, effectively increasing the heat rejection capacity from the condenser coils into the air. This measure is not applicable to the replacement of an air-cooled condenser with an evaporative condenser.

Applicable evaporative pre-cooling product types include:

- Evaporative media panels that incoming air must pass through
- Misting based system that sprays fine droplets into the air in front of the air intake area.

Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- Must have chemical or mechanical water treatment
 - Must have periodic purge control for sump-based systems
- Must have a control system for operation
 - Minimum temperature controls for sump-based systems
 - Minimum enthalpy controls for mist-based systems
- All air to condenser coils must pass through the evaporative pre-cooling system
- Systems must be installed by a qualified contractor and must be commissioned

- Evaporative effectiveness performance of greater than or equal to 0.75 (i.e., 75 percent) for average dry bulb temperature and humidity during peak hours
- Operation manuals must be provided
- If these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Baseline Condition

The baseline conditions are the operation of a direct expansion (DX) unit or air-cooled chiller without evaporative pre-cooling.

High-Efficiency Condition

Evaporative pre-cooling systems must exceed the evaporative effectiveness performance of 75 percent for average dry bulb temperature humidity during peak hours. Table 99 contains values that can be used as a reference for evaluating evaporative effectiveness.

Table 99. Evaporative Pre-Cooling—Average Weather During Peak Conditions²²⁸

Climate zone	Temperature (°F)	Humidity (%)
Climate Zone 1: Amarillo	95.8	25
Climate Zone 2: Dallas	101.2	34
Climate Zone 3: Houston	99.1	37
Climate Zone 4: Corpus Christi	92.5	49
Climate Zone 5: El Paso	97.4	15

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Energy\ Savings\ [kWh] = (Cap_C \times \eta_C) \times EFLH_{red}$$

Equation 60

$$Peak\ Demand\ Savings\ [kW] = (Cap_C \times \eta_C) \times CF$$

Equation 61

²²⁸ Extracted from weather data from building models that were used to create summer peak period value used for this measure.

Where:

Cap_c = Rated equipment cooling capacity of the existing equipment at AHRI-standard conditions [tons]; 1 ton = 12,000 Btuh

η_c = Cooling efficiency of existing equipment [kW/ton]

Note: For DX systems, use EER for kW savings calculations and SEER/IEER for kWh savings calculations. For air-cooled chillers, use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. In the cases where the full-load efficiency is provided in terms of EER or SEER/IEER rather than kW/ton and IPLV, a unit conversion to kW/ton needs to be performed using the following conversion:

$$\frac{kW}{Ton} = \frac{12}{EER}$$

Equation 62

$EFLH_{red}$ = Annual cooling energy reduction divided by the rated full loaded demand. Annual cooling energy reduction is determined according to the same method as other HVAC coefficients contained in the TRM. Rated full loaded demand is the Cap_c divided by its rated full load efficiency (see Table 100 through Table 104)

CF = Seasonal peak coincidence factor. The average peak hour energy reduction divided by the rated full loaded demand (see Table 100 through Table 104)

Deemed Energy and Demand Savings Tables

The CF and $EFLH_{red}$ values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 33. These building types are derived from the EIA CBECS study.²²⁹

The CF and $EFLH_{red}$ values for packaged and split AC are presented in Table 100 through Table 104. These tables also include an *other* building type, which can be used for business types that are not explicitly listed. The CF and $EFLH_{red}$ values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

²²⁹ The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines Commercial buildings as those *buildings greater than 1,000 square feet that devote more than half of their floor space to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type—Large Multifamily—included.*

Deemed savings are estimated using building simulation models, which estimate the hourly impacts of installing an evaporative pre-cooling system (i.e., modeling the difference between base and change case). The base models are the same models used to derive values for the other commercial HVAC sections of the TRM. Adjustments are made for the evaporative pre-cooling measure by updating all existing HVAC equipment to operate with evaporative pre-cooling when the outside temperature is above 70°F.

Table 100. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 1: Amarillo

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Education	College/university	0.19	130	0.17	150
	Primary school	0.20	83	0.13	69
	Secondary school	0.19	89	0.17	102
Food sales	Convenience store	0.18	125	-	-
	Supermarket	0.08	37	-	-
Food service	Full-service restaurant	0.21	134	-	-
	Quick-service restaurant	0.18	109	-	-
Healthcare	Inpatient	0.21	160	0.18	151
	Outpatient	0.17	145	-	-
Large multifamily	Midrise apartment	0.18	113	0.10	59
Lodging	Large hotel	0.13	111	0.15	165
	Nursing home	0.18	115	0.10	60
	Small hotel/motel	0.13	104	-	-
Mercantile	Stand-alone retail	0.19	108	0.14	74
	Strip mall	0.21	121	-	-
Office	Large office	0.25	206	0.18	119
	Medium office	0.19	75	-	-
	Small office	0.20	111	-	-
Public assembly	Public assembly	0.20	112	0.13	93
Religious worship	Religious worship	0.19	65	0.14	45
Service	Service: Excluding food	0.21	104	-	-
Warehouse	Warehouse	0.12	34	-	-
Other	Other	0.08	34	0.10	45

Table 101. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 2: Dallas

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Education	College/university	0.21	192	0.19	195
	Primary school	0.24	120	0.12	80
	Secondary school	0.21	131	0.19	132
Food sales	Convenience store	0.24	214	-	-
	Supermarket	0.15	78	-	-
Food service	Full-service restaurant	0.23	194	-	-
	Quick-service restaurant	0.24	185	-	-
Healthcare	Inpatient	0.24	230	0.22	216
	Outpatient	0.19	174	-	-
Large multifamily	Midrise apartment	0.16	230	0.15	120
Lodging	Large hotel	0.15	137	0.18	212
	Nursing home	0.16	234	0.15	122
	Small hotel/motel	0.15	133	-	-
Mercantile	Stand-alone retail	0.24	158	0.19	120
	Strip mall	0.23	156	-	-
Office	Large office	0.26	220	0.23	231
	Medium office	0.20	102	-	-
	Small office	0.22	156	-	-
Public assembly	Public assembly	0.24	161	0.12	108
Religious worship	Religious worship	0.24	95	0.19	72
Service	Service: Excluding food	0.23	150	-	-
Warehouse	Warehouse	0.20	93	-	-
Other	Other	0.15	78	0.12	72

Table 102. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 3: Houston

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Education	College/university	0.20	173	0.17	175
	Primary school	0.21	118	0.10	74
	Secondary school	0.20	118	0.17	119

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Food sales	Convenience store	0.22	193	-	-
	Supermarket	0.14	76	-	-
Food service	Full-service restaurant	0.21	171	-	-
	Quick-service restaurant	0.22	167	-	-
Healthcare	Inpatient	0.21	202	0.19	187
	Outpatient	0.18	157	-	-
Large multifamily	Midrise apartment	0.17	257	0.14	105
Lodging	Large hotel	0.14	120	0.14	193
	Nursing home	0.17	261	0.14	107
	Small hotel/motel	0.13	113	-	-
Mercantile	Stand-alone retail	0.22	152	0.19	128
	Strip mall	0.21	152	-	-
Office	Large office	0.24	203	0.23	150
	Medium office	0.19	94	-	-
	Small office	0.20	138	-	-
Public assembly	Public assembly	0.21	159	0.10	99
Religious worship	Religious worship	0.22	92	0.19	77
Service	Service: Excluding food	0.21	132	-	-
Warehouse	Warehouse	0.18	81	-	-
Other	Other	0.13	76	0.10	74

Table 103. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Education	College/university	0.13	161	0.11	160
	Primary school	0.14	113	0.07	68
	Secondary school	0.13	110	0.11	109
Food sales	Convenience store	0.14	188	-	-
	Supermarket	0.08	74	-	-
Food service	Full-service restaurant	0.13	157	-	-

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
	Quick-service restaurant	0.14	162	-	-
Healthcare	Inpatient	0.15	199	0.09	169
	Outpatient	0.12	150	-	-
Large multifamily	Midrise apartment	0.14	181	0.09	104
Lodging	Large hotel	0.08	116	0.10	179
	Nursing home	0.14	183	0.09	106
	Small hotel/motel	0.08	109	-	-
Mercantile	Stand-alone retail	0.14	148	0.12	120
	Strip mall	0.13	146	-	-
Office	Large office	0.16	192	0.13	137
	Medium office	0.11	90	-	-
	Small office	0.13	131	-	-
Public assembly	Public assembly	0.14	152	0.07	92
Religious worship	Religious worship	0.14	89	0.12	72
Service	Service: Excluding food	0.13	122	-	-
Warehouse	Warehouse	0.12	74	-	-
Other	Other	0.08	74	0.07	68

Table 104. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 5: El Paso

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Education	College/university	0.27	240	0.22	254
	Primary school	0.30	161	0.17	120
	Secondary school	0.27	163	0.22	172
Food sales	Convenience store	0.25	232	-	-
	Supermarket	0.12	76	-	-
Food service	Full-service restaurant	0.25	223	-	-
	Quick-service restaurant	0.25	201	-	-
Healthcare	Inpatient	0.26	273	0.20	247
	Outpatient	0.23	259	-	-

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH _{red}	CF	EFLH _{red}
Large multifamily	Midrise apartment	0.28	264	0.15	140
Lodging	Large hotel	0.19	201	0.19	300
	Nursing home	0.28	268	0.15	142
	Small hotel/motel	0.17	193	-	-
Mercantile	Stand-alone retail	0.25	198	0.18	131
	Strip mall	0.26	207	-	-
Office	Large office	0.32	314	0.22	199
	Medium office	0.25	137	-	-
	Small office	0.26	215	-	-
Public assembly	Public assembly	0.30	217	0.17	162
Religious worship	Religious worship	0.25	119	0.18	79
Service	Service: Excluding food	0.25	173	-	-
Warehouse	Warehouse	0.25	82	-	-
Other	Other	0.12	76	0.15	79

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

Pre-cooling components may consist of pumps, sprayers, electronic controllers, and evaporative media, with the evaporative media requiring periodic replacement.

The estimated useful life (EUL) for an evaporative pre-cooling system is 10 years, consistent with the typical manufacturer warranty for evaporative pre-cooling equipment.²³⁰

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.

- Decision/action type: Retrofit or new construction

²³⁰ ET13SCE1020: Evaporative Condenser Air Pre-Coolers, Southern California Edison. December 2015. https://wcec.ucdavis.edu/wp-content/uploads/2016/06/et13sce1020_evaporative_pre-cooler_final.pdf.

- Climate zone or county
- Building type
- Baseline equipment type
- Baseline equipment rated cooling capacity
- Baseline equipment cooling efficiency ratings
- Baseline number of units
- Baseline manufacturer and model
- Installed number of units
- Installed evaporative pre-cooling system manufacturer and model
- Installed evaporative pre-cooling system evaporative effectiveness
- Copy of operation manuals
- **For Other building types only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 47612—Provides deemed savings for Condenser Evaporative Pre-cooling

Relevant Standards and Reference Sources

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

Document Revision History

Table 105. Evaporative Pre-Cooling—Revision History

TRM version	Date	Description of change
v5.0	10/2017	Measure origin.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Specified that formulas use tons and kW/ton values and added conversion factors from other units.
v10.0	10/2022	No revision.
v11.0	10/2023	Aligned building type names across all commercial measures.
v12.0	10/2024	Minor text edits.

TRM version	Date	Description of change
v13.0	10/2025	No revision.

2.2.9 High-Volume Low-Speed Fans Measure Overview

TRM Measure ID: NR-HV-HF

Market Sector: Commercial

Measure Category: HVAC

Applicable Business Types: All commercial, agriculture

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Circulation fans are used in agricultural applications such as dairy, swine, or poultry barns to destratify air, reduce animal heat stress, control insects, dry surfaces, and cool people and animals. This measure applies to the installation of high-volume low-speed (HVLS) fans in a horizontal orientation in such agricultural applications. HVLS fans may be installed in lieu of conventional (small diameter) circulation fans in new construction applications or in replacement of existing (still functioning) conventional circulation fans in retrofit projects.

Deemed savings are provided for displaced fan load only: applications in which HVLS fans are installed to reduce air conditioning requirements may be considered in the future: for now, such applications would require additional M&V to demonstrate (and claim) complete savings.

Eligibility Criteria

This measure applies to HVLS fans installed in any nonresidential application. Use the *other* building type for anything not explicitly listed in Table 107 and Table 108.

HVLS fans may be used to replace existing conventional circulating fans or installed in new barns. To claim savings for a retrofit, the conventional fans being replaced should be in proper working condition.

Default values are provided for dairy applications while other facility types are eligible and should use the dairy values until other livestock specific factors are developed.

Baseline Condition

The baseline condition is an installation of conventional fans.

Retrofit (Early Retirement)

When replacing existing (working) fans, the baseline is set by the number of fans to be replaced, with power requirements calculated according to their operating airflow rates (CFM), and rated efficiency (e.g., CFM/watt).

Replace on Burnout/New Construction

When existing fans are reaching the end of their useful life, or for new construction, the baseline assumes installation of conventional fans that would produce a comparable total airflow (CFM) as the HVLS fan to be installed.

High-Efficiency Condition

HVLS fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 50,000 CFM and 150,000 or more CFM.²³¹ To be eligible for this measure, HVLS fans shall be a minimum of 8 feet in diameter and move more cubic feet of air per watt than conventional circulating fans. The fan should be installed in a horizontal orientation and have the ability to operate at different speeds.

The current federal standard²³² requires that all ceiling fans manufactured on or after January 21, 2020, must comply with the minimum requirements in Table 106.

Table 106. HVLS Fans—Circulating Fan Minimum Efficiency Requirements

Fan type	η_{base} (CFM/W)	η_{base} (CFEI) ²³³
Standard	$0.65 \times D + 38.03$	—
Large-diameter ²³⁴	—	1.00 (high speed)
		1.31 (40% speed)

²³¹ Motor hp from manufacturer product specification sheets available from <https://macroairfans.com/downloads/> and <https://www.bigassfans.com/aedownloads/>. Airflow range from Kammel et al, “Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns,” available at https://www.researchgate.net/publication/271433461_Design_of_high_volume_low_speed_fan_supplemental_cooling_system_in_dairy_freestall_barns, and from MacroAir Fans “Horse Barn Ventilation Systems” white paper, available at <http://www.ergingreentech.com/pdf/MacroAir/Horseventilationwhitepaper.pdf>.

²³² Current federal standard for ceiling fans. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32>.

²³³ CFEI is a ratio of the input power of a baseline reference fan divided by the input power of the rated fan.

²³⁴ *Large-diameter ceiling fan* means a ceiling fan that is not a highly-decorative ceiling fan or belt-driven ceiling fan and has a represented value of blade span, as determined in [10 CFR 429.32\(a\)\(3\)\(i\)](https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20U%20to%20Subpart%20B%20of%20Part%20430), greater than seven feet. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20U%20to%20Subpart%20B%20of%20Part%20430>.

The efficiency of the baseline conventional fans used in agricultural applications is assumed to be 22 CFM/W.²³⁵

Energy and Demand Savings Methodology

Savings are estimated assuming operation of the baseline (conventional) and high efficiency (HVLS) fans at their rated speed and power input during all hours of expected use.

Savings Algorithms and Input Variables

For agricultural applications and all other fans with efficiency rated in CFM/W:

$$W_{base} = \frac{CFM_{HVLS}}{\eta_{base}}$$

Equation 63

$$Energy\ Savings[\Delta kWh] = \left(\frac{W_{base} - W_{HVLS}}{1,000} \right) \times AOH$$

Equation 64

$$Peak\ Demand\ Savings\ [\Delta kW] = \left(\frac{W_{base} - W_{HVLS}}{1,000} \right) \times CF_S$$

Equation 65

Other fans with efficiency rated in CFEI:

$$Energy\ Savings[\Delta kWh] = \frac{W_{HVLS}}{1,000} \times (CFEI_{HVLS,HS} - 1) \times AOH$$

Equation 66

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{W_{HVLS}}{1,000} \times (CFEI_{HVLS,HS} - 1) \times CF_S$$

Equation 67

Where:

W_{base}	=	Power input required to move replaced fans at rated speed (see Equation 63)
W_{HVLS}	=	Power input required to move installed HVLS fans at rated speed
CFM_{HVLS}	=	Airflow rate produced by installed HVLS fans

²³⁵ Database of circulating fans tested by the Bioenvironmental and Structural Systems Laboratory of the Agricultural and Biological Engineering Dept., University of Illinois at Urbana-Champaign, including 231 fan models by 17 manufacturers. Average efficacy ratio (CFM/watt) of single-phase, 230 V circulating fans 48" diameter and larger. Available at <http://www.bess.illinois.edu/currentc.asp>.

η_{base}	=	Baseline fan efficiency [CFM/W] = 22 for agricultural applications; see Table 106 for all other applications
$CFEI_{HVLS,HS}$	=	HVLS fan rated efficiency at high speed [CFEI] ²³⁶
AOH	=	Annual operating hours (see Table 107)
CF_s	=	Summer peak coincidence factor (see Table 108)
1,000	=	Constant to convert from W to kW

Table 107. HVLS Fans—Circulating Fan Annual Operating Hours²³⁷

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture ²³⁸	2,215	3,969	4,750	5,375	3,034
Food service: Full-service restaurant					4,368
Manufacturing: 1 shift (<70hr/week)					2,786
Manufacturing: 2 shift (70-120 hr/week)					5,188
Manufacturing: 3 shift (>120 hr/week)					6,414
Warehouse					3,501
Other					2,638

Table 108. HVLS Fans—Circulating Fan Coincident Factors^{239,240}

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture					1.00
Food service: Full-service restaurant					0.90
Manufacturing: 1 shift (<70hr/week)	0.83	0.84	0.83	0.85	0.85

²³⁶ US DOE Compliance Certification Management System (CCMS) Ceiling Fan product listing. https://www.regulations.doe.gov/certification-data/CCMS-4-Ceiling_Fans.html#q=Product_Group_s%3A%22Ceiling%20Fans%22.

²³⁷ AOH for non-agricultural applications are based on assumptions from measure 2.1.1 *Lamps and Fixtures* based on the assumption that fan operation will coincide with lighting operation.

²³⁸ Docket No. 40885 provides demand and energy savings by building type and cooling equipment for the four different climate zones. This original petition was dated October 29, 2012. An amended petition dated November 13, 2012, was approved, which provides the original energy and demand coefficients (Table 2 18: CF and EFLH Values for Amarillo (Climate Zone 1) through Table 2-16, but also amended Tables (B3a through B3d and B4a through B4d).

²³⁹ Summer CFs for agricultural applications assume continuous operation during peak conditions.

²⁴⁰ Summer CFs for non-agricultural applications are based on assumptions from measure 2.1.1 *Lamps and Fixtures* based on the assumption that fan operation will coincide with lighting operation.

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Manufacturing: 2 shift (70-120 hr/week)					0.85
Manufacturing: 3 shift (>120 hr/week)					
Warehouse	0.79	0.81	0.79	0.80	0.85
Other					0.65

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters.

Measure Life and Lifetime Savings

The EUL of an HVLS fan is closely related to that of its motor. The US DOE Advanced Manufacturing Office's Motor Systems Tip Sheet #3²⁴¹ suggests motors should last approximately 35,000 hours. Based on the average annual operations across the available building types, the EUL for HVLS fans is estimated to be nine years.

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.

All Projects:

- Climate zone or county
- Decision/action type: Retrofit or NC
- Building type (specify if other)
- **For agricultural only:** Barn type (animal)
- HVLS fan(s): quantity, diameter, rated HP, rated CFM, rated efficiency
- Fan operating hours (customer-reported estimated)

²⁴¹ DOE Motor Systems Tip Sheet #3 available at https://www.energy.gov/sites/prod/files/2014/04/f15/extend_motor_operlife_motor_systemts3.pdf.

- Screenshot of CCMS product listing
- Proof of purchase (e.g., invoice showing model number and quantity)

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 109. HVLS Fans—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	No revision.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	Expanded measure to apply to non-agricultural end uses. Incorporated new efficiency metric for large-diameter fans.
v13.0	10/2025	Corrected typos and clarified units in algorithm.

2.2.10 Small Commercial Evaporative Cooling Measure Overview

TRM Measure ID: NR-HV-EC

Market Sector: Small Commercial

Measure Category: HVAC

Applicable Building Types: Small commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of direct evaporative coolers instead of refrigerated air conditioning systems in small commercial applications. This measure applies to both retrofit and new construction applications.

Eligibility Criteria

Direct evaporative cooling must be the primary whole-building cooling source. Installed systems must have a saturation efficiency of 0.85 or greater. Portable, window, indirect, and hybrid systems are not eligible.

Baseline Condition

The baseline conditions related to efficiency and system capacity for replace-on-burnout and new construction are as follows:

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for packaged DX air conditioners < 65,000 Btuh are provided in Table 32. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.

Table 110. Evaporative Cooling—NC/ROB Baseline Efficiency Levels for DX AC²⁴²

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source ²⁴³
Packaged air conditioner	< 5.4	All	11.8 EER ²⁴⁴ 14.0 SEER	DOE Standards/ IECC 2015

High-Efficiency Condition

The high-efficiency condition is a direct evaporative cooling system(s) with a saturation efficiency of at least 0.85.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = Cap_C \times \frac{1}{\eta_{baseline,C}} \times DF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times CRF$$

Equation 68

$$\text{Energy Savings [kWh]} = Cap_C \times \frac{1}{\eta_{baseline,C}} \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times CRF$$

Equation 69

Where:

- Cap_C = Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh²⁴⁵; 1 ton = 12,000 Btuh
- $\eta_{baseline,C}$ = Cooling efficiency of standard equipment (ROB/NC) [Btuh/W] (see Table 32)
- Note: Use EER for kW savings calculations and SEER for kWh savings calculations.*
- CF_S = Summer peak coincidence factor (see Table 39)
- $EFLH_C$ = Cooling equivalent full-load hours [hours] (see Table 39)
- CRF = Consumption reduction factor²⁴⁶ = 75%

²⁴² IECC 2015 Table C403.2.3(1) and C403.2.3(2).

²⁴³ These baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 431.97. <http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf>.

²⁴⁴ IECC 2015 Table C403.2.3(1) and C403.2.3(2).

²⁴⁵ New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.

²⁴⁶ Department of Energy, <https://www.energy.gov/energysaver/evaporative-coolers>.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values match those previously defined for commercial direct expansion (DX) HVAC measures. See Section 2.2.2, Split and Packaged Air Conditioners and Heat Pumps Measure Overview.

This measure is restricted to climate zone 5.

Table 111. Evaporative Cooling—CF and EFLH Values for Climate Zone 5: El Paso

Building type	Principal building activity	DX AC	
		CF _s	EFLH _c
Data center	Data center	0.88	2,547
Education	College/university	0.87	1,092
	Primary school	0.91	996
	Secondary school	0.87	742
Food sales	Convenience store	0.76	1,251
	Supermarket	0.38	347
Food service	Full-service restaurant	0.76	1,276
	24-hour full-service restaurant	0.74	1,413
	Quick-service restaurant	0.76	1,082
	24-hour quick-service restaurant	0.77	1,171
Healthcare	Inpatient	0.81	2,555
	Outpatient	0.81	2,377
Large multifamily	Midrise apartment	0.88	1,209
Lodging	Large hotel	0.63	1,701
	Nursing home	0.88	1,228
	Small hotel/motel	0.63	1,921
Mercantile	Stand-alone retail	0.80	904
	24-hour retail	0.86	1,228
	Strip mall	0.83	931
Office	Large office	0.98	2,423
	Medium office	0.77	1,173
	Small office	0.84	1,037

Building type	Principal building activity	DX AC	
		CF _s	EFLH _c
Public assembly	Public assembly	0.91	1,339
Religious worship	Religious worship	0.63	478
Service	Service: Excluding food	0.76	988
Warehouse	Warehouse	0.75	324
Other	Other	0.38	324

Claimed Peak Demand Savings

A summer peak period value is used for this measure. 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 HV-EvapCool.²⁴⁷

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.

- Climate zone or county
- Decision/action type: ROB or NC
- Building type
- Baseline number of units
- Baseline rated cooling capacity (CFM)
- Installed number of units
- Installed equipment cooling capacity (CFM)
- Installed manufacturer and model
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach

²⁴⁷ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC-specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building types only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

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 112. Evaporative Cooling—Revision History

TRM version	Date	Description of change
v9.0	10/2021	Measure origin.
v10.0	10/2022	No revision.
v11.0	10/2023	Aligned building type names across all commercial measures.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.2.11 Small Commercial Smart Thermostats Measure Overview

TRM Measure ID: NR-HV-ST

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Small commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of a smart thermostat in small commercial applications.

Eligibility Criteria

All commercial customers with refrigerated air conditioning are eligible to claim cooling savings for this measure. Customers must have electric central heating (either an electric resistance furnace or a heat pump) to claim heating savings.

The thermostat must control a single-zone direct expansion (DX) split or packaged air conditioner (AC) or heat pump (HP) limited to 10 tons (120,000 Btu/hr) or lower.

Customers should be advised against using the emergency heat (EM HEAT) setting on HP thermostats; this setting is meant only for use in emergency situations when the HP is damaged or malfunctioning. Supplemental heating automatically kicks on in below-freezing conditions using the regular HEAT setting. Contractors installing a new HP thermostat with equipment install shall advise customer of correct thermostat usage.

No demand savings should be claimed if the customer is participating in a utility load management program offering.

Baseline Condition

The baseline condition for retrofit applications is a manual or programmable thermostat. The baseline condition for new construction applications is a programmable thermostat.²⁴⁸

²⁴⁸ IECC 2015 C40.2.4.2.

High-Efficiency Condition

The high-efficiency condition is a single-zone HVAC system being controlled by a smart or connected thermostat. The ENERGY STAR qualified product listing (QPL)²⁴⁹ does not include units marketed for commercial applications; until those units are included, all products marketed as commercial smart or connected thermostats are allowed to use the savings methodology specified in this measure.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for energy and demand savings for small commercial smart thermostats.

$$\text{Total Energy Savings [kWh]} = kWh_c + kWh_H$$

Equation 70

$$\text{Cooling Energy Savings [kWh}_c\text{]} = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times EFLH_c \times CRF \times BAF$$

Equation 71

$$\text{Heating Energy Savings [kWh}_H\text{]} = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times EFLH_c \times HRF \times BAF$$

Equation 72

$$\text{Summer Peak Demand Savings [kW]} = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times CF_s \times CRF \times BAF$$

Equation 73

$$\text{Winter Peak Demand Savings [kW]} = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times CF_w \times HRF \times BAF$$

Equation 74

Where:

$CAP_{C/H}$	=	Controlled-HVAC rated cooling/heating capacity (Btuh) ²⁵⁰
$\eta_{C/H}$	=	HVAC rated cooling/heating efficiency (see Table 32 for retrofit applications; use rated system efficiencies from AHRI or equivalent certification for new construction)

²⁴⁹ ENERGY STAR QPL. <https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results>.

²⁵⁰ Eligible cooling and heating capacity is capped at 10 tons (or 120,000 btu/hr).

Note: Use EER2/EER for summer kW, SEER2/IEER for cooling kWh, and HSPF2/HSPF for heating kWh and winter kW savings calculations. For heating equipment rated in COP, convert to HSPF by multiplying by 3.412. Heating efficiency should be converted from 1.0 COP and set to 3.412 HSPF when thermostat is installed in combination with centrally-controlled electric resistance heat.²⁵¹

$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours (see Table 35 through Table 39)
$CF_{S/W}$	=	Summer/winter coincidence factor (see Table 35 through Table 39)
CRF	=	Cooling reduction factor = 10% ²⁵²
HRF	=	Heating reduction factor = 8% ²⁵³
BAF	=	Baseline adjustment factor (1.0 for manual baseline, 0.6 for programmable and new construction baselines, and 0.8 for unknown baseline) ^{254,255}

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone in the *split and packaged air conditioners and heat pumps* measure in Table 35 through Table 39.

Claimed Peak Demand Savings

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

Claimed Peak Demand Savings

Not applicable.

²⁵¹ COP converted to HSPF using $HSPF = COP \div 1,055 \text{ J/Btu} \times 3,600 \text{ J/W-h} = COP \times 3.412$.

²⁵² The lower 95 percent confidence limit of weighted national average assumed for *residential connected thermostats* measure in Volume 2. While not directly applicable to commercial applications, this approach was used by the Illinois TRM as a precursor to sector specific data collection. Additionally, the deemed value falls between the range observed in other state TRMs (from 2–5 percent in the Mid-Atlantic TRM to 14–20 percent in the Wisconsin TRM). This factor is approved on a probationary basis with intent to review consumption data of sampling of participating projects after at least two years of measure availability.

²⁵³ Ibid.

²⁵⁴ This factor represents the ratio of thermostat adjustment savings to thermostat replacement savings. It is based on actual thermostat algorithm data (i.e., degrees of setback, hours values, fan models) from two years of ComEd AirCare Plus program data (PY9+ and CY2018), including 382 thermostat adjustment installations and 3,847 thermostat replacement installations.

²⁵⁵ A review of ComEd's 2020 Baseline Study and 2019–2020 Program Data indicates that replacement thermostats are approximately 50 percent manual and 50 percent programmable. The unknown value may be applied as a default if applied consistently for all thermostats in a program year.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID HV-ProgTstat.²⁵⁶

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- Decision/action type (retrofit, new construction)
- Baseline thermostat type (manual, programmable, unknown)
- Manufacturer and model number
- Quantity of newly installed thermostats
- HVAC equipment age (retrofit only)
- Cooling type (split AC, packaged AC, split HP, packaged HP)
- Heating type (gas, electric resistance, HP)
- Cooling capacity (Btuh)
- Heating capacity (Btuh)
- Rated cooling efficiency (new construction only)
- Rated heating efficiency (new construction only)

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.

²⁵⁶ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

Document Revision History

Table 113. Smart Thermostats—Revision History

TRM version	Date	Description of change
v10.0	10/2022	Measure origin.
v11.0	10/2023	No revision.
v12.0	10/2024	Minor footnote correction.
v13.0	10/2025	No revision.

2.3 NONRESIDENTIAL: BUILDING ENVELOPE

2.3.1 Cool Roofs Measure Overview

TRM Measure ID: NR-BE-CR

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

Reflective roofing materials reduce the overall heat load on a building by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during the cooling season but reduces free heat during the heating season, so the measure saves energy in the summer but uses more energy in winter. Cool roofs are most beneficial in warmer climates and may not be recommended for buildings where the primary heat source is electric resistance. The measure is for retrofit of existing buildings.

Eligibility Criteria

The ENERGY STAR® Roofing Products Certification program was discontinued effective June 1, 2022.²⁵⁷ Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification.²⁵⁸ For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under the High-Efficiency Condition section below; a roof installed in a new construction application is not eligible for applying these methodologies.
- A roof with a low slope of 2:12 inches or less²⁵⁹

²⁵⁷ ENERGY STAR Roof Products Sunset Decision Memo.
<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf>.

²⁵⁸ ENERGY STAR Program Requirements for Roof Products v2.1.
https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.

²⁵⁹ As defined in proposed ASTN Standard E 1918-97.

- An initial solar reflectance of greater than or equal to 65 percent
- A three-year solar reflectance of greater than or equal to 50 percent
- 75 percent of the roof surface over conditioned space must be replaced
- No significant obstruction of direct sunlight to roof
- The facility must be conditioned with central cooling, heating, or both

In lieu of the former ENERGY STAR list of qualified products, roofing product must now have a performance rating that is validated by the Cool Roof Rating Council (CRRC)^{260,261} and be listed on the CRRC Rated Roof Products Directory.²⁶² This is consistent with the former ENERGY STAR test criteria's allowances for products already participating in the CRRC Product Rating program²⁶³ to submit solar reflectance and thermal emittance product information derived from CRRC certification. If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V methodology or the Full M&V methodology must be used.

Baseline Condition

The baseline is the thermal resistance (i.e., R-value) of the existing roof makeup and the solar reflectance and emissivity of the surface layer. The R-value is estimated based on code envelope requirements applicable in the construction year. Solar reflectance and emissivity of the surface layer are assumed to be 0.2 and 0.9, respectively, based on roof properties listed in the Lawrence Berkeley National Lab (LBLN) Cool Roofing Materials Database.²⁶⁴

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building and typical code requirements applicable in the construction year.

Table 114. Cool Roofs—Assumed Cooling and Heating Efficiencies (COP)

Construction year; applicable code	RTU	PTHP cooling	PTHP heating	Air-cooled chiller	Water-cooled chiller
Before 2011; 2000 IECC	2.9	2.9	2.9	2.5	4.2
Between 2011-2016; 2009 IECC	3.8	3.1	2.9	2.8	5.5
After 2016; 2015 IECC	3.8	3.1	2.9	2.8	5.5

²⁶⁰ CRRC guidance for roof rating alternative to discontinued ENERGY STAR program. <https://coolroofs.org/documents/CRRC-ENERGY-STAR-Sunset-Info-Sheet-2022-03-07.pdf>.

²⁶¹ CRRC Roof Rating program. <https://coolroofs.org/programs/roof-rating-program>.

²⁶² CRRC Rated Roof Products Directory. <https://coolroofs.org/directory/roof>.

²⁶³ CRRC Rated Products Directory: <https://coolroofs.org/directory>.

²⁶⁴ Lawrence Berkeley National Lab Cool Roofing Material Database. <https://buildings.lbl.gov/publications/cool-color-roofing-materials>.

High-Efficiency Condition

The high-efficiency condition depends on the project scope. The project scope is defined as one of the following:

- Adding surface layer only,
- Adding insulation and surface layer, and
- Rebuilding entire roof assembly.

If the project scope is only to add a new CRRC-rated material as the new surface layer, then the R-value used for the baseline condition is used for the high-efficiency condition. If the project scope is to add insulation and a CRRC-rated material as the new surface layer, then the R-value of the additional insulation is added to the R-value used for the baseline condition. If the entire roof assembly is rebuilt, then the R-value for each layer of the new roof construction is summed to get a total new R-value.

The measure requires installation of roof products that have been rated by the CRRC and demonstrate compliance with the previous ENERGY STAR-certified roof product performance specifications for the relevant roof application. Initial and three-year reflectance ratings must meet or exceed the minimum thresholds specified in Table 115.

Table 115. Cool Roofs—ENERGY STAR Specification²⁶⁵

Roof slope	Characteristic	Performance specification
Low slope $\leq 2/12$	Initial solar reflectance	≥ 0.65
	Three-year solar reflectance	≥ 0.50

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy savings are estimated using EnergyPlus v8.3.0 whole-building simulation. The prototype building characteristics match those used for developing commercial HVAC coincidence factors and EFLH and can be found from Table 117 through Table 121. The savings represent the difference of the modeled energy use of the baseline condition and the high-efficiency condition divided by the square foot of the roof area. The demand savings are calculated following the method described in TRM Volume 1.

²⁶⁵ ENERGY STAR Roof Products Specification.

https://www.energystar.gov/products/spec/roof_products_specification_version_3_0_pd.

The deemed energy and demand savings factors are used in the following formulas to calculate savings:

$$\text{Energy Savings [kWh]} = \text{Roof Area} \times \text{ESF}$$

Equation 75

$$\text{Summer Peak Demand Savings [kW]} = \text{Roof Area} \times \text{CF}_S \times 10^{-5}$$

Equation 76

$$\text{Winter Peak Demand Savings [kW]} = \text{Roof Area} \times \text{CF}_W \times 10^{-6}$$

Equation 77

Where:

<i>Roof Area</i>	=	<i>Total area of ENERGY STAR roof (sq. ft.)</i>
<i>ESF</i>	=	<i>Energy savings factor from Table 117 through Table 121 by building type, pre-/post-insulation levels, and heating/cooling system</i>
<i>CF_S</i>	=	<i>Peak summer coincidence factor from Table 117 through Table 121 by building type, pre-/post-insulation levels, and heating/cooling system</i>
<i>CF_W</i>	=	<i>Peak winter coincidence factor from Table 117 through Table 121 by building type, pre/post insulation levels, and heating/cooling system</i>

If the insulation levels are unknown, use the mapping in Table 116 to estimate the R-value based on the construction year.

Table 116. Cool Roofs—Estimated R-Value Based on Construction Year

Construction Year	Estimated R-value ²⁶⁶
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

²⁶⁶ Estimates R-values are based on applicable code requirements in the construction year.

Table 117. Cool Roofs—Savings Coefficients for Climate Zone 1: Amarillo

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Education - chiller	R ≤ 13	R ≤ 13	0.65	11.80	8.31
	R ≤ 13	13 < R ≤ 20	1.10	21.76	31.52
	R ≤ 13	20 < R	1.25	25.53	37.31
	13 < R ≤ 20	13 < R ≤ 20	0.26	4.85	4.59
	13 < R ≤ 20	20 < R	0.38	7.80	9.20
	20 < R	20 < R	0.17	3.40	1.17
Education - RTU	R ≤ 13	R ≤ 13	0.26	8.26	2.62
	R ≤ 13	13 < R ≤ 20	0.43	15.47	12.49
	R ≤ 13	20 < R	0.49	18.20	14.02
	13 < R ≤ 20	13 < R ≤ 20	0.12	4.11	2.05
	13 < R ≤ 20	20 < R	0.18	6.67	3.58
	20 < R	20 < R	0.08	2.91	0.28
Hotel	R ≤ 13	R ≤ 13	0.07	1.33	-2.60
	R ≤ 13	13 < R ≤ 20	0.07	1.83	6.98
	R ≤ 13	20 < R	0.07	2.03	11.77
	13 < R ≤ 20	13 < R ≤ 20	0.04	0.81	-1.45
	13 < R ≤ 20	20 < R	0.04	1.00	3.39
	20 < R	20 < R	0.03	0.60	-1.12
Office - chiller	R ≤ 13	R ≤ 13	0.21	6.80	1.43
	R ≤ 13	13 < R ≤ 20	0.31	3.44	3.50
	R ≤ 13	20 < R	0.33	19.30	3.87
	13 < R ≤ 20	13 < R ≤ 20	0.09	16.58	0.11
	13 < R ≤ 20	20 < R	0.11	5.94	0.47
	20 < R	20 < R	0.06	2.36	0.08
Office - RTU	R ≤ 13	R ≤ 13	0.28	7.46	11.88
	R ≤ 13	13 < R ≤ 20	0.87	15.48	168.51
	R ≤ 13	20 < R	1.10	18.61	236.76
	13 < R ≤ 20	13 < R ≤ 20	0.15	4.12	-1.23
	13 < R ≤ 20	20 < R	0.38	6.73	67.02
	20 < R	20 < R	0.11	2.92	-2.61
Retail	R ≤ 13	R ≤ 13	0.72	19.28	31.74
	R ≤ 13	13 < R ≤ 20	1.26	36.23	36.71
	R ≤ 13	20 < R	1.25	38.58	35.31
	13 < R ≤ 20	13 < R ≤ 20	0.13	4.81	1.88
	13 < R ≤ 20	20 < R	0.12	6.47	0.48
	20 < R	20 < R	0.09	3.32	1.30

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Warehouse	R ≤ 13	R ≤ 13	0.04	3.83	-0.20
	R ≤ 13	13 < R ≤ 20	0.11	6.99	3.89
	R ≤ 13	20 < R	0.14	8.07	5.35
	13 < R ≤ 20	13 < R ≤ 20	0.01	1.35	-0.10
	13 < R ≤ 20	20 < R	0.04	2.24	1.36
	20 < R	20 < R	0.01	0.90	-0.07
Other	R ≤ 13	R ≤ 13	0.04	1.33	-2.60
	R ≤ 13	13 < R ≤ 20	0.07	1.83	3.50
	R ≤ 13	20 < R	0.07	2.03	3.87
	13 < R ≤ 20	13 < R ≤ 20	0.01	0.81	-1.45
	13 < R ≤ 20	20 < R	0.04	1.00	0.47
	20 < R	20 < R	0.01	0.60	-2.61

Table 118. Cool Roofs—Savings Coefficients for Climate Zone 2: Dallas

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Education - chiller	R ≤ 13	R ≤ 13	0.56	10.49	5.11
	R ≤ 13	13 < R ≤ 20	0.82	16.50	8.60
	R ≤ 13	20 < R	0.92	18.86	11.17
	13 < R ≤ 20	13 < R ≤ 20	0.29	5.41	2.36
	13 < R ≤ 20	20 < R	0.36	7.28	4.55
	20 < R	20 < R	0.24	4.37	1.88
Education - RTU	R ≤ 13	R ≤ 13	0.27	10.65	1.53
	R ≤ 13	13 < R ≤ 20	0.39	18.31	3.68
	R ≤ 13	20 < R	0.43	21.33	4.89
	13 < R ≤ 20	13 < R ≤ 20	0.17	7.21	0.77
	13 < R ≤ 20	20 < R	0.21	10.08	1.97
	20 < R	20 < R	0.13	5.88	0.60
Hotel	R ≤ 13	R ≤ 13	0.07	1.71	-0.64
	R ≤ 13	13 < R ≤ 20	0.07	2.30	0.78
	R ≤ 13	20 < R	0.07	2.56	1.39
	13 < R ≤ 20	13 < R ≤ 20	0.05	1.17	-0.46
	13 < R ≤ 20	20 < R	0.05	1.42	0.17
	20 < R	20 < R	0.05	1.01	-0.36

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Office - chiller	R ≤ 13	R ≤ 13	0.23	11.99	0.81
	R ≤ 13	13 < R ≤ 20	0.33	27.48	1.78
	R ≤ 13	20 < R	0.34	30.55	1.93
	13 < R ≤ 20	13 < R ≤ 20	0.13	6.68	0.10
	13 < R ≤ 20	20 < R	0.15	9.76	0.26
	20 < R	20 < R	0.10	6.01	0.08
Office - RTU	R ≤ 13	R ≤ 13	0.27	12.14	14.86
	R ≤ 13	13 < R ≤ 20	0.52	24.53	84.63
	R ≤ 13	20 < R	0.62	29.45	112.16
	13 < R ≤ 20	13 < R ≤ 20	0.18	7.25	11.53
	13 < R ≤ 20	20 < R	0.28	11.09	39.06
	20 < R	20 < R	0.15	6.03	8.66
Retail	R ≤ 13	R ≤ 13	0.61	22.03	13.53
	R ≤ 13	13 < R ≤ 20	0.97	37.67	17.30
	R ≤ 13	20 < R	0.98	40.54	17.32
	13 < R ≤ 20	13 < R ≤ 20	0.16	7.57	1.28
	13 < R ≤ 20	20 < R	0.17	9.67	1.29
	20 < R	20 < R	0.13	6.22	1.04
Warehouse	R ≤ 13	R ≤ 13	0.05	4.01	-0.07
	R ≤ 13	13 < R ≤ 20	0.09	6.54	1.47
	R ≤ 13	20 < R	0.16	11.16	2.38
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.18	-0.05
	13 < R ≤ 20	20 < R	0.08	4.94	0.86
	20 < R	20 < R	0.01	1.02	-0.03
Other	R ≤ 13	R ≤ 13	0.05	1.71	-0.64
	R ≤ 13	13 < R ≤ 20	0.07	2.30	0.78
	R ≤ 13	20 < R	0.07	2.56	1.39
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.17	-0.46
	13 < R ≤ 20	20 < R	0.05	1.42	0.17
	20 < R	20 < R	0.01	1.01	-0.36

Table 119. Cool Roofs—Savings Coefficients for Climate Zone 3: Houston

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Education - chiller	R ≤ 13	R ≤ 13	0.62	9.56	-0.28
	R ≤ 13	13 < R ≤ 20	0.87	15.28	3.52
	R ≤ 13	20 < R	0.95	17.53	4.52
	13 < R ≤ 20	13 < R ≤ 20	0.33	5.04	-0.28
	13 < R ≤ 20	20 < R	0.39	6.81	0.50
	20 < R	20 < R	0.26	4.05	-0.29
Education - RTU	R ≤ 13	R ≤ 13	0.29	9.39	-0.03
	R ≤ 13	13 < R ≤ 20	0.40	15.76	0.90
	R ≤ 13	20 < R	0.44	18.26	1.08
	13 < R ≤ 20	13 < R ≤ 20	0.18	6.21	-0.01
	13 < R ≤ 20	20 < R	0.22	8.58	0.16
	20 < R	20 < R	0.14	5.08	-0.07
Hotel	R ≤ 13	R ≤ 13	0.08	1.69	0.54
	R ≤ 13	13 < R ≤ 20	0.07	2.26	0.17
	R ≤ 13	20 < R	0.07	2.50	-0.02
	13 < R ≤ 20	13 < R ≤ 20	0.06	1.21	0.37
	13 < R ≤ 20	20 < R	0.05	1.43	0.21
	20 < R	20 < R	0.05	1.03	0.32
Office - chiller	R ≤ 13	R ≤ 13	0.25	9.45	0.70
	R ≤ 13	13 < R ≤ 20	0.33	21.39	1.26
	R ≤ 13	20 < R	0.34	23.54	1.23
	13 < R ≤ 20	13 < R ≤ 20	0.17	10.75	0.65
	13 < R ≤ 20	20 < R	0.18	12.84	0.61
	20 < R	20 < R	0.12	4.54	0.12
Office - RTU	R ≤ 13	R ≤ 13	0.28	8.30	6.91
	R ≤ 13	13 < R ≤ 20	0.46	18.66	37.60
	R ≤ 13	20 < R	0.54	22.36	50.18
	13 < R ≤ 20	13 < R ≤ 20	0.19	5.42	4.29
	13 < R ≤ 20	20 < R	0.26	8.39	16.87
	20 < R	20 < R	0.15	4.35	3.35
Retail	R ≤ 13	R ≤ 13	0.62	17.21	9.86
	R ≤ 13	13 < R ≤ 20	1.00	29.60	17.11
	R ≤ 13	20 < R	1.01	31.61	16.52
	13 < R ≤ 20	13 < R ≤ 20	0.41	10.43	7.67
	13 < R ≤ 20	20 < R	0.41	11.89	7.07
	20 < R	20 < R	0.14	4.66	1.07

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Warehouse	R ≤ 13	R ≤ 13	0.05	2.96	-0.09
	R ≤ 13	13 < R ≤ 20	0.09	5.13	0.76
	R ≤ 13	20 < R	0.16	9.21	1.26
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.32	-0.07
	13 < R ≤ 20	20 < R	0.08	4.66	0.43
	20 < R	20 < R	0.01	0.79	0.08
Other	R ≤ 13	R ≤ 13	0.05	1.69	-0.28
	R ≤ 13	13 < R ≤ 20	0.07	2.26	0.17
	R ≤ 13	20 < R	0.07	2.50	-0.02
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.21	-0.28
	13 < R ≤ 20	20 < R	0.05	1.43	0.16
	20 < R	20 < R	0.01	0.79	-0.29

Table 120. Cool Roofs—Savings Coefficients for Climate Zone 4: Corpus Christi

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Education - chiller	R ≤ 13	R ≤ 13	0.60	8.46	0.28
	R ≤ 13	13 < R ≤ 20	0.83	13.55	17.33
	R ≤ 13	20 < R	0.90	15.49	30.14
	13 < R ≤ 20	13 < R ≤ 20	0.31	4.48	-3.69
	13 < R ≤ 20	20 < R	0.36	6.00	6.37
	20 < R	20 < R	0.24	3.64	-0.06
Education - RTU	R ≤ 13	R ≤ 13	0.28	7.34	-0.41
	R ≤ 13	13 < R ≤ 20	0.38	11.78	5.15
	R ≤ 13	20 < R	0.41	13.53	8.09
	13 < R ≤ 20	13 < R ≤ 20	0.17	4.64	-1.46
	13 < R ≤ 20	20 < R	0.20	6.29	1.47
	20 < R	20 < R	0.14	3.77	-0.14
Hotel	R ≤ 13	R ≤ 13	0.07	1.13	1.99
	R ≤ 13	13 < R ≤ 20	0.07	1.44	-1.23
	R ≤ 13	20 < R	0.07	1.57	-2.70
	13 < R ≤ 20	13 < R ≤ 20	0.05	0.78	1.36
	13 < R ≤ 20	20 < R	0.05	0.90	0.00
	20 < R	20 < R	0.04	0.67	1.19

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Office - chiller	R ≤ 13	R ≤ 13	0.22	6.44	2.33
	R ≤ 13	13 < R ≤ 20	0.31	13.55	2.86
	R ≤ 13	20 < R	0.32	15.30	2.47
	13 < R ≤ 20	13 < R ≤ 20	0.17	6.34	1.78
	13 < R ≤ 20	20 < R	0.18	7.96	1.40
	20 < R	20 < R	0.10	3.27	0.45
Office - RTU	R ≤ 13	R ≤ 13	0.26	5.02	23.11
	R ≤ 13	13 < R ≤ 20	0.40	8.66	78.05
	R ≤ 13	20 < R	0.45	10.09	100.16
	13 < R ≤ 20	13 < R ≤ 20	0.18	3.61	15.10
	13 < R ≤ 20	20 < R	0.24	4.83	37.21
	20 < R	20 < R	0.15	2.95	10.35
Retail	R ≤ 13	R ≤ 13	0.62	13.05	54.33
	R ≤ 13	13 < R ≤ 20	0.99	21.99	35.94
	R ≤ 13	20 < R	1.00	23.21	34.63
	13 < R ≤ 20	13 < R ≤ 20	0.41	8.08	16.20
	13 < R ≤ 20	20 < R	0.41	8.95	14.89
	20 < R	20 < R	0.13	3.42	2.05
Warehouse	R ≤ 13	R ≤ 13	0.05	2.10	0.22
	R ≤ 13	13 < R ≤ 20	0.09	3.51	1.39
	R ≤ 13	20 < R	0.16	6.54	1.35
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.21	0.28
	13 < R ≤ 20	20 < R	0.08	3.71	0.24
	20 < R	20 < R	0.01	0.70	-0.07
Other	R ≤ 13	R ≤ 13	0.05	1.13	-0.41
	R ≤ 13	13 < R ≤ 20	0.07	1.44	-1.23
	R ≤ 13	20 < R	0.07	1.57	-2.70
	13 < R ≤ 20	13 < R ≤ 20	0.02	0.78	-3.69
	13 < R ≤ 20	20 < R	0.05	0.90	0.00
	20 < R	20 < R	0.01	0.67	-0.14

Table 121. Cool Roofs—Savings Coefficients for Climate Zone 5: El Paso

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Education - chiller	R ≤ 13	R ≤ 13	0.69	9.09	3.85
	R ≤ 13	13 < R ≤ 20	0.97	14.42	4.87
	R ≤ 13	20 < R	1.07	16.52	5.43
	13 < R ≤ 20	13 < R ≤ 20	0.36	4.80	1.87
	13 < R ≤ 20	20 < R	0.44	6.47	2.34
	20 < R	20 < R	0.28	3.91	1.19
Education - RTU	R ≤ 13	R ≤ 13	0.30	8.21	3.09
	R ≤ 13	13 < R ≤ 20	0.42	13.43	4.02
	R ≤ 13	20 < R	0.46	15.49	4.27
	13 < R ≤ 20	13 < R ≤ 20	0.18	5.16	1.47
	13 < R ≤ 20	20 < R	0.22	7.09	1.72
	20 < R	20 < R	0.14	4.14	0.86
Hotel	R ≤ 13	R ≤ 13	0.10	1.33	7.04
	R ≤ 13	13 < R ≤ 20	0.08	1.58	1.80
	R ≤ 13	20 < R	0.08	1.68	-0.78
	13 < R ≤ 20	13 < R ≤ 20	0.07	0.95	4.98
	13 < R ≤ 20	20 < R	0.06	1.04	2.57
	20 < R	20 < R	0.06	0.81	4.27
Office - chiller	R ≤ 13	R ≤ 13	0.29	9.72	7.27
	R ≤ 13	13 < R ≤ 20	0.39	17.57	12.46
	R ≤ 13	20 < R	0.42	20.35	13.25
	13 < R ≤ 20	13 < R ≤ 20	0.17	6.68	0.12
	13 < R ≤ 20	20 < R	0.20	9.22	0.79
	20 < R	20 < R	0.14	5.39	2.02
Office - RTU	R ≤ 13	R ≤ 13	0.31	9.93	24.02
	R ≤ 13	13 < R ≤ 20	0.55	16.57	105.15
	R ≤ 13	20 < R	0.64	19.26	135.96
	13 < R ≤ 20	13 < R ≤ 20	0.20	5.75	16.21
	13 < R ≤ 20	20 < R	0.29	7.78	47.02
	20 < R	20 < R	0.16	4.70	12.77
Retail	R ≤ 13	R ≤ 13	0.67	16.55	42.72
	R ≤ 13	13 < R ≤ 20	1.01	26.85	67.80
	R ≤ 13	20 < R	1.02	28.78	65.27
	13 < R ≤ 20	13 < R ≤ 20	0.19	5.83	6.64
	13 < R ≤ 20	20 < R	0.19	7.24	4.12
	20 < R	20 < R	0.15	4.74	5.40

Building type	Pre-R-value	Post R-value	ESF	CF _s	CF _w
Warehouse	R ≤ 13	R ≤ 13	0.04	2.76	-0.61
	R ≤ 13	13 < R ≤ 20	0.09	4.91	1.33
	R ≤ 13	20 < R	0.15	8.27	2.06
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.31	-0.42
	13 < R ≤ 20	20 < R	0.07	3.98	0.30
	20 < R	20 < R	0.01	0.76	-0.19
Other	R ≤ 13	R ≤ 13	0.04	1.33	-0.61
	R ≤ 13	13 < R ≤ 20	0.08	1.58	1.33
	R ≤ 13	20 < R	0.08	1.68	-0.78
	13 < R ≤ 20	13 < R ≤ 20	0.02	0.95	-0.42
	13 < R ≤ 20	20 < R	0.06	1.04	0.30
	20 < R	20 < R	0.01	0.76	-0.19

Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

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) Remote Ex-Ante Database Interface (READI) tool for EUL ID BldgEnv-CoolRoof.²⁶⁷

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- Total and treated roofing square footage (over conditioned space)
- Roof slope
- Existing roof insulation R-value, or year of building construction

²⁶⁷ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

- New roof insulation R-value, if adding insulation
- New roofing initial solar reflectance
- New roofing three-year solar reflectance
- New roofing rated life (if available)
- Copy of CRRC certification
- Copy of proof of purchase including date of purchase, manufacturer, and model

Building Type References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Commercial Cool Roof.

Relevant Standards and Reference Sources

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

Document Revision History

Table 122. Cool Roofs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Clarified that reflectance is three years basis. Rounded off values, too many insignificant digits.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials. Added new high-performance roof calculator for use in determining ENERGY STAR roof savings.
v5.0	10/2017	No revision.
v6.0	10/2018	Changed savings methodology from algorithms to simulation models. Deemed savings are presented per square foot by building type and climate zone.
v7.0	10/2019	Minor error updates to Savings Factor Table for greater than and less than symbols. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.

TRM version	Date	Description of change
v9.0	10/2021	Added building type to tracking data requirements. Updated EUL reference.
v10.0	10/2022	Changed eligibility criteria from strictly ENERGY STAR to CRRC certification.
v11.0	10/2023	No revision.
v12.0	10/2024	Reordered building types in tables.
v13.0	10/2025	Updated documentation requirements to only require roofing product rated life when available.

2.3.2 Window Treatments Measure Overview

TRM Measure ID: NR-BE-WT

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

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 section presents the deemed savings methodology for the installation of window films and fixed solar screens. The installation of window treatments decreases the window-shading coefficient and reduces the solar heat transmitted to the building space. During months when perimeter cooling is required in the building, this measure decreases cooling energy use and summer demand.

Eligibility Criteria

This measure is applicable for treatment of single or double-paned clear glass windows without reflective or low-e coatings in south or west facing orientations (as specified in Table 123). The treatment can be a film applied to the window or a permanent, fixed, interior or exterior solar screen. This methodology may be adapted for windows with existing shading devices on an individual project basis with prior evaluator approval of baseline solar heat gain coefficient (SHGC).

Existing windows must have no solar films/screens, interior shades, or exterior awnings or overhangs, and must be installed in buildings that are mechanically cooled (direct expansion (or chilled water)). While highly reflective louvered or Venetian blinds can help reduce solar heat gain, they must be completely lowered and closed to be as effective as permanent shading devices.²⁶⁸ The louvered or Venetian blinds are not eligible for the measure, although windows with existing interior louvered or Venetian blinds are not excluded from using this measure.

²⁶⁸ "Energy Efficient Window Coverings," US Department of Energy.
[https://www.energy.gov/energysaver/energy-efficient-window-coverings#:~:text=Window%20blinds%E2%80%94vertical%20\(Venetian%20blinds,while%20providing%20good%20daylight%20indoors.](https://www.energy.gov/energysaver/energy-efficient-window-coverings#:~:text=Window%20blinds%E2%80%94vertical%20(Venetian%20blinds,while%20providing%20good%20daylight%20indoors.)

Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatments. However, existing windows with interior louvered or Venetian blinds are an allowable baseline with reduced SHGC values from Table 124.

High-Efficiency Condition

The high-efficiency condition is an eligible window treatment applied to eligible windows.

Energy and Demand Savings Methodology

The demand and energy savings equations in this section originated in calculations by the Electric Utility Marketing Managers of Texas (EUMMOT) utilities, as presented in the EUMMOT program manual *Commercial Standard Offer Program: Measurement and Verification Guidelines for Retrofit and New Construction Projects*. The method estimates the reduction in solar heat gain/insolation attributable to a given window treatment using shading coefficients for the treated and untreated window and solar heat gain estimates by window orientation, according to ASHRAE Fundamentals. The reduction in building energy use attributable to the reduction in cooling system energy use is estimated based on the reduced heat removal requirement for a standard efficiency cooling system.

Savings Algorithms and Input Variables

$$Demand\ Savings_o\ [kW] = \frac{A_{film,o} \times SHGF_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

Equation 78

$$Peak\ Demand\ Savings\ [kW] = DemandSavings_{o,max}$$

Equation 79

$$Energy\ Savings_o\ [kWh] = \frac{A_{film,o} \times SHG_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

Equation 80

$$Total\ Energy\ Savings\ [kWh] = \sum Energy\ Savings_o$$

Equation 81

Where:

<i>Demand Savings_o</i>	=	<i>Peak demand savings per window orientation</i>
<i>Energy Savings_o</i>	=	<i>Energy savings per window orientation</i>
<i>A_{film,o}</i>	=	<i>Area of window treatment applied to orientation [ft²]</i>

$SHGF_o$	=	Peak solar heat gain factor for orientation of interest [Btu/hr-ft ² -year] (see Table 123)
SHG_o	=	Solar heat gain for orientation of interest [Btu/ft ² -year] (see Table 123)
$SHGC_{pre}$	=	Solar heat gain coefficient for existing glass with no interior-shading device (see Table 124)
$SHGC_{post}$	=	Solar heat gain coefficient for new film/fixed-shading device, from manufacturer specs
<i>Note: Shading coefficients (SC) have been retired, but if a product specification lists SC instead of SHGC, you can convert to SHGC by multiplying SC by 0.87.²⁶⁹</i>		
COP	=	Cooling equipment coefficient of performance (COP) based on Table 125 or actual COP equipment, whichever is greater; if building construction year is unknown, assume IECC 2009 as applicable code
3,412	=	Constant to convert from Btu to kWh

Table 123. Windows Treatments—Solar Heat Gain Factors²⁷⁰

Orientation ²⁷¹	Solar heat gain (SHG) [Btu/ft ² -year]	Peak hour solar heat gain (SHGF) [Btu/hr-ft ² -year]				
		Climate Zone 1: Amarillo ²⁷²	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
SE	158,844	28	30	26	27	35
SSE	134,794	28	31	28	28	37
S	120,839	37	44	47	45	56
SSW	134,794	88	94	113	113	101
SW	158,844	152	151	170	173	141
WSW	169,696	191	184	201	206	160
W	163,006	202	189	201	207	155
WNW	139,615	183	167	171	178	128
NW	107,161	136	120	115	121	85

²⁶⁹ 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

²⁷⁰ Values are taken from the 1997 ASHRAE Fundamentals, Chapter 29 Table 17, based on the amount of solar radiation transmitted through single-pane clear glass for a cloudless day at 32°N Latitude for the 21st day of each month by hour of day and solar orientation. The SHG values listed above have been aggregated into daily totals for weekdays during the months of April through October.

²⁷¹ N = North, S = South, E = East, and W = West.

²⁷² Coincidence factors specific to Climate Zone 1 could not be calculated since utility load data is not currently available for this region. In their absence, Climate Zone 2 values may be used.

Table 124. Windows Treatments—Recommended Clear Glass SHGC_{pre} by Window Thickness²⁷³

Existing window configuration	Louvered Blinds	SHGC _{pre}
Single-pane 1/8-inch clear glass	No	0.86
Single-pane 1/4-inch clear glass		0.81
Double-pane 1/8-inch clear glass		0.76
Double-pane 1/4-inch clear glass		0.70
Single-pane 1/8-inch clear glass	Yes ²⁷⁴	0.64
Single-pane 1/4-inch clear glass		0.60
Double-pane 1/8-inch clear glass		0.61
Double-pane 1/4-inch clear glass		0.57

Table 125. Windows Treatments—Recommended COP by HVAC System Type²⁷⁵

Construction year; applicable code	AC/HP	PTAC/PTHP	Air-cooled chiller	Water-cooled chiller
Before 2011; 2000 IECC	2.9	2.9	2.5	4.2
Between 2011-2016; 2009 IECC	3.8	3.1	2.8	5.5
After 2016; 2015 IECC	3.8	3.1	2.8	5.5

Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GlazDaylt-WinFilm.²⁷⁶

²⁷³ 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC). <https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online>.

²⁷⁴ 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 14A IAC Values for Louvered Shades: Uncoated Single Glazings, Table 14B IAC Values for Louvered Shades: Uncoated Double Glazings. <https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online>.

²⁷⁵ Based on review applicable codes, including IECC 2000, 2009, and 2015.

²⁷⁶ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Existing window type, thickness, and SHGC
- Description of existing window presence of exterior shading from other buildings or obstacles
- Window film or solar screen SHGC
- Eligible window treatment application area by orientation (e.g., S, SSW, SW)
- Construction year, if available
- Cooling equipment type
- Cooling equipment rated efficiency

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for reflective window films and sunscreens.

Relevant Standards and Reference Sources

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

Document Revision History

Table 126. Windows Treatments—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Eliminated east-facing windows from consideration for energy savings.
v3.0	04/10/2015	References to EPE-specific deemed savings removed (EPE to adopt methods used by the other utilities). Demand savings: Frontier Energy updated to incorporate new peak demand definition. Provided deemed values for shading coefficients and HVAC efficiencies. SHGF: Used CZ2 savings for CZ1 until better values can be developed.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.

TRM version	Date	Description of change
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits. Updated peak demand values for climate zones and PDPF values.
v9.0	10/2021	Corrected footnote for SC to SHGC conversion. Updated performance factors to 2017 ASHRAE Fundamentals. Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	Extended eligibility to windows with existing louvered or Venetian blinds. Added reduced baseline SHGC values for windows with louvered blinds.
v12.0	10/2024	Updated measure to indicate solar screen must be permanent, fixed, and interior or exterior.
v13.0	10/2025	No revision.

2.3.3 Entrance and Exit Door Air Infiltration Measure Overview

TRM Measure ID: NR-BE-DI

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

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 measure applies to the installation of weatherstripping or door sweeps on entrance and exit doors for a contained, pressurized space. Entrance and exit doors often leave clearance gaps to allow for proper operation. The gaps around the doors allow for the infiltration of unconditioned air into the building, adding to the cooling and heating load of the HVAC system. Weatherstripping and door sweeps are designed to be installed along the bottom and jambs of exterior doors to prevent air infiltration to conditioned space.

Eligibility Criteria

Weatherstripping or doors sweeps must be installed on doors of a conditioned and/or heated space. Treated doors must have visible gaps of 1/8–1/2 inches along the outside edge of the door. Spaces with interior vestibule doors are not eligible.

Baseline Condition

The baseline standard for this measure is a commercial building with exterior doors that are not sealed from unconditioned space.

High-Efficiency Condition

The high-efficiency condition for this measure is a commercial building with exterior doors that have been sealed from unconditioned space using weatherstripping and/or brush style door sweeps.

Energy and Demand Savings Methodology

This savings methodology was derived by analyzing TMY3 weather data for each Texas weather zone representative city.

Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).²⁷⁷ Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,²⁷⁸ and an average building height of 20 feet is assumed for the deemed savings approach.

Because air infiltration is a function of differential pressure due to stack effect, wind speed, velocity head, and the design conditions of the building, TMY3 for each Texas weather zone reference city was applied to account for the varying weather conditions that are characteristic throughout an average year.

Figure 5.13 from the ASHRAE CHLCM provides the infiltration rate based on various crack width and the corresponding pressure difference across a door. Figures 5.1 and 5.2 (CHLCM) provide the differential pressure due to stack and wind pressure necessary to determine the total pressure difference across the door.

Applying a regression analysis to Figure 5.1 returns an equation that allows solving for the pressure difference due to stack effect, Δp_s . The aggregate curve fit for Figure 5.1 is shown below where ΔT is the difference between the exterior dry bulb temperature from the TMY3 data and the interior cooling or heating temperature setpoint.

$$\Delta p_s / C_d = 0.0003298(\Delta T) - 0.0012222$$

Equation 82

Where C_d is an assumed constant, 0.63, and the neutral pressure distance is 10 feet.

From Figure 5.2, $\Delta p_w / C_p$ is determined by applying a polynomial regression, which returns an equation for solving for the pressure difference due to wind, Δp_w . The curve fit for Figure 5.2 is shown below where x is the wind velocity based on TMY3 data.

$$\Delta p_w / C_p = 0.00047749x^2 - 0.00013041x$$

Equation 83

Where C_p is an assumed constant, 0.13 (average wind pressure coefficient from Table 5.5 from CHLCM).

This yields the total pressure difference across the door, Δp_{Total} :

$$\Delta p_{Total} = \Delta p_s + \Delta p_w$$

Equation 84

²⁷⁷ ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980.
http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf.

²⁷⁸ Cho, H., K. Gowri, and B. Liu, "Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements: Modeling of Air Infiltration through Door Openings." November 2010.
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf.

Solving for Δp_{Total} allows for the air infiltration rate per linear foot to be determined in Figure 5.13 (CHLCM). Applying a power regression analysis for each crack width (described in inches) represented in Figure 5.13 (CHLCM) returns the equations listed below. In these equations, Q is the infiltration rate in cubic feet per minute through cracks around the door, and P is the perimeter of the door in feet.

$$Q/P_{1/8"} = 41.572x^{0.5120}$$

Equation 85

$$Q/P_{1/4"} = 81.913x^{0.5063}$$

Equation 86

$$Q/P_{1/2"} = 164.26x^{0.5086}$$

Equation 87

These infiltration rates were further disaggregated based on TMY3 average monthly day and night conditions.

Derivation of Design and Average Outside Ambient Temperatures

Taking average daytime and nighttime outdoor temperature values, standard set points, and setbacks for daytime and nighttime design cooling and heating will yield the temperature difference needed for the sensible heat equation:

$$\Delta T = T_{design} - T_{avg\ outside\ ambient}$$

Equation 88

Where:

T_{design} = Daytime and nighttime design temperature [°F] (see Table 128)

$T_{avg\ outside\ ambient}$ = Average outside ambient temperature, specified by month [°F] (see Table 127)

Table 127. Air Infiltration—Average Monthly Ambient Temperatures (°F)²⁷⁹

Month	Climate Zone 1: Amarillo		Climate Zone 2: Dallas		Climate Zone 3: Houston		Climate Zone 4: Corpus Christi		Climate Zone 5: El Paso	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Jan	41.5	31.5	48.1	40.3	54.8	47.0	58.1	50.9	50.9	42.4
Feb	44.9	34.5	52.8	44.8	59.4	50.5	61.7	54.4	55.8	45.2
Mar	52.9	40.7	63.6	54.4	65.5	56.8	69.1	61.3	61.0	48.2
April	65.4	52.7	71.4	62.7	73.1	64.7	75.9	67.7	72.7	60.5
May	69.2	57.2	77.6	68.7	79.4	71.1	80.5	72.0	80.9	69.0
June	79.9	69.7	85.3	75.0	85.1	76.2	86.4	77.9	88.2	76.1
July	84.5	72.1	90.4	80.6	87.8	78.0	88.6	78.0	86.7	76.5
Aug	81.4	69.7	89.1	79.2	88.0	77.5	88.0	78.4	84.2	74.4
Sept	75.3	64.3	84.5	73.8	85.5	73.6	85.0	75.2	80.9	67.3
Oct	63.6	50.4	70.2	59.9	75.4	61.8	77.5	67.9	70.2	59.7
Nov	48.5	38.5	59.3	52.3	67.6	57.9	72.3	63.8	57.3	47.0
Dec	41.8	32.4	49.5	41.8	59.2	50.0	60.4	53.7	49.1	39.4

Table 128. Air Infiltration—Daytime and Nighttime Design Temperatures

Temperature description	T _{design} (°F)
Daytime cooling design temperature	74
Daytime heating design temperature	70
Nighttime cooling design temperature ²⁸⁰	78
Nighttime heating design temperature ²⁸¹	66

Savings Algorithms and Input Variables

To calculate HVAC load associated with air infiltration, the following sensible heat equation is used:

Electric Cooling Energy Savings

Cooling Energy Savings [kWh]_{Day}

$$= \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times Hours_{day} \times TDF}{12,000 Btuh/ton}$$

Equation 89

²⁷⁹ TMY3 climate data.

²⁸⁰ Assuming four-degree setback.

²⁸¹ Ibid.

Cooling Energy Savings [kWh]_{Night}

$$= \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times Hours_{night} \times TDF}{12,000 \text{ Btuh/ton}}$$

Equation 90

Cooling Energy Savings [kWh]

$$= \text{Cooling Energy Savings [kWh]}_{Day} + \text{Cooling Energy Savings [kWh]}_{Night}$$

Equation 91

Electric Heating Energy Savings

Heating Energy Savings [kWh]_{Day}

$$= \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times Hours_{day} \times TDF}{COP \times 3,412 \text{ Btuh/kW}}$$

Equation 92

Heating Energy Savings [kWh]_{Night}

$$= \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times Hours_{night} \times TDF}{COP \times 3,412 \text{ Btuh/kW}}$$

Equation 93

Heating Energy Savings [kWh]

$$= \text{Cooling Energy Savings [kWh]}_{Day} + \text{Cooling Energy Savings [kWh]}_{Night}$$

Equation 94

Electric Cooling Demand Savings (weighted by climate zone peak hour probability)

Summer Peak Demand Savings [kW]_{Day}

$$= \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times TDF}{12,000 \text{ Btuh/ton}}$$

Equation 95

Electric Heating Demand Savings (weighted by climate zone peak hour probability)

Winter Peak Demand Savings [kW]_{Day/Night}

$$= \frac{CFM_{pre,day/night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times TDF}{COP \times 3,412 \text{ Btuh/kW}}$$

Equation 96

Where:

CFM_{pre}	=	Calculated pre-retrofit air infiltration (cubic feet per minute)
$CFM_{reduction}$	=	59% ²⁸²
TDF	=	Technical degradation factor = 85% ²⁸³
1.08	=	Sensible heat equation conversion ²⁸⁴
ΔT	=	Change in temperature across gap barrier [°F]
$Hours_{day}$	=	12-hour cycles per day, per month = 4,380 hours
$Hours_{night}$	=	12-hour cycles per night, per month = 4,380 hours
COP	=	Heating coefficient of performance; 1.0 for electric resistance and 3.3 for heat pumps

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings per treatment type²⁸⁵ are specified below based on climate zone and existing door gap width. The gap width shall be measured on each of the four edges of the door to the nearest ¼ inch. When reporting entire door savings, the reported gap width for the door should reflect the average of the four measurements. When reporting savings separately for weatherstripping and door sweeps, weatherstripping treatments should report the gap width as the average of the measurements at the top, left, and right edges; and door sweeps should report the measurement from the bottom edge. The average gap width should be rounded to nearest gap width in inches in Table 129 through Table 134. Projects that have more than ten doors at the same project site can provide a sample of measurements of 20 percent of the claimed doors and apply the average to all doors in the project.

Heating savings are specified for both electric resistance (ER) and heat pump (HP) heating. Cooling savings are available for buildings with electric cooling and gas heat, but no heating savings should be claimed for buildings with gas heat.

For doors with existing weatherstripping, a factor of 0.6 shall be applied to the deemed savings for partial existing weatherstripping and a factor of 0.25 shall be applied to the deemed savings for full existing weatherstripping.

²⁸² CLEARresult, “Commercial Door Air Infiltration Memo”. March 18, 2015. Average reduction in Arkansas based on test results from the CLEARresult Brush Weatherstripping Testing Method and Results (59% infiltration reduction).

²⁸³ This factor is applied to account for the difference between the laboratory test from the “Commercial Door Air Infiltration Memo” and the real-world ability to seal the openings around a door. In the absence of research regarding the actual difference, this factor was set to 0.85.

²⁸⁴ 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

²⁸⁵ Standard door measurements: 36” width and 80” height.

Table 129. Air Infiltration—Cooling Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	31	62	124
	Door Sweep (bottom)	6	11	23
	Entire Door (top, bottom, and 2 sides)	37	74	147
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	64	128	255
	Door Sweep (bottom)	12	24	47
	Entire Door (top, bottom, and 2 sides)	75	152	301
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	49	100	198
	Door Sweep (bottom)	9	18	36
	Entire Door (top, bottom, and 2 sides)	58	118	234
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	82	165	328
	Door Sweep (bottom)	15	30	60
	Entire Door (top, bottom, and 2 sides)	97	195	388
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	46	92	183
	Door Sweep (bottom)	8	17	34
	Entire Door (top, bottom, and 2 sides)	54	109	217

Table 130. Air Infiltration—ER Heating Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	1,496	3,018	5,994
	Door Sweep (bottom)	275	554	1,101
	Entire Door (top, bottom, and 2 sides)	1,771	3,572	7,095
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	700	1,414	2,807
	Door Sweep (bottom)	129	260	516
	Entire Door (top, bottom, and 2 sides)	828	1,674	3,322
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	371	752	1,492
	Door Sweep (bottom)	68	138	274
	Entire Door (top, bottom, and 2 sides)	440	890	1,766
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	300	607	1,204
	Door Sweep (bottom)	55	111	221
	Entire Door (top, bottom, and 2 sides)	356	718	1,425
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	662	1,339	2,657
	Door Sweep (bottom)	122	246	488
	Entire Door (top, bottom, and 2 sides)	784	1,585	3,145

Table 131. Air Infiltration—HP Heating Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	453	914	1,816
	Door Sweep (bottom)	83	168	334
	Entire Door (top, bottom, and 2 sides)	537	1,082	2,150
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	212	429	851
	Door Sweep (bottom)	39	79	156
	Entire Door (top, bottom, and 2 sides)	251	507	1,007
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	113	228	452
	Door Sweep (bottom)	21	42	83
	Entire Door (top, bottom, and 2 sides)	133	270	535
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	91	184	365
	Door Sweep (bottom)	17	34	67
	Entire Door (top, bottom, and 2 sides)	108	218	432
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	201	406	805
	Door Sweep (bottom)	37	75	148
	Entire Door (top, bottom, and 2 sides)	237	480	953

Table 132. Air Infiltration—Summer Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	0.087	0.173	0.345
	Door Sweep (bottom)	0.016	0.032	0.063
	Entire Door (top, bottom, and 2 sides)	0.102	0.205	0.408
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	0.074	0.147	0.292
	Door Sweep (bottom)	0.014	0.027	0.054
	Entire Door (top, bottom, and 2 sides)	0.087	0.174	0.346
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	0.070	0.142	0.284
	Door Sweep (bottom)	0.013	0.026	0.052
	Entire Door (top, bottom, and 2 sides)	0.083	0.168	0.336
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	0.070	0.142	0.283
	Door Sweep (bottom)	0.013	0.026	0.052
	Entire Door (top, bottom, and 2 sides)	0.083	0.168	0.334
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	0.068	0.136	0.270
	Door Sweep (bottom)	0.012	0.025	0.050
	Entire Door (top, bottom, and 2 sides)	0.080	0.160	0.319

Table 133. Air Infiltration—ER Winter Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	0.405	0.817	1.624
	Door Sweep (bottom)	0.074	0.150	0.298
	Entire Door (top, bottom, and 2 sides)	0.479	0.967	1.922
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	0.648	1.300	2.587
	Door Sweep (bottom)	0.119	0.239	0.475
	Entire Door (top, bottom, and 2 sides)	0.768	1.539	3.062
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	0.366	0.737	1.465
	Door Sweep (bottom)	0.067	0.135	0.269
	Entire Door (top, bottom, and 2 sides)	0.433	0.872	1.734
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	0.274	0.550	1.096
	Door Sweep (bottom)	0.050	0.101	0.201
	Entire Door (top, bottom, and 2 sides)	0.325	0.652	1.297
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	0.152	0.309	0.613
	Door Sweep (bottom)	0.028	0.057	0.113
	Entire Door (top, bottom, and 2 sides)	0.180	0.365	0.725

Table 134. Air Infiltration—HP Winter Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Treatment Type	Average Gap width (inches)		
		1/8	1/4	1/2
Climate Zone 1: Amarillo	Weatherstripping (top and 2 sides)	0.211	0.426	0.846
	Door Sweep (bottom)	0.039	0.078	0.155
	Entire Door (top, bottom, and 2 sides)	0.249	0.505	1.001
Climate Zone 2: Dallas	Weatherstripping (top and 2 sides)	0.279	0.560	1.116
	Door Sweep (bottom)	0.051	0.103	0.205
	Entire Door (top, bottom, and 2 sides)	0.331	0.663	1.320
Climate Zone 3: Houston	Weatherstripping (top and 2 sides)	0.162	0.325	0.645
	Door Sweep (bottom)	0.030	0.060	0.119
	Entire Door (top, bottom, and 2 sides)	0.191	0.385	0.764
Climate Zone 4: Corpus Christi	Weatherstripping (top and 2 sides)	0.142	0.286	0.568
	Door Sweep (bottom)	0.026	0.053	0.104
	Entire Door (top, bottom, and 2 sides)	0.168	0.338	0.673
Climate Zone 5: El Paso	Weatherstripping (top and 2 sides)	0.075	0.152	0.302
	Door Sweep (bottom)	0.014	0.028	0.056
	Entire Door (top, bottom, and 2 sides)	0.089	0.180	0.358

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 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID BS-Wthr.²⁸⁶ This measure life is consistent with the residential air infiltration measure in the Texas TRM.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Treated door quantity
- Existing gap width on each edge of the door
- Reported average gap width (1/8", 1/4", or 1/2")
- Existing weatherization measure (full, partial, none)
- New weatherization measure (weatherstripping, door sweep, entire door)
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
 - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach)

References and Efficiency Standards

Petitions and Rulings

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

²⁸⁶ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

Relevant Standards and Reference Sources

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

Document Revision History

Table 135. Air Infiltration—Revision History

TRM version	Date	Description of change
v6.0	10/2018	Measure origin.
v7.0	10/2019	Minor text revisions.
v8.0	10/2020	General reference checks and text edits. Degradation factor added to deemed savings values. Guidance clarified for measuring gap sizes.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	Adjusted savings normalization from per-linear-foot to per-standard-door. Updated documentation requirements.
v13.0	10/2025	Adjusted savings normalization from per-standard-door to treatment type (weatherstripping, door sweep, entire door). Updated curve fits developed from ASHRAE CLCM. Adjusted assumed heating setpoints. Removed $\frac{3}{4}$ " gap savings.

2.3.4 Ceiling Insulation Measure Overview

TRM Measure ID: NR-BE-CI

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: Small commercial and multifamily

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Not applicable

Savings Methodology: Engineering modeling, engineering algorithms

Measure Description

This measure estimates energy savings associated with improvements in ceiling insulation for small commercial building envelopes. Insulation over the ceiling reduces the overall cooling and heating load on a building by reducing the total energy exchange with the exterior conditions. The added insulation will reduce the cooling energy use when the exterior temperature is higher than the interior temperature. The added insulation will reduce the heating energy use when the exterior temperature is lower than the interior temperature.

Eligibility Criteria

This measure is applicable for small commercial buildings less than 5,000 square feet floor area and all master metered multifamily buildings.

Baseline Condition

The baseline condition is a vented, unfinished attic. The existing R-level will be the roof assembly plus the added insulation. Because existing ceiling insulation must be removed during measure implementation, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

High-Efficiency Condition

The high efficiency condition is the average R-value of the roof assembly and installed insulation. The ceiling insulation level of R-38 is recommended throughout Texas as prescribed by the Department of Energy²⁸⁷ and aligns with the code minimum for IECC 2015.

²⁸⁷ https://www.energy.gov/energysaver/insulation?nrg_redirect=301794

Energy and Demand Savings Methodology

Savings Methodology

Electric energy savings are calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

$$\text{Annual Energy Savings (kWh)} = \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}}$$

Equation 97

$$\Delta kWh_{\text{cooling}} = \left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) \times \text{Area} \times EFLH_C \times \frac{\Delta T_{\text{cooling}}}{1,000} / \eta_{\text{cooling}}$$

Equation 98

$$\Delta kWh_{\text{heating}} = \left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) \times \text{Area} \times EFLH_H \times \frac{\Delta T_{\text{heating}}}{1,000} / \eta_{\text{heating}}$$

Equation 99

Summer Peak Demand Savings:

$$\text{Peak Demand Savings (kW)} = \frac{(\Delta kWh_{\text{cooling}})}{EFLH_C} \times CF_s$$

Equation 100

Winter Peak Demand Savings:

$$\text{Peak Demand Savings (kW)} = \frac{(\Delta kWh_{\text{heating}})}{EFLH_H} \times CF_w$$

Equation 101

Where:

R_{existing}	=	Existing condition of insulation prior to retrofit [hr-°F-ft²/Btu]. Assume roof assembly = R-3 and add insulation value.
R_{new}	=	Post-retrofit insulation condition [hr-°F-ft²/Btu]. Assume roof assembly = R-3 and add insulation value.
Area	=	Treated attic area [sq. feet]

$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours [hours] (see Table 35 through Table 39)
$\Delta T_{cooling}$	=	Temperature difference [°F] during cooling season between design day outdoor air temperature and assumed 65°F base temperature, see Table 136 below.
$\eta_{Cooling}$	=	Efficiency of cooling system (SEER) [Btuh/W]. Actual, if known. If equipment type is known, assume SEER = 13
$\Delta T_{heating}$	=	Temperature difference [°F] during heating season between design day outdoor air temperature and assumed 65°F base temperature, see Table 137 below.
$\eta_{Heating}$	=	Efficiency of heating system (HSPF) [Btuh/W]. Actual, if known. If equipment type is unknown, assume gas heating and no electric heating savings.
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 35 through Table 39)

Table 136. Ceiling Insulation—Cooling Season Temperature Difference

Climate Zone	Design Temperature (°F) ²⁸⁸	$\Delta T_{cooling}$
1	98.8	33.8
2	101.4	36.4
3	97.6	32.6
4	96.9	31.9
5	101.2	36.2

Table 137. Ceiling Insulation—Heating Season Temperature Difference

Climate Zone	Design Temperature (°F) ²⁸⁹	$\Delta T_{heating}$
1	10.8	54.2
2	23.4	41.6
3	31.4	33.6
4	34.6	30.4
5	25.7	39.3

²⁸⁸ ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

²⁸⁹ ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

Deemed Energy and Demand Savings

There are no deemed energy or demand savings for this measure.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for small commercial ceiling insulation is 25 years to match residential ceiling insulation.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Base R-value of original insulation
- R-value of installed insulation
- Building type
- Cooling efficiency: a photo of the HVAC nameplate photo OR an evaluator pre-approved inspection approach
- Heating type/efficiency (Gas, electric heat pump, electric resistance heat)
 - Additional documentation is required to validate heat pump and electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach);
- Square footage of conditioned space directly below the treated attic
- Two pictures: (1) a picture showing the entire attic floor, and (2) a closeup picture of a ruler that shows the measurement of the depth of the insulation
Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.

Petitions and Rulings

Not applicable.

Document Revision History

Table 138. Ceiling Insulation—Revision History

TRM version	Date	Description of change
v13.0	10/2025	Measure origin.

2.4 NONRESIDENTIAL: FOOD SERVICE EQUIPMENT

2.4.1 ENERGY STAR® Combination Ovens Measure Overview

TRM Measure ID: NR-FS-CO

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: All commercial kitchens

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 combination ovens. Combination ovens are convection ovens that include the added capability to inject steam into the oven cavity and typically offer at least three distinct cooking modes: combination mode to roast or bake with moist heat, convection mode to operate purely as a convection oven providing dry heat, and straight pressure-less steamer. The energy and demand savings are determined on a per-oven basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specifications, with half-size and full-size ovens as defined below and a pan capacity ≥ 3 and ≤ 40 .^{290, 291}

- Full-size combination oven: capable of accommodating two 12.7 x 20.8 x 2.5-inch steam table pans per rack position, loaded from front-to-back or lengthwise.
- Half-size combination oven: capable of accommodating a single 12.7 x 20.8 x 2.5-inch steam table pan per rack position, loaded from front-to-back or lengthwise.
- Two-thirds-size combination ovens were added to the current ENERGY STAR specification but are excluded from this measure until the ENERGY STAR food service calculator is updated to include category-specific input assumptions.

²⁹⁰ ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf.

²⁹¹ ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results>.

Eligible building types include any nonresidential application.

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

- Dual-fuel heat source combination 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
- Full- and half-size gas combination ovens with a pan capacity of < 5 or > 40
- Full- and half-size electric combination ovens with a pan capacity of < 3 or > 40
- Two-thirds-size combination ovens with a pan capacity > 5
- Mini and quadruple gas rack ovens
- Electric rack ovens

Baseline Condition

The baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20 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 139.

Table 139. Combination Ovens—ENERGY STAR Specification²⁹²

Operation	Idle rate (kW) ²⁹³	Cooking energy efficiency (%)
Full-size and half-size ovens with 5–40 pan capacity		
Steam mode	$\leq 0.133P + 0.64$	≥ 55
Convection mode	$\leq 0.083P + 0.35$	≥ 78
Full-size and half-size ovens with 3–4 pan capacity		
Steam mode	$\leq 0.60P$	≥ 51
Convection mode	$\leq 0.05P + 0.55$	≥ 70

²⁹² ENERGY STAR Commercial Ovens Key Product Criteria.
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

²⁹³ P = Pan capacity.

Furthermore, pan capacity²⁹⁴ must be ≥ 3 and ≤ 40 (for both half- and full-size combination ovens). Pan capacity must be ≥ 3 and ≤ 5 for two-thirds-size combination ovens.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

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

Equation 102

$$kWh_{base} = kWh_{conv,base} + kWh_{st,base}$$

Equation 103

$$kWh_{ES} = kWh_{conv,ES} + kWh_{st,ES}$$

Equation 104

kWh_{conv} and kWh_{st} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 105, except they require their respective input assumptions relative to preheat, cooking and idle operation in convection and steam modes as seen in Table 140.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times DOH \times E_{food} \times 50\%}{\eta_{cook}} \right) + E_{idle} \times \left(\left(DOH - \frac{W_{food} \times DOH}{PC} \right) \times 50\% \right) \right) \times \frac{AOD}{1,000}$$

Equation 105

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

Equation 106

Where:

kWh_{base}	=	Baseline annual energy consumption [kWh]
kWh_{ES}	=	ENERGY STAR annual energy consumption [kWh]
E_{ph}	=	Preheat energy [Wh]
ΔE_{ph}	=	Difference in baseline and ENERGY STAR preheat energy

²⁹⁴ Pan capacity is defined as the number of steam table pans the combination oven can accommodate as per the ASTM F-1495-05 standard specification.

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 hour [lb/hr]
η_{cook}	=	Cooking energy efficiency [%]
PC	=	Production capacity per hour [lb/hr]
DOH	=	Equipment daily operating hours [hr/day]
AOD_s	=	Facility annual operating days [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

Table 140. Combination Ovens—Savings Calculation Input Assumptions²⁹⁵

Parameter		Convection mode		Steam mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	$P < 5$	410		600	
	$5 \geq P < 15$	3,000	1,500	3,000	1,500
	$P \geq 15$	3,750	2,000	3,750	2,000
W_{food}	$P < 5$	10.4			
	$5 \geq P < 15$	16.7			
	$P \geq 15$	20.8			
E_{food}		73.2		30.8	
η_{cook}	$3 \geq P < 5$	65%	70%	47%	51%
	$P \geq 5$	72%	78%	52%	55%
E_{idle}^{296}	$3 \geq P < 5$	680	700	2,090	1,800
	$5 \geq P < 15$	1,320	1,180	5,260	1,970
	$P \geq 15$	2,280	2,010	8,710	3,300
PC^{297}	$P < 5$	29	37	45	59
	$P \geq 5$	107	174	151	247

²⁹⁵ ENERGY STAR Commercial Food Service Equipment Calculator. March 2024 update.
https://www.energystar.gov/products/commercial_food_service_equipment.

²⁹⁶ Idle estimates are generalized into three ranges (3-4, 5-14, ≥ 15). Calculation for idle energy uses the most representative capacity for each range, which were 3 pan, 10 pan, and 20 pan.

²⁹⁷ The 3/2021 ENERGY STAR calculator update no longer varies C_{cap} by pan capacity. However, this is assumed to be an error. The values specified for pan capacity of 15 or greater are specified in the previous calculator version.

Table 141. Combination Ovens—Operating Schedule Assumptions²⁹⁸

Building type	DOH	AOD	CF ^{299,300}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	12	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

Table 142. Combination Ovens—Energy and Peak Demand Savings (Education: K-12)

Pan capacity	kWh savings	kW savings
3-4	104	0.042
5-14	2,202	0.677
15-40	3,216	1.053

Table 143. Combination Ovens—Energy and Peak Demand Savings (Education: College and university)

Pan capacity	kWh savings	kW savings
3-4	249	0.061
5-14	4,781	0.985
15-40	7,135	1.532

Table 144. Combination Ovens—Energy and Peak Demand Savings (All Other)

Pan capacity	kWh savings	kW savings
3-4	420	0.086
5-14	7,835	1.385
15-40	11,764	2.155

Claimed Peak Demand Savings

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

²⁹⁸ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

²⁹⁹ 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.

³⁰⁰ Adjusted CF for Education = All other CF × (AOD ÷ 365).

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.³⁰¹

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
- Facility type (Education: K-12, Education: College and university, All other)

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 145. Combination Ovens—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.

³⁰¹ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

TRM version	Date	Description of change
v3.0	04/10/2015	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	Updated title to reflect ENERGY STAR measure.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	Incorporated March 2021 calculator updates. Corrected ENERGY STAR idle rate formulas. Updated tracking system requirements and EUL reference.
v10.0	10/2022	Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	No revision.
v12.0	10/2024	Specified reduced operating schedule for education applications. Aligned deemed savings tables and calculations input assumptions to ENERGY STAR March 2024 update.
v13.0	10/2025	Simplified savings estimates to three categories. Reduced CF for education applications proportional to AOD.

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: All commercial kitchens

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:^{302, 303}

- 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.

Eligible building types include any nonresidential application.³⁰⁴

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

³⁰² ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf.

³⁰³ ENERGY STAR Qualified Product Listing. <https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results>.

³⁰⁴ CEE Commercial Kitchens Initiative's overview of the food service industry. <https://cee1.my.site.com/>.

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

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 146.

Table 146. Convection Ovens—ENERGY STAR Specification³⁰⁵

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:

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

³⁰⁵ ENERGY STAR Commercial Ovens Key Product Criteria.
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

Equation 107

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

Equation 108

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

Equation 109

kWh_{ph} , kWh_{cook} , and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 110, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 147.

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

Equation 110

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

Equation 111

Where:

kWh_{base}	=	Baseline annual energy consumption [kWh]
kWh_{ES}	=	ENERGY STAR annual energy consumption [kWh]
E_{ph}	=	Preheat energy [Wh]
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/hr]
η_{cook}	=	Cooking energy efficiency [%]
PC	=	Production capacity [lb/hr]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Coincidence factor

Table 147. Convection Ovens—Savings Calculation Input Assumptions³⁰⁶

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}						8.33
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

Table 148. Convection Ovens—Operating Schedule Assumptions³⁰⁷

Building type	DOH	AOD	CF ^{308,309}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	12	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

Table 149. Convection Ovens—Energy and Peak Demand Savings

Building type	Oven size	kWh savings	kW savings
Education: K-12	Full size ≥ 5 pans	766	0.299
	Full size < 5 pans	1,158	0.459
	Half size	77	0.018

³⁰⁶ ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

³⁰⁷ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

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.

³⁰⁹ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Building type	Oven size	kWh savings	kW savings
Education: College and university	Full size ≥ 5 pans	1,814	0.435
	Full size < 5 pans	2,758	0.668
	Half size	153	0.025
All other	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.³¹⁰

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
- Facility type (Education: K-12, Education: College and university, All other)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

³¹⁰ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Relevant Standards and Reference Sources

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

Document Revision History

Table 150. Convection Ovens—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	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	Updated title to reflect ENERGY STAR Measure.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Corrected convection oven definitions. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	Incorporated changes from March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	No revision.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.3 Electric Deck Ovens

TRM Measure ID: NR-FS-DO

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: All commercial kitchens

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

A commercial electric deck oven is an appliance that cooks food products within a heated chamber. The food product can be placed directly on the floor of the chamber during cooking and energy is delivered to the food product by convective, conductive, or radiant heat transfer. The chamber can be heated by electric forced convection, radiation, or quartz tubes. The top and bottom heat of the oven can be controlled independently.

Deck ovens are available in various sizes measured by the surface area of the oven cavity floor. Sizes range from approximately 1,000 sq. in. to 2,200 sq. ft. Deck ovens are typically stackable to allow for multiple ovens on a single floor space.

Deck oven performance is determined by applying the American Society for Testing and Materials (ASTM) Standard Test Method for Performance of Deck Ovens F1965-99, the industry standard for quantifying the efficiency and performance of commercial deck ovens.

The following metrics define deck oven energy performance:

- *Cooking energy efficiency:* Quantity of energy imparted to the specific food product, expressed as a percentage of energy consumed by the deck oven during the cooking event.
- *Idle energy rate:* The deck oven's rate of energy consumption (Btu/h or kW), when emptied, required to maintain its cavity temperature at the specified thermostat set point.
- *Production capacity:* The maximum rate (lb/hr) at which a deck oven can bring the specified food product to a specified cooked condition.

Eligibility Criteria

This measure only applies to deck ovens installed in retrofit applications. New construction applications are ineligible unless pre-approved by the evaluator. Eligible units must meet the criteria described in the high-efficiency condition.

The following products are excluded from the eligibility criteria:

- Gas or dual-fuel heat source deck ovens
- Used or rebuilt deck ovens
- Replacement of gas deck ovens

Eligible building types include any nonresidential application.

Baseline Condition

There are currently no federal minimum standards for commercial electric deck ovens. Therefore, the baseline condition is defined as an electric deck oven that does not meet program criteria. Consequently, the baseline condition for existing models was established through lab-based performance tests conducted by the Southern California Edison Foodservice Technology Center (SCE FTC) and Pacific Gas & Electric Food Service Technology Center (PG&E FSTC).

Generally, new construction is ineligible to claim savings under this measure. However, utilities may work with the EM&V team to determine the baseline standard for new construction applications, if applicable.

High-Efficiency Condition

Eligible equipment must meet the energy efficiency and idle rate requirement from Table 151.

Table 151. Deck Ovens—Measure Case Specification

Operation	Criteria
Cooking energy efficiency	≥ 60%
Idle energy rate	≤ 1.3 kW

In absence of lab testing, eligible products must be included on the current California Energy Wise Foodservice Qualified Product Listing (QPL).³¹¹

³¹¹ CA Energy Wise Foodservice QPL. <https://caenergywise.com/instant-rebates/qpl/>. For assistance with qualifying new models, reach out to the California Foodservice Instant Rebates program. <https://caenergywise.com/instant-rebates/#contact-us>.

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The annual electric unit energy savings is calculated as the difference between the baseline and measure case unit energy consumption (UEC). The daily electric UEC (baseline or measure case) is equal to the sum of the energy required for cooking, preheat, and idle modes of oven operation. The calculations below represent the measure case condition.

The inputs for calculating the yearly UEC of a commercial electric deck oven are specified below. The days of operation are calculated from on-site monitored data and survey responses, as shown in the referenced source. The commercial cooktop hours of operation day were derived from field data from 14 test sites, assuming one boil cycle per hour. The field monitoring sample included quick- and full-service restaurants, hospitality locations, and cafeterias.

The deemed values are calculated by using the following equations:

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

Equation 112

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

Equation 113

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

Equation 114

Annual kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and measure cases, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 152. Peak demand savings are calculated by Equation 118 using their respective input assumptions from Table 152.

$$kWh_{ph} = N_{ph} \times E_{ph} \times AOD$$

Equation 115

$$kWh_{cook} = \left(\frac{W_{food} \times E_{food}}{\eta_{cook}} \right) \times AOD$$

Equation 116

$$kWh_{idle} = E_{idle} \times \left(DOH - \frac{W_{food}}{PC} - (N_{ph} \times t_{ph}) \right) \times AOD$$

Equation 117

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{DOH \times AOD} \times CF$$

Equation 118

Where:

$kWh_{cook,base}$	=	Cooking energy, baseline, annual [kWh]
$kWh_{cook,measure}$	=	Cooking energy, measure case, annual [kWh]
$kWh_{idle,base}$	=	Idle energy, baseline, annual [kWh]
$kWh_{idle,measure}$	=	Idle energy, measure case, annual [kWh]
$kWh_{ph,base}$	=	Preheat energy, baseline, annual [kWh]
$kWh_{ph,measure}$	=	Preheat energy, measure case, annual [kWh]
η_{cook}	=	Cooking energy efficiency
E_{ph}	=	Measured preheat energy [kWh]
E_{food}	=	Cooking energy efficiency
E_{idle}	=	Measured idle energy rate [kW]
W_{food}	=	Estimated pounds of food cooked per day [lbs]
PC	=	Measured production capacity [lbs/hr]
N_{ph}	=	Estimated number of preheats per day [#]
t_{ph}	=	Estimated preheat time [hr]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
CF	=	Peak coincidence factor

Table 152. Deck Ovens—Calculation Inputs³¹²

Parameter	Baseline	High-efficiency
η_{cook}	40%	60%
E_{ph} (kWh)	6.5	3.0
E_{food} (kWh/lb)	0.0732	
E_{idle} (kW)	1.9	1.3
W_{food} (lb/day)	200	
PC (lb/hr)	60	
N_{ph}	1	
t_{ph} (hr)	0.5	

³¹² Input assumptions were developed through lab-based equipment performance tests conducted by the SCE FTC and PG&E FSTC.

Table 153. Deck Ovens—Operating Schedule Assumptions³¹³

Building type	DOH	AOD	CF ^{314,315}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	12	355	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following table are based on the input assumptions from Table 152.

Table 154. Deck Ovens—Annual Energy and Peak Demand Savings

Building type	Energy savings (kWh)	Peak demand savings (kW)
Education: K-12	3,060	1.25
Education: College and university	5,044	1.24
All other	7,313	1.55

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL IDs Cook-ElecCombOven and Cook-ElecConvOven.³¹⁶

³¹³ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³¹⁴ 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.

³¹⁵ Adjusted CF for Education = All other CF × (AOD ÷ 365).

³¹⁶ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Building type
- Oven quantity
- Manufacturer and model number
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility equipment AOD and DOH (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 155. Deck Ovens—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.4 ENERGY STAR® Dishwashers Measure Overview

TRM Measure ID: NR-FS-DW

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: All commercial kitchens and multifamily buildings

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.^{317, 318} These categories are described in Table 156:

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

³¹⁷ ENERGY STAR Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria v3.0. https://www.energystar.gov/products/commercial_dishwashers/partners.

³¹⁸ ENERGY STAR Qualified Product Listing. <https://www.energystar.gov/productfinder/product/certified-commercial-dishwashers/results>.

Eligible building types include any nonresidential application.³¹⁹

Dishwashers intended for use in residential or laboratory applications are not eligible for ENERGY STAR under this product specification. Residential equipment is eligible for installation in commercial applications. In this scenario, refer to the residential savings methodology described in Volume 2. 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 156. 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.

³¹⁹ CEE Commercial Kitchens Initiative's overview of the Food Service Industry: <https://cee1.my.site.com/>

Baseline Condition

Baseline equipment is either a low-temperature³²⁰ or high-temperature³²¹ machine as defined by Table 156, 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 157.

Table 157. Dishwashers—ENERGY STAR Specification³²²

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 (UC)	≤ 0.25	≤ 1.19	≤ 0.30	≤ 0.86
Stationary single-tank door (SSTD)	≤ 0.30	≤ 1.18	≤ 0.55	≤ 0.89
Single-tank conveyor (STC)	≤ 0.85	≤ 0.79	≤ 1.20	≤ 0.70
Multiple-tank conveyor (MTC)	≤ 1.00	≤ 0.54	≤ 1.85	≤ 0.54
Pot, pan, and utensil (PP&U)	–	–	≤ 0.90	≤ 0.58 ³²³

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values are calculated using the following algorithms:

³²⁰ Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

³²¹ High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

³²² ENERGY STAR Commercial Dishwashers Key Product Criteria.
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria.

³²³ Water consumption for pot, pan, and utensil is specified in gallons-per-square-foot rather than gallons-per-rack.

Energy Savings [ΔkWh]

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

Equation 119

$$V_{base} = AOD \times DOH \times N_{racks} \times V_{rack,base}$$

Equation 120

$$V_{ES} = AOD \times DOH \times N_{racks} \times V_{rack,ES}$$

Equation 121

$$Peak Demand Savings [\Delta kW] = \frac{\Delta kWh}{DOH \times AOD} \times CF$$

Equation 122

Where:

ρ_{water}	=	Density of water [lb/gallon]
C_p	=	Specific heat of water [Btu/lb °F]
ΔT_{DHW}	=	Inlet water temperature increase for building water heater [°F]
ΔT_{boost}	=	Inlet water temperature for booster water heater [°F]
η_{DHW}	=	Building electric water heater and booster heater efficiency [%]
N_{racks}	=	Number of racks washed per hour
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]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
3,412	=	Constant to convert from Btu to kWh
60	=	Constant to convert from minutes to hours
CF	=	Peak coincidence factor

Table 158. Dishwashers—Savings Calculation Input Assumptions³²⁴

Inputs	UC	SSTD	STC	MTC	PP&U
ρ_{water}	61.4 ÷ 7.48 = 8.2				
C_p	1.0				
ΔT_{DHW}	Gas water heaters: 0°F Electric water heaters: 70 °F				
ΔT_{boost}	Gas booster heaters: 0 °F Electric booster heaters: 40 °F				
η_{DHW}	98%				
Low-temperature units					
N_{racks} per hr	4.17	15.560	22.22	33.33	–
$V_{\text{rack,base}}$	1.73	2.10	1.31	1.04	–
$V_{\text{rack,ES}}$	1.19	1.18	0.79	0.54	–
$E_{\text{idle,base}}$	0.50	0.60	1.60	2.00	–
$E_{\text{idle,ES}}$	0.25	0.30	0.85	1.00	–
t_{wash}	2.0	1.5	0.3	0.3	–
High-temperature units					
N_{racks} per hr	4.17	15.56	22.22	33.33	15.56
$V_{\text{rack,base}}$	1.09	1.29	0.87	0.97	0.70
$V_{\text{rack,ES}}$	0.86	0.89	0.70	0.54	0.58
$E_{\text{idle,base}}$	0.76	0.87	1.93	2.59	1.20
$E_{\text{idle,ES}}$	0.30	0.55	1.20	1.85	0.90
t_{wash}	2.0	1.0	0.3	0.2	3.0

³²⁴ ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Table 159. Dishwashers—Operating Schedule Assumptions³²⁵

Building type	DOH	AOD	CF ^{326,327}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	18	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above. Dual sanitizing dishwashers, with options for high and low temperature sanitization, should select the high temperature savings category unless documentation is provided demonstrating the use of low temperature/chemical sanitization is provided.

Table 160. Dishwashers—Energy and Peak Demand Savings (Education: K-12)

Facility description	UC		SSTD		STC		MTC		PP&U	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Low temp./electric water heater	650	0.265	2,854	1.163	2,865	1.167	3,993	1.627	—	—
High temp./electric water heater with electric booster heater	707	0.288	2,071	0.844	1,803	0.734	4,891	1.992	616	0.251
High temp./gas water heater with electric booster heater	529	0.216	916	0.373	1,101	0.449	2,230	0.909	270	0.110
High temp./electric water heater with gas booster heater	606	0.247	1,411	0.575	1,402	0.571	3,371	1.373	418	0.170

³²⁵ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³²⁶ 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.

³²⁷ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Table 161. Dishwashers—Energy and Peak Demand Savings (Education: College/University)

Facility description	UC		SSTD		STC		MTC		PP&U	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Low temp./ electric water heater	1,565	0.385	6,871	1.691	6,896	1.698	9,613	2.366	—	—
High temp./ electric water heater with electric booster heater	1,703	0.419	4,985	1.227	4,339	1.068	11,774	2.898	1,484	0.365
High temp./gas water heater with electric booster heater	1,275	0.314	2,205	0.543	2,652	0.653	5,370	1.322	650	0.160
High temp./ electric water heater with gas booster heater	1,458	0.359	3,396	0.836	3,375	0.831	8,114	1.997	1,007	0.248

Table 162. Dishwashers—Energy and Peak Demand Savings (All Other)

Facility description	UC		SSTD		STC		MTC		PP&U	
	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 163. 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
- Machine type
- Sanitization method (high temperature, low temperature)
- 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
- Facility type (Education: K-12, Education: College and university, All other)

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 164. Dishwashers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Update savings based on the newest version of ENERGY STAR deemed input variables.
v2.1	01/30/2015	Corrections to Water Use per Rack in Table 2-90.
v3.0	04/30/2015	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	Added high-efficiency requirements for pots, pans, and utensils.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	General reference checks and text edits. Updated ENERGY STAR specification and incorporated March 2021 calculator update. Updated variable definitions.
v10.0	10/2022	Corrected mismatch between formula definitions and variables. Replaced URL for ENERGY STAR listing.
v11.0	10/2023	Clarified that residential dishwashing equipment can be installed in commercial applications following the methodology in Volume 2 of TRM.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables. Added guidance for dual sanitizing dishwashers and updated documentation requirements.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.5 ENERGY STAR® Electric Griddles Measure Overview

TRM Measure ID: NR-FS-GR

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: All commercial kitchens

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 electric griddles. Commercial griddles are a versatile piece of cooking equipment with a flat cooking surface whose uses range from searing, browning, toasting, and warming. An energy-efficient commercial electric griddle reduces energy consumption primarily through the application of advanced controls and improved temperature uniformity. The energy and demand savings are determined on a per-griddle basis and only considers electric commercial griddles.

Eligibility Criteria

Eligible units must comply with the current ENERGY STAR specifications.³²⁸ The efficiency requirements for this appliance are evaluated on a per-square-foot basis.

Eligible building types include any nonresidential application.³²⁹

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

- Gas or dual-fuel heat source griddles
- Dual technology griddles such as fry-top ranges

Baseline Condition

There are currently no federal minimum standards for commercial griddles. Therefore, the baseline condition for retrofit situations is a single-sided or double-sided electric griddle that does not meet the ENERGY STAR key product criteria.

³²⁸ ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-griddles/results>.

³²⁹ "Commercial Kitchens Initiative," Consortium for Energy Efficiency (CEE). Section 2.2, p. 8. https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v1.2 specification, effective January 1, 2011.³³⁰ Qualified products must meet the minimum idle energy rate requirement from Table 165.

Table 165. Griddles—ENERGY STAR Specification³³¹

Operation	Criteria
Cooking energy efficiency at heavy-load conditions	Reported
Normalized idle energy rate	≤ 320 watts/ft ²

Furthermore, the ENERGY STAR qualification criteria do not specify a cooking-energy efficiency threshold and therefore shall only be recorded for evaluation of the energy savings.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

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

Equation 123

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

Equation 124

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

Equation 125

kWh_{ph} , kWh_{cook} , and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 14, except they require their respective input assumptions relative to preheat, cooking and idle operation as seen in Table 166.

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

Equation 126

³³⁰ ENERGY STAR Program Requirements for Commercial Griddles. Eligibility Criteria Version 1.2. <https://www.energystar.gov/sites/default/files/Commercial%20Griddles%20Version%201.2%20%28Rev%20December%20-%202020%29.pdf>.

³³¹ ENERGY STAR Commercial Griddles Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_product_criteria.

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

Equation 127

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 per pan [lb/hr]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

Table 166. Griddles—Savings Calculation Input Assumptions³³²

Parameter	Single-sided		Double-sided	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph} (Wh/ft ²)	667	333	667	333
W_{food} (lb/day/ ft ²)	17			
E_{food} (Wh/lb)	139		139	
η_{cook} (%)	65%	70%	65%	72%
E_{idle} (W/ft ²)	400	320	400	320
PC (lbs/hr/ft ²)	5.83	6.67	11.67	13.92

³³² ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Table 167. Griddles—Operating Schedule Assumptions³³³

Building type	DOH	AOD	CF ^{334,335}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	12	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

Table 168. Griddles—Energy and Peak Demand Savings (Education: K-12)

Griddle size (ft ²)	Single-sided		Double-sided	
	kWh	kW	kWh	kW
< 6	522	0.11	700	0.19
≥ 6 and < 8	783	0.17	1,049	0.28
≥ 8 and < 10	1,044	0.23	1,399	0.37
≥ 10 and < 12	1,305	0.29	1,749	0.47
≥ 12 and < 14	1,566	0.34	2,099	0.56
≥ 14	1,827	0.40	2,449	0.66

Table 169. Griddles—Energy and Peak Demand Savings (Education: College/University)

Griddle size (ft ²)	Single-sided		Double-sided	
	kWh	kW	kWh	kW
< 6	1,087	0.18	1,343	0.25
≥ 6 and < 8	1,630	0.27	2,015	0.37
≥ 8 and < 10	2,174	0.36	2,687	0.49
≥ 10 and < 12	2,717	0.46	3,358	0.61
≥ 12 and < 14	3,261	0.55	4,030	0.74
≥ 14	3,804	0.64	4,702	0.86

³³³ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³³⁴ 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.

³³⁵ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Table 170. Griddles—Energy and Peak Demand Savings (All Other)

Griddle size (ft ²)	Single-sided		Double-sided	
	kWh	kW	kWh	kW
< 6	1,759	0.26	2,120	0.34
≥ 6 and < 8	2,639	0.39	3,179	0.50
≥ 8 and < 10	3,519	0.52	4,239	0.67
≥ 10 and < 12	4,398	0.65	5,299	0.84
≥ 12 and < 14	5,278	0.78	6,359	1.01
≥ 14	6,158	0.92	7,418	1.17

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) Remote Ex-Ante Database Interface (READI) tool for EUL ID Cook-ElecGriddle.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.

- Manufacturer and model number
- Griddle top dimensions and surface area
- Griddle configuration (single-sided, double-sided)
- ENERGY STAR idle rate
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility type (Education: K-12, Education: College and university, All other)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

³³⁶ DEER READI. <https://cedars.cpuc.ca.gov/deer-resources/>.

Relevant Standards and Reference Sources

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

Document Revision History

Table 171. ENERGY STAR Griddles—Revision History

TRM version	Date	Description of change
v11.0	10/2023	Measure origin.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables. Updated griddle size to specify a range of griddle sizes based on normal rounding convention. Other minor text updates.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.6 ENERGY STAR® Electric Fryers Measure Overview

TRM Measure ID: NR-FS-EF

Market Sector: Commercial

Measure Category: Cooking equipment

Applicable Building Types: All commercial kitchens

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 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.^{337, 338}

- 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 any nonresidential application.³³⁹

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

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

³³⁷ 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>.

³³⁸ ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-fryers/results>.

³³⁹ CEE Commercial Kitchens Initiative's overview of the Food Service Industry: <https://cee1.my.site.com/>.

Baseline Condition

The baseline condition is an electric standard-size fryer or large vat fryer 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 and large vat fryers must meet or exceed the requirements listed in Table 172.

Table 172. Fryers—ENERGY STAR Specification³⁴⁰

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:

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

Equation 128

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

Equation 129

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

Equation 130

kWh_{ph} , kWh_{cook} , and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 131, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 173.

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

Equation 131

³⁴⁰ ENERGY STAR Commercial Fryers Key Product Criteria.

https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria.

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

Equation 132

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 hour [lb/hr]
η_{cook}	=	Cooking energy efficiency [%]
PC	=	Production capacity [lb/hr]
t_{ph}	=	Preheat time [min/day]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
60	=	Constant to convert from min to hr
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

Table 173. Fryers—Savings Calculation Input Assumptions³⁴¹

Parameter	Standard-sized vat		Large vat	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
E _{ph}	2,400	1,900	2,400	1,900
W _{food}	9.375		12.5	
E _{food}	167			
η _{cook}	75%	83%	70%	80%
E _{idle}	1,200	800	1,350	1,100
PC	65	70	100	110
t _{ph}	15			

Table 174. Fryers—Operating Schedule Assumptions³⁴²

Building type	DOH, standard	DOH, Large vat	AOD	CF ^{343,344}
Education: K-12	6	6	180	0.44
Education: College and university	10	10	260	0.64
All other	16	12	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 175 are based on the assumptions specified above.

Table 175. Fryers—Energy and Peak Demand Savings

Building type	Fryer type	kWh savings	kW savings
Education: K-12	Standard	650	0.228
	Large vat	704	0.250

³⁴¹ ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

³⁴² Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³⁴³ 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.

³⁴⁴ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Building type	Fryer type	kWh savings	kW savings
Education: College and university	Standard	1,496	0.336
	Large vat	1,619	0.367
All other	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.³⁴⁵

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 type (standard or large vat)
- 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
- Facility type (Education: K-12, Education: College and university, All other)

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.

³⁴⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Document Revision History

Table 176. Fryers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	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	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Savings and efficiencies revised for ENERGY STAR 3.0 specifications. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	Incorporated March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	Minor variable definition updates.
v11.0	10/2023	Updated documentation requirements to collect fryer type rather than fryer width.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.7 ENERGY STAR® Electric Steam Cookers Measure Overview

TRM Measure ID: NR-FS-SC

Market Sector: Commercial

Measure Category: Cooking equipment

Applicable Building Types: All commercial kitchens

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 $\geq$ 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.^{346, 347} Eligible building types include any nonresidential application..³⁴⁸

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

Baseline Condition

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

³⁴⁶ 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.

³⁴⁷ ENERGY STAR Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results>.

³⁴⁸ CEE Commercial Kitchens Initiative's overview of the Food Service Industry: <https://cee1.my.site.com/>.

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 177.

Table 177. Steam Cookers—ENERGY STAR Specification³⁴⁹

Pan capacity	Cooking energy efficiency (%) ³⁵⁰	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

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

Equation 133

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

Equation 134

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

Equation 135

kWh_{ph} , kWh_{cook} , and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 134, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 178.

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

Equation 136

³⁴⁹ ENERGY STAR Commercial Steam Cookers Key Product Criteria.

https://www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria.

³⁵⁰ 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.

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

Equation 137

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 or 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 hour [lb/hr]
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
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

Table 178. Steam Cookers—Savings Calculation Input Assumptions³⁵¹

Parameter	Baseline value	ENERGY STAR value
E _{ph}	1,776	1,671.7
W _{food}		10.81
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

Table 179. Steam Cookers—Operating Schedule Assumptions³⁵²

Building type	DOH	AOD	CF ^{353,354}
Education: K-12	6	180	0.44
Education: College and university	9.25	260	0.64
All other		311	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

³⁵¹ ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

³⁵² Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³⁵³ 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.

³⁵⁴ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Table 180. Steam Cookers—Energy and Peak Demand Savings (Education: K-12)

Steam cooker type	P	kWh savings	kW savings
Boiler-based	3-pan	3,006	1.217
	4-pan	3,694	1.497
	5-pan	4,367	1.771
	6-pan and larger	5,040	2.046
Steam generator	3-pan	2,528	1.022
	4-pan	3,062	1.240
	5-pan	3,579	1.450
	6-pan and larger	4,095	1.661

Table 181. Steam Cookers—Energy and Peak Demand Savings (Education: College/University)

Steam cooker type	P	kWh savings	kW savings
Boiler-based	3-pan	6,678	1.770
	4-pan	8,211	2.178
	5-pan	9,710	2.577
	6-pan and larger	11,210	2.976
Steam generator	3-pan	5,614	1.487
	4-pan	6,804	1.803
	5-pan	7,955	2.110
	6-pan and larger	9,105	2.416

Table 182. Steam Cookers—Energy and Peak Demand Savings (All Other)

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

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.³⁵⁵

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
- Facility type (Education: K-12, Education: College and university, All other)

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 183. Steam Cookers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	Updated EUL based on ENERGY STAR and DEER 2014.
v3.0	04/10/2015	Updated to newer ENERGY STAR Steam Cooker Program Requirements Version 1.2. Simplified calculation methodology to a

³⁵⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

TRM version	Date	Description of change
		single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	Incorporated March 2021 calculator update. Corrected formula errors. Updated EUL reference.
v10.0	10/2022	Corrected formula error and minor variable definition updates.
v11.0	10/2023	No revision.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.8 Contact Conveyor Toasters

TRM Measure ID: NR-FS-CT

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: All commercial kitchens

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 section presents the deemed savings methodology for commercial electric contact conveyor toasters. These appliances, which caramelize and transport bread products through a heated chamber via a belt or chain, utilize resistance heating elements within heavy metal plates known as "platens." The design of high-performance conveyor toasters (HPCT) includes advanced features such as internal ambient air heaters and heat shields to optimize thermal efficiency by maintaining consistent temperatures and minimizing heat loss. Dampers at the openings regulate internal airflow, enhancing temperature stability and energy conservation. The energy and demand savings are determined per contact conveyor toaster, and only electric contact conveyor toasters are considered.

Eligibility Criteria

The eligible units must meet the energy-per-sandwich requirement specified in the High Efficiency Condition section. Only contact conveyor toasters qualify for this measure.

Eligible building types include any nonresidential application.

Baseline Condition

Commercial conveyor toasters are not regulated by state or national codes. Therefore, equipment manufacturers often need more incentives to test baseline models. Consequently, the baseline condition for existing models was established using a sample of economy-grade equipment tested by Southern California Edison Foodservice Technology Center (SCE FTC). The base case is defined as a standard performance conveyor toaster with an energy consumption per sandwich exceeding 3.75 W per bun and other specifications shown in Table 184 below.

Generally, new construction is ineligible to claim savings under this measure. However, utilities may work with the EM&V team to determine the baseline standard for new construction applications, if applicable.

Table 184. Contact Conveyor Toasters—Baseline Lab-Tested Specification

Energy per sandwich (W-Hr/bun)	Idle energy rate (kW)	Cooking energy rate (kW)	Preheat energy rate (kW)	Preheat time (min)	Production capacity (units/Hr)
≥ 3.75	0.982	2.04	2.33	21.42	338.00

High-Efficiency Condition

Eligible units must not exceed energy-consumption-per-sandwich of 3.75 W per bun, as calculated in Equation 138, and other lab-tested specifications, as shown in Table 185. This is assessed following the ASTM F2380-18 test procedure.³⁵⁶ The specification was developed based on lab-based equipment performance tests conducted collaboratively by the Pacific Gas & Electric (PG&E) Food Service Technology Center (FSTC) and SCE FTC.

In absence of lab testing, eligible products must be included on the current California Energy Wise Foodservice Qualified Product Listing (QPL).³⁵⁷

Table 185. Contact Conveyor Toasters—Lab-Tested Specifications

Energy per sandwich (W-Hr/bun)	Idle energy rate (kW)	Cooking energy rate (kW)	Preheat energy rate (kW)	Preheat time (min)	Production capacity (units/Hr)
≤ 3.75	0.64	2.06	2.12	9.83	698

$$\text{Energy per sandwich} = \frac{E_{\text{cook}} \times 1,000}{PC}$$

Equation 138

Where:

E_{cook}	=	Cooking energy rate [kW]
1,000	=	Constant to convert from W to kW
PC	=	Production capacity (buns/hour)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

³⁵⁶ ASTM Standard Test Method for Performance of Conveyor Toasters. <https://www.astm.org/f2380-18.html>.

³⁵⁷ California Energy Wise Foodservice QPL. <https://caenergywise.com/instant-rebates/qpl/>. For assistance with qualifying new models, reach out to the California Foodservice Instant Rebates program. <https://caenergywise.com/instant-rebates/#contact-us>.

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

Equation 139

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

Equation 140

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

Equation 141

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and high-efficiency cases, as shown in Equation 140, and the peak demand savings calculation, as shown in Equation 143, except they require their respective input assumptions relative to preheat, cooking, and idle operation, as seen in Table 186.

$$kWh = \left(\left(E_{ph} \times N_{ph} \times \frac{t_{ph}}{60} \right) + \left(\frac{E_{cook} \times N_{buns}}{PC} \right) + \left(E_{idle} \times \left(t_{on} - \frac{N_{buns}}{PC} - \frac{N_{ph} \times t_{ph}}{60} \right) \right) \right) \times t_{days}$$

Equation 142

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

Equation 143

Where:

kWh_{base}	=	Baseline annual energy consumption [kWh]
kWh_{HE}	=	High-efficiency annual energy consumption [kWh]
kWh_{ph}	=	Preheat energy [kWh]
kWh_{cook}	=	Cooking energy [kWh]
kWh_{idle}	=	Idle energy [kWh]
E_{ph}	=	Preheat energy rate [kW]
E_{idle}	=	Idle energy rate [kW]
N_{ph}	=	Number of preheats per day
N_{buns}	=	Number of sandwich buns cooked per day
t_{ph}	=	Estimated preheat time [min]
60	=	Constant to convert from minutes to hours
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
CF	=	Peak coincidence factor

Table 186. Contact Conveyor Toasters—Savings Calculation Input Assumptions³⁵⁸

Parameter	Baseline	High efficiency
E _{ph} (kW)	2.33	2.12
E _{cook} (kW)	2.04	2.06
E _{idle} (kW)	0.98	0.64
PC (buns/hr)	338	698
N _{ph} (PH/day)	1	
N _{buns} (buns/day) ³⁵⁹	650	
t _{ph} (min)	21	10

Table 187. Contact Conveyor Toasters—Operating Schedule Assumptions³⁶⁰

Building type	DOH	AOD	CF ^{361,362}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other	16	364	0.90

Deemed Energy and Demand Savings Tables

The following table provides the estimated energy and demand savings per contact conveyor toaster based on the input assumptions from Table 186.

Table 188. Contact Conveyor Toasters—Energy and Peak Demand Savings

Building Type	Energy savings (kWh)	Peak demand savings (kW)
Education: K-12	550	0.22
Education: College and university	1,150	0.28
All other	2,358	0.36

³⁵⁸ Input assumptions primarily informed by lab-based equipment performance tests conducted by the SCE FTC and PG&E FSTC.

³⁵⁹ Emerging Technologies, "High-Performance Conveyorized Toaster: ET18SCE1120." June 2020. p. 31. https://www.caetrm.com/media/reference-documents/2020-06-12_h.e._toaster_report_final_draft.pdf.

³⁶⁰ Fisher-Nickel, Inc., "Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report." Prepared for the California Energy Commission. October 2014. Appendix E.

³⁶¹ 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.

³⁶² Adjusted CF for Education = All other CF × (AOD ÷ 365).

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

There is no estimated useful life (EUL) specifically for an electric toaster, but its method of operation is similar to that of an electric convection oven. Therefore, the 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-ElecConvOven.³⁶³

Program Tracking Data and Evaluation Requirements

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

- Building type
- Toaster quantity
- Manufacturer and model number
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility equipment AOD and DOH (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 189. Contact Conveyor Toasters—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	Updated coincidence factor for Education building types.

³⁶³ California Public Utilities Commission (CPUC), Energy Division. 2020.
https://www.caetrm.com/media/reference-documents/EEPolicyManualRevised_032020.pdf

2.4.9 Radiant Conveyor Toasters

TRM Measure ID: NR-FS-RT

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: All commercial kitchens

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 section covers the deemed savings methodology for the installation of commercial radiant conveyor toasters. A radiant conveyor toaster is an appliance that uses radiant heat to toast baked goods on both sides. It is placed on a belt and carried through a heated chamber, dropping to an unheated holding area for product pickup once the toasting cycle is complete.

Advanced radiant conveyor toasters optimize energy usage by employing sensors to detect activity. Energy-efficient models feature a setback mode, which reduces energy consumption during periods of activity by lowering cavity temperature and slowing or stopping the conveyor belt.

Eligibility Criteria

The eligible product must pertain to conveyor toasters that use radiant heat as the primary heat source for testing and utilize automation in activating an energy setback mode described in the High-Efficiency Condition section.

Eligible building types include any nonresidential application.

Baseline Condition

Commercial radiant toasters are not regulated by state or national codes. Therefore, equipment manufacturers often need more incentives to test baseline models. Consequently, the baseline condition for existing models was established using a sample of economy-grade equipment tested by the Southern California Edison Foodservice Technology Center (SCE FTC). The baseline condition is a radiant conveyor toaster without an automatic setback mode, whose specifications are shown in Table 190 below.

Generally, new construction is ineligible to claim savings under this measure. However, utilities may work with the EM&V team to determine the baseline standard for new construction applications, if applicable.

Table 190. Radiant Conveyor Toasters—Baseline Specification³⁶⁴

Outlet voltage	Time in cooking mode (%)
120 V	100%
208/240 V	

High-Efficiency Condition

The industry standard for evaluating radiant conveyor toaster energy consumption performance is the American Society Testing and Materials (ASTM) Standard F2380.³⁶⁵ This standard provides precise metrics that define radiant conveyor toaster energy performance.

- **Cooking rate:** The energy consumption of the toaster while conducting active toasting operations. The cooking rate can vary slightly depending on the exact heat settings, but it is generally close to the manufacturer-rated input.
- **Idle rate:** The energy consumption of the toaster while maintaining a ready-to-toast state unless an energy-saving or setback mode is activated. This is identical to the cooking rate.
- **Production capacity:** The toaster's maximum rate (slices per hour) can toast the product.

The eligible product must be a radiant conveyor toaster with automatic energy savings or setback mode and meet the specifications in Table 191. The specification was developed based on lab-based equipment performance tests conducted collaboratively by the Pacific Gas & Electric (PG&E) Food Service Technology Center (FSTC) and SCE FTC.

In absence of lab testing, eligible products must be included on the current California Energy Wise Foodservice Qualified Product Listing (QPL).³⁶⁶

Table 191. Radiant Conveyor Toasters—Lab-Tested Specification³⁶⁷

Outlet voltage	Time in cooking mode (%)
120 V	66.2%
208/240 V	

³⁶⁴ Energy Solutions (ES). 2022. "Conveyor Toaster Supporting Data."

³⁶⁵ Standard Test Method for Performance of Conveyor Toasters: <https://www.astm.org/f2380-18.html>.

³⁶⁶ CA Energy Wise Foodservice QPL. <https://caenergywise.com/instant-rebates/qpl/>. For assistance with qualifying new models, reach out to the California Foodservice Instant Rebates program. <https://caenergywise.com/instant-rebates/#contact-us>.

³⁶⁷ Energy Solutions (ES). 2022. "Conveyor Toaster Supporting Data."

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

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

Equation 144

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

Equation 145

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

Equation 146

kWh_{cook} , and kWh_{idle} are each calculated the same for both the baseline and high-efficiency cases, as shown in Equation 145 Equation 105, except they require their respective input assumptions, as seen in Table 192.

$$kWh = kW_{input} \times (PTCM + (PTSM \times SEF)) \times DOH \times AOD$$

Equation 147

Where:

kWh_{base}	=	Baseline annual energy consumption [kWh]
kWh_{ES}	=	High-efficiency annual energy consumption [kWh]
kWh_{cook}	=	Cooking energy [kWh]
kWh_{idle}	=	Idle energy [kWh]
kW_{input}	=	Average toaster input rate [kW]
$PTCM$	=	Percentage time spent in cooking mode [%]; see Table 190 and Table 191
$PTSM$	=	Percentage time spent in setback mode = $1 - PTCM$ [%]
SEF	=	Setback energy factor [%]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]

Table 192. Radiant Conveyor Toasters—Savings Calculation Input Assumptions³⁶⁸

Parameter	Baseline		High efficiency	
	120 V	208/240 V	120 V	208/240 V
kW _{input}	1.58	2.92	1.45	2.67
SEF	41.9%			

Table 193. Radiant Conveyor Toasters—Operating Schedule Assumptions³⁶⁹

Building Type	DOH	AOD
Education: K-12	6	180
Education: College and university	10	260
All other	10.4	344

Deemed Energy Savings Tables

The following table provides the estimated energy savings per radiant conveyor toaster based on the input assumptions from Table 192.

Table 194. Radiant Conveyor Toaster—Energy Savings

Building type	Outlet voltage	Annual energy savings (kWh)
Education: K-12	120 V	454
	208/240 V	836
Education: College and university	120 V	1,093
	208/240 V	2,014
All other	120 V	1,507
	208/240 V	2,778

³⁶⁸ Input assumptions primarily informed by lab-based equipment performance tests conducted by the SCE FTC and PG&E FSTC.

³⁶⁹ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

Deemed Demand Savings Tables

No peak demand savings are associated with the radiant conveyor toaster measure. Electric savings are expected during off-peak periods when the radiant conveyor toaster is not in active use. Peak periods will not exhibit substantial differences between baseline and efficient case radiant conveyor toasters.

Claimed Peak Demand Savings

Not applicable.

Measure Life and Lifetime Savings

There is no estimated useful life (EUL) specifically for an electric toaster, but its method of operation is similar to that of an electric convection oven. Therefore, the 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-ElecConvOven.³⁷⁰

Program Tracking Data and Evaluation Requirements

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

- Building type
- Toaster quantity
- Manufacturer and model number
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility equipment AOD and DOH (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.

³⁷⁰ California Public Utilities Commission (CPUC), Energy Division. 2020.
https://www.caetrm.com/media/reference-documents/EEPolicyManualRevised_032020.pdf

Document Revision History

Table 195. Radiant Conveyor Toasters—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	No revision.

2.4.10 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: All commercial kitchens

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.^{371, 372} Eligible building types include any nonresidential application.³⁷³

³⁷¹ 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.

³⁷² ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-hot-food-holding-cabinets/results>.

³⁷³ CEE Commercial Kitchens Initiative's overview of the Food Service Industry:
<https://cee1.my.site.com/>.

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 196 summarizes idle energy rate requirement based on cabinet interior volume.

Table 196. HFHCs—ENERGY STAR Specification^{374,375}

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

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

Deemed values are calculated using the following algorithms:

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

Equation 148

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

Equation 149

³⁷⁴ ENERGY STAR Commercial Fryers Key Product Criteria.

https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria.

³⁷⁵ V = Interior Volume which equals Interior Height x Interior Width x Interior Depth.

Where:

V	=	Product interior volume [ft ³]
$E_{Idle,base}$	=	Baseline idle energy rate [W]
$E_{Idle,ES}$	=	ENERGY STAR idle energy rate after installation [W]
DOH	=	Equipment daily operating hours [hrs/day]
AOD	=	Facility annual operating days [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

Table 197. HFHCs—Savings Calculation Input Assumptions³⁷⁶

Input variable	Product interior volume range		
	$0 < V < 13$	$13 \leq V < 28$	$28 \leq V$
V^{377}	8	22	53
$E_{Idle,base}$	$30 \times V$		
$E_{Idle,ES}$	$21.5 \times V$	$2 \times V + 254$	$3.8 \times V + 203.5$

Table 198. HFHCs—Operating Schedule Assumptions³⁷⁸

Building type	DOH	AOD	$CF^{379,380}$
Education: K-12	6	180	0.44
Education: College and university	9	260	0.64
All other		365	0.90

³⁷⁶ ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

³⁷⁷ Averages of product interior volume determined based on review of ENERGY STAR qualified product listing. Accessed 7/30/2020.

³⁷⁸ Fisher-Nickel, Inc., "Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report." Prepared for the California Energy Commission. October 2014. Appendix E.

³⁷⁹ 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.

³⁸⁰ Adjusted CF for Education = All other CF $\times$ (AOD $\div$ 365).

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 199 are based on the input assumptions specified above.

Table 199. HFHCs—Energy and Peak Demand Savings

Building type	Product interior volume (ft ³)	kWh savings	kW savings
Education: K-12	0 < V < 13	73	0.030
	13 ≤ V < 28	391	0.159
	28 ≤ V	1,280	0.521
Education: College and university	0 < V < 13	159	0.044
	13 ≤ V < 28	847	0.232
	28 ≤ V	2,773	0.758
All other	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.³⁸¹

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
- Facility type (Education: K-12, Education: College and university, All other)

³⁸¹ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

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.

Document Revision History

Table 200. HFHCs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	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	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits. Removed ENERGY STAR qualification requirement and deferred to meeting criteria.
v9.0	10/2021	Incorporated March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	Minor formatting.
v11.0	10/2023	No revision.
v12.0	10/2024	Specified reduced operating schedule for education applications and updated corresponding deemed savings tables.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.11 ENERGY STAR® Refrigerated Chef Bases

TRM Measure ID: NR-FS-CB

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: All commercial kitchens

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR refrigerated chef bases. A refrigerated chef base is used to keep ingredients, or prepared meals close to the cooking station, making food preparation more efficient. The capacity or size of a chef base is represented by its refrigerated volume. The refrigerated compartment can be equipped with drawers or doors according to customer specifications. A typical chef base operates using a conventional vapor compression refrigeration cycle charged with R-404a or R-290 propane. The energy and demand savings are determined on a per-volume basis.

Eligibility Criteria

Qualifying chef base models must meet ENERGY STAR Commercial Refrigerators and Freezers Version 5.0 specifications for chef bases.

Eligible building types include any non-residential application.³⁸²

The following products are excluded from the eligibility criteria:

- Used or rebuilt equipment

Baseline Condition

The baseline condition for retrofit situations is a refrigerated chef base unit that does not meet the ENERGY STAR key product criteria.

³⁸² "Commercial Kitchens Initiative," Consortium for Energy Efficiency (CEE). Section 2.2, p. 8.
https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

High-Efficiency Condition

Qualifying chef base models must meet ENERGY STAR Version 5.0 specifications and comply with the maximum daily energy consumption (MDEC) value corresponding to its refrigerated volume, as specified by the equation $0.05 \times V + 2.1$ (where V equals total refrigerated volume).

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The deemed values are calculated by using the following algorithms:

$$\text{Energy Savings } [\Delta kWh] = (kWh_{\text{daily,base}} - kWh_{\text{daily,ES}}) \times AOD$$

Equation 150

Where:

$kWh_{\text{daily,base}}$ = Average daily operational energy consumption, baseline [kWh]

$kWh_{\text{daily,ES}}$ = Average daily operational energy consumption, efficient case [kWh]

Daily average energy consumption for the baseline is estimated using the equation provided in the ENERGY STAR CFS Calculator for Conventional Refrigerated Chef Bases. The estimate for baseline daily energy consumption is shown in Equation 151. The input assumptions for refrigerated volume used the ENERGY STAR QPL to determine the average volume within each of four volume ranges, shown in Table 201. Annual kWh_{avg} is calculated the same for both the baseline and high-efficiency cases, as shown in Equation 152, where it is assumed that the average electric demand for any time interval is the same throughout the day and the peak demand can be calculated by dividing the daily energy consumption by 24 hours. Peak demand savings are calculated with Equation 152 using their respective input assumptions from Table 202.

Where:

$$kWh_{daily,base} = 0.05 \times V + 2.625$$

Equation 151

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh_{daily}}{24} \times CF$$

Equation 152

Table 201. Refrigerated Chef Bases—Refrigerated Volumes for Baseline

Refrigerated volume (ft ³)	Average refrigerated volume (ft ³)
0 < V ≤ 7.5	4.42
7.5 < V ≤ 15	11.06
15 < V ≤ 22.5	18.43
22.5 < V ≤ 30	23.94

Table 202. Refrigerated Chef Bases—Daily Energy Consumption³⁸³

Refrigerated volume (ft ³)	kWh _{daily,base}	kWh _{daily,ES}
0 < V ≤ 7.5	2.846	1.254
7.5 < V ≤ 15	3.178	2.230
15 < V ≤ 22.5	3.546	2.368
22.5 < V ≤ 30	3.822	1.770

³⁸³ ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment.
<https://www.energystar.gov/cfs/calculator>.

Table 203. Refrigerated Chef Bases—Operating Schedule Assumptions³⁸⁴

Building type	AOD	CF ^{385,386}
Education: K-12	180	0.44
Education: College and university	260	0.64
All other	365	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following table are based on the input assumptions from Table 201 through Table 203.

Table 204. Refrigerated Chef Bases—Annual Energy and Peak Demand Savings³⁸⁷

Building type	Refrigerated volume (ft ³)	Energy savings [kWh]	Peak demand savings [kW]
Education: K-12	0 < V ≤ 7.5	287	0.03
	7.5 < V ≤ 15	171	0.02
	15 < V ≤ 22.5	212	0.02
	22.5 < V ≤ 30	369	0.04
Education: College and university	0 < V ≤ 7.5	414	0.04
	7.5 < V ≤ 15	247	0.03
	15 < V ≤ 22.5	306	0.03
	22.5 < V ≤ 30	534	0.05
All other	0 < V ≤ 7.5	581	0.06
	7.5 < V ≤ 15	346	0.04
	15 < V ≤ 22.5	430	0.04
	22.5 < V ≤ 30	749	0.08

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

³⁸⁴ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³⁸⁵ 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.

³⁸⁶ Adjusted CF for Education = All other CF × (AOD ÷ 365).

³⁸⁷ ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment. <https://www.energystar.gov/cfs/calculator>

Measure Life and Lifetime Savings

Currently, no lifetime value is specified for this measure in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool. The estimated useful life (EUL) is 12 years, as specified in the ENERGY STAR Commercial Food Service Savings Calculator.³⁸⁷

Program Tracking Data and Evaluation Requirements

To ensure that the appropriate incentives, savings, and cost-effectiveness values are applied for each application, the following data must be collected for each application:

- Equipment manufacturer and model number
- Refrigerated Chef Base Volume
- Building Location
- Building Type
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Recommended: Facility equipment AOD and DOH
- Copy of ENERGY STAR certification or alternative

References and Efficiency Standards

Petitions and Rulings

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 205. Refrigerated Chef Bases—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.12 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.^{388, 389}

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.³⁹⁰

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

³⁸⁸ 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>.

³⁸⁹ ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-ice-machines/results>.

³⁹⁰ CEE Commercial Kitchens Initiative's overview of the Food Service Industry: <https://cee1.my.site.com/>.

Baseline Condition

The baseline condition is an ice maker meeting the federal standards published in 10 CFR 431 listed in Table 206. 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 206. Ice Makers—Federal Standard³⁹¹

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

³⁹¹ 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 207.

Table 207. Ice Makers—ENERGY STAR Specification³⁹²

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

³⁹² 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

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

Equation 153

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{AOD} \times CF$$

Equation 154

Where:

E_{base}	=	Baseline rated energy consumption (kWh) per 100 pounds of ice (see Table 206)
E_{ES}	=	ENERGY STAR rated energy consumption (kWh) per 100 pounds of ice (see Table 207)
H	=	Harvest rate in pounds of ice produced per 24 hours
DC	=	Machine duty cycle, 75% ³⁹³
AOD	=	Facility annual operating days (see Table 208)
CF	=	Seasonal peak coincidence factor (see Table 208)

Table 208. Ice Makers—Operating Schedule and Coincidence Factors^{394,395}

Building type	AOD	Summer CF	Winter CF
Education: K-12	180	0.022	0.021
Education: College and university	260	0.032	0.030
All other	365	0.045	0.042

Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure.

³⁹³ The assumed duty cycle value of 80 percent 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.

³⁹⁴ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

³⁹⁵ 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* and *Peak Weekday* values used for summer calculations. *Off Peak Season* and *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.³⁹⁶

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:

- 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
- Facility type (Education: K-12, Education: College and university, All other)

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.

³⁹⁶ 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 209. Ice Makers—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Incorporated March 2021 calculator update.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	Specified reduced operating schedule for education applications.
v13.0	10/2025	Revised demand factors and demand calculation formula. Updated coincidence factor for Education building types.

2.4.13 ENERGY STAR® Induction Cooktops

TRM Measure ID: NR-FS-IC

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: All commercial kitchens

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

A cooktop is cooking appliance that heats a cooking container, such as a pot or pan, to cook the food inside. As a primary cooking tool in commercial and residential applications, cooktops have developed designs customized to specific needs. However, commercial cooktops generally have significantly more durable construction than their residential counterparts.

Cooktops, available in gas and electric varieties, are one of the primary appliances in nearly every commercial kitchen. They are used for various cooking applications such as sautéing, braising, simmering, and boiling. Commercial kitchens can generally be expected to have at least two burners, with standard configurations including a six-foot range top.

Induction cooktops generate a magnetic field that excite the molecules of the cookware. This direct heating process makes the cooking extremely responsive to the cooktop controls. The induction process also minimizes hot surfaces for reduced safety risks and is more energy efficient than alternative cooking processes. However, it's important to note that any cookware used with induction cooktops must be induction compatible, meaning they must be made of ferromagnetic material such as cast iron or most types of stainless steel. Full aluminum or copper cookware will not work with induction cooktops.

American Society for Testing and Materials (ASTM) F1521 is the industry standard for evaluating cooktop energy consumption and performance.³⁹⁷ This standard for range top performance is a testament to the rigorous testing and quality control that goes into the production of induction cooktops.

³⁹⁷ ASTM F1521-12(2018) Standard Test Method for Performance of Range Tops:
<https://www.astm.org/f1521-12r18.html>

The following metrics define the range of top energy performance:

- *Cooking efficiency*: The energy consumption of the cooktop while heating water in a pot from ambient conditions to 200°F.
- *Production capacity*: The maximum rate (pound per hour) at which the cooktop can heat food products.

Eligibility Criteria

Eligible units must comply with the current ENERGY STAR specification. Qualified products must also meet the minimum cooking (boil) energy efficiency requirement from Table 210.

Eligible building types include any nonresidential application.

Baseline Condition

There are currently no federal minimum standards for commercial electric cooktops. Therefore, the baseline condition is defined as an electric range with an electric resistance cooktop or a standalone electric resistance cooktop that does not meet ENERGY STAR key product criteria.

High-Efficiency Condition

The high-efficiency condition is the current ENERGY STAR v1.0 specification, effective September 1, 2023.³⁹⁸ Induction cooktops must be ENERGY STAR-compliant.³⁹⁹

Table 210. Induction Cooktops—ENERGY STAR Specification

Operation	Criteria
Cooking (boil) energy efficiency	≥ 80%

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The annual electric energy savings were calculated as the difference between the baseline and ENERGY STAR unit energy consumption (UEC). The inputs for calculating the yearly UEC of a commercial induction cooktop are specified below. The days of operation are calculated from on-site monitored data and survey responses. Commercial cooktop hours of operation were derived from field data from 14 test sites, assuming one boil cycle per hour. The field monitoring sample included quick- and full-service restaurants, hospitality locations, and cafeterias.

³⁹⁸ ENERGY STAR Commercial Electric Cooktops Version 1.0 Specification:
<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Commercial%20Electric%20Cooktops%20Version%201.0%20Specification.pdf>.

³⁹⁹ ENERGY STAR Electric Cooktop Qualified Product Listing. Only induction cooktops are eligible.
<https://www.energystar.gov/productfinder/product/certified-residential-electric-cooking-products/results>.

The deemed values are calculated by using the following algorithms:

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

Equation 155

Annual kWh_{cook} is calculated in the same way for both the baseline and ENERGY STAR cases, as shown in Equation 156, and peak demand savings are calculated with Equation 157 using their respective input assumptions from Table 211.

$$kWh_{cook} = kW_{BC} \times N_{boils} \times \frac{t_{boil}}{60} \times DOH \times AOD$$

Equation 156

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{DOH \times AOD} \times CF$$

Equation 157

Where:

$kWh_{cook,base}$	=	Baseline cooking/boiling energy consumption [kWh]
$kWh_{cook,ES}$	=	ENERGY STAR cooking/boiling energy consumption [kWh]
kW_{BC}	=	Energy consumption per boil cycle
N_{boils}	=	Estimated number of boils per hour
t_{boil}	=	Boil time per cycle [min]
60	=	Constant to convert from minutes to hours
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
CF	=	Peak coincidence factor

Table 211. Induction Cooktops—Savings Calculation Inputs and Assumptions⁴⁰⁰

Parameter	Baseline	ENERGY STAR
kW_{BC} (kW)	1.54	2.38
N_{boils} ⁴⁰¹		1
t_{boil} (min)	41.51	23.32

⁴⁰⁰ Input assumptions primarily informed by lab-based equipment performance tests conducted by the SCE FTC and PG&E FSTC.

⁴⁰¹ ENERGY STAR Commercial Food Service Equipment Calculator.

<https://www.energystar.gov/cfs/calculator>.

Table 212. Induction Cooktops—Operating Schedule Assumptions⁴⁰²

Building Type	DOH	AOD	CF ^{403,404}
Education: K-12	6	180	0.44
Education: College and university	10	260	0.64
All other		326	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings are specified per burner in the following table based on the input assumptions from Table 211.

Table 213. Induction Cooktops—Annual Energy and Peak Demand Savings per Burner

Building Type	Energy Savings [kWh]	Peak Demand Savings [kW]
Education: K-12	152	0.06
Education: College and university	366	0.09
All other	459	0.13

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

Currently, no lifetime value is specified for this measure in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool. The estimated useful life (EUL) is 10 years, as specified in the ENERGY STAR Commercial Food Service Savings Calculator.³⁸⁷

⁴⁰² Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

⁴⁰³ 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.

⁴⁰⁴ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Program Tracking Data and Evaluation Requirements

To ensure that the appropriate incentives, savings, and cost-effectiveness values are applied for each application, the following data must be collected for each application:

- Building Type
- Cooktop quantity
- Manufacturer and model number
- Copy of ENERGY STAR certificate or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility equipment AOD and DOH (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 214. Induction Cooktops—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	Clarify deemed savings table units. Update documentation requirements. Updated coincidence factor for Education building types.

2.4.14 Induction Soup Wells

TRM Measure ID: NR-FS-SW

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: All commercial kitchens, grocery

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

A commercial soup well is an appliance used to maintain hot soups at an appropriate serving temperature throughout the duration of a foodservice facility's operating hours. Certain high powered soup wells known as rethermalizers heat the soup directly in the soup well container prior to holding.

Most soup wells available in the current market use a wet well technology, meaning they are filled with water which is heated to high temperatures. The container holding the soup is then placed in the heated water to maintain temperature. Induction soup wells operate by generating a magnetic field to heat the soup container directly.

Both wet well and induction soup wells are available in 120 V configurations, units featuring multiple wells are available in higher voltages. Soup wells range in holding capacity between 4 and 11 quarts, though the most standard capacities are 7-quart and 11-quart units. There is no current industry standard for evaluating soup well energy consumption and performance.

Eligibility Criteria

Eligible units are defined as electric soup wells that heat product through induction heating.

The following products are excluded from the eligibility criteria:

- Used or rebuilt equipment
- Steam tables
- Resistance heating soup wells

Eligible building types include any nonresidential application.

Baseline Condition

The baseline condition is defined as any electric soup well that does not use induction heating as its primary form of heating, typically using electric resistance heating.

High-Efficiency Condition

The high-efficiency condition is defined as an electric soup well that heats product through induction heating.

In absence of lab testing, eligible products must be included on the current California Energy Wise Foodservice Qualified Product Listing (QPL).⁴⁰⁵

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The annual electric unit energy saving (UES) is calculated as the difference between the baseline and measure case unit energy consumption (UEC). The daily electric UEC (baseline or measure case) is equal to the average energy rate multiplied by the operational hours per day.

The deemed values are calculated by using the following algorithms:

$$\text{Energy Savings } [\Delta kWh] = kWh_{avg,base} - kWh_{avg,EE}$$

Equation 158

Where:

$$kWh_{avg,base} = \text{Baseline average annual energy consumption [kWh]}$$

$$kWh_{avg,EE} = \text{High-efficiency average annual energy consumption [kWh]}$$

Annual kWh_{avg} is calculated the same for both the baseline and measure cases, except they require their respective input assumptions relative to operational energy rate as seen in Table 215.

$$kWh_{avg} = E_{avg} \times DOH \times AOD$$

Equation 159

$$\text{Peak Demand Savings } [\Delta kW] = \Delta E_{avg} \times CF$$

Equation 160

⁴⁰⁵ California Energy Wise Foodservice QPL. <https://caenergywise.com/instant-rebates/qpl/>. For assistance with qualifying new models, reach out to the California Foodservice Instant Rebates program. <https://caenergywise.com/instant-rebates/#contact-us>.

Where:

E_{avg}	=	Average energy rate [kW]
DOH	=	Equipment daily operating hours [hr/day]
AOD	=	Facility annual operating days [days/year]
CF	=	Peak coincidence factor

Table 215. Induction Soup Wells—Calculation Inputs⁴⁰⁶

Parameter	Variable
$E_{avg,base}$ (kW)	0.188
$E_{avg,EE}$ (kW)	0.104

Table 216. Induction Soup Wells—Operating Schedule Assumptions⁴⁰⁷

Building type	DOH	AOD	CF ^{408,409}
Education: K-12	6	180	0.44
Education: College and university	6.9	260	0.64
All other		326	0.90

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following table are based on the input assumptions from Table 215.

Table 217. Induction Soup Wells—Annual Energy and Peak Demand Savings

Building type	Energy savings (kWh)	Peak demand Savings (kW)
Education: K-12	91	0.04
Education: College and university	150	0.05
All other	189	0.08

⁴⁰⁶ Input assumptions primarily informed by lab-based equipment performance tests conducted by the SCE FTC and PG&E FSTC.

⁴⁰⁷ Fisher-Nickel, Inc., "Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report." Prepared for the California Energy Commission. October 2014. Appendix E.

⁴⁰⁸ 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.

⁴⁰⁹ Adjusted CF for Education = All other CF × (AOD ÷ 365).

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

There is no estimated useful life (EUL) specifically for commercial soup wells, but its method of operation is similar to that of insulated holding cabinets. Therefore, the 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-HoldCab.⁴¹⁰

Program Tracking Data and Evaluation Requirements

To ensure that the appropriate incentives, savings, and cost-effectiveness values are applied for each application, the following data must be collected for each application:

- Building type
- Soup well quantity
- Manufacturer and model number
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility equipment AOD and DOH (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 218. Induction Soup Wells—Revision History

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

⁴¹⁰ California Public Utilities Commission (CPUC), Energy Division. 2020.
https://www.caetrm.com/media/reference-documents/EEPPolicyManualRevised_032020.pdf.

TRM version	Date	Description of change
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.15 Demand-Controlled Kitchen Ventilation Measure Overview

TRM Measure ID: NR-FS-KV

Market Sector: Commercial

Measure Category: Food service

Applicable Building Types: All 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. New construction eligibility is limited to kitchens with a total kitchen hood exhaust airflow rate of less than or equal to 5,000 cubic feet per minute (CFM).

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.

Current code includes DCV as a compliance option for kitchens with a total kitchen hood exhaust airflow rate of greater than 5,000 CFM. While there are other compliance options, DCV is most likely. Therefore, new construction applications are ineligible to claim savings when total kitchen hood exhaust airflow rate exceeds this threshold.

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.⁴¹¹ 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 from the FSTC Outdoor Air Load Calculator (OALC).⁴¹² This output is adjusted by population to account for the percentage of sites with electric resistance or heat pump heating.⁴¹³ Additionally, because output from the OALC is per 1,000 CFM, a CFM per HP ratio⁴¹⁴ 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

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

Equation 161

$$\text{Peak Demand Savings } [\Delta kW] = \Delta kWh \times CF$$

Equation 162

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 220)
$\text{AvgSav}_{kWh/HP}$	=	Average hourly energy savings per horsepower by building type (see Table 219)

⁴¹¹ Fisher, D., Swierczyna, R., and Karas, A. (February 2013) Future of DCV for Commercial Kitchens. *ASHRAE Journal*, 48-53.

⁴¹² Food Service Technology Center Outdoor Air Load Calculator. No longer available online.

⁴¹³ Percentage of buildings with electric resistance and heat pump heat are taken from the Energy Information Administration 2018 Commercial Buildings Energy Survey (CBECS), table b.13 Selected Principal Building Activity: Part 2, Number of Buildings.
<https://www.eia.gov/consumption/commercial/data/2018/>.

⁴¹⁴ 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.

<i>DOH</i>	=	<i>Equipment daily operating hours, facility specific (if unknown, use defaults from Table 219)</i>
<i>AOD</i>	=	<i>Facility annual operating days, facility specific (if unknown use defaults from Table 219)</i>
<i>MAU</i>	=	<i>Make-up air unit factor applied to account for presence of dedicated MAU; value = 1 if there is a dedicated MAU; see Table 219 for values when there is no dedicated MAU</i>
<i>CF</i>	=	<i>Seasonal peak coincidence factor; see Table 221</i>

Table 219. DCKV—Savings Calculation Input Assumptions

Building type	AvgSav _{kWh/HP}	DOH	AOD	MAU with no dedicated MAU
Food service: Full-service restaurant ⁴¹⁵	0.667	15	365	0.65
Food service: Quick-service restaurant ⁴¹⁶				
Food service: 24-hour restaurant ⁴¹⁷	0.631	24	365	0.65
Education: K-12 or college/university with summer session ⁴¹⁸	0.566	11	260	0.51
Education: K-12 without summer session	0.566	11	180	0.51

Table 220. DCKV—Population-Adjusted Interactive HVAC Savings per hp

Climate zone	Building type	Interactive savings (kWh/hp)
Climate Zone 1: Amarillo	Food service: Full-service restaurant	2,666
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	6,143
	Education: K-12 or college/university with summer session	2,045
	Education: K-12 without summer session	1,793

⁴¹⁵ Pennsylvania TRM, “3.5.3 High-Efficiency Fan Motors for Walk-In Refrigerated Cases”. Page 369, Table 3-93. June 2016.

⁴¹⁶ Ibid.

⁴¹⁷ All values are the average of Hotel Restaurant data from Future of DCV for Commercial Kitchens.

⁴¹⁸ 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 219.

Climate zone	Building type	Interactive savings (kWh/hp)
Climate Zone 2: Dallas	Food service: Full-service restaurant	2,313
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	4,840
	Education: K-12 or college/university with summer session	1,761
	Education: K-12 without summer session	1,331
Climate Zone 3: Houston	Food service: Full-service restaurant	1,996
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	4,060
	Education: K-12 or college/university with summer session	1,577
	Education: K-12 without summer session	1,189
Climate Zone 4: Corpus Christi	Food service: Full-service restaurant	1,885
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	3,696
	Education: K-12 or college/university with summer session	1,493
	Education: K-12 without summer session	1,063
Climate Zone 5: El Paso	Food service: Full-service restaurant	2,033
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	4,522
	Education: K-12 or college/university with summer session	1,579
	Education: K-12 without summer session	1,252

Table 221. DCKV—Seasonal Peak CFs⁴¹⁹

Climate zone	Education: No Summer		Education: Summer		All Other	
	Summer	Winter	Summer	Winter	Summer	Winter
Climate Zone 1: Amarillo	6.55E-05	7.22E-05	9.47E-05	1.04E-04	1.33E-04	1.46E-04
Climate Zone 2: Dallas	6.69E-05	7.13E-05	9.68E-05	1.03E-04	1.36E-04	1.45E-04
Climate Zone 3: Houston	6.60E-05	7.06E-05	9.53E-05	1.02E-04	1.34E-04	1.43E-04
Climate Zone 4: Corpus Christi	6.47E-05	7.17E-05	9.34E-05	1.04E-04	1.31E-04	1.45E-04
Climate Zone 5: El Paso	7.16E-05	7.22E-05	1.03E-04	1.04E-04	1.45E-04	1.46E-04

⁴¹⁹ CF 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.

Deemed Energy and Demand Savings Tables

Table 222. DCKV—Energy Savings per hp

Climate zone	Building type	Annual savings (kWh/hp)	
		With dedicated MAU	Without dedicated MAU
Climate Zone 1: Amarillo	Food service: Full-service restaurant	6,311	5,048
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	11,667	9,709
	Education: K-12 or college/university with summer session	3,665	2,879
	Education: K-12 without summer session	2,914	2,371
Climate Zone 2: Dallas	Food service: Full-service restaurant	5,958	4,695
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	10,364	8,406
	Education: K-12 or college/university with summer session	3,381	2,595
	Education: K-12 without summer session	2,453	1,909
Climate Zone 3: Houston	Food service: Full-service restaurant	5,641	4,378
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	9,585	7,627
	Education: K-12 or college/university with summer session	3,197	2,411
	Education: K-12 without summer session	2,310	1,767
Climate Zone 4: Corpus Christi	Food service: Full-service restaurant	5,530	4,266
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	9,220	7,263
	Education: K-12 or college/university with summer session	3,113	2,327
	Education: K-12 without summer session	2,185	1,641
Climate Zone 5: El Paso	Food service: Full-service restaurant	5,678	4,415
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	10,046	8,089
	Education: K-12 or college/university with summer session	3,199	2,413
	Education: K-12 without summer session	2,374	1,830

Table 223. 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	Food service: Full-service restaurant	0.84	0.67	0.92	0.74
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.55	1.29	1.71	1.42
	Education: K-12 or college/university with summer session	0.35	0.27	0.38	0.30
	Education: K-12 without summer session	0.19	0.16	0.21	0.17
Climate Zone 2: Dallas	Food service: Full-service restaurant	0.81	0.64	0.86	0.68
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.41	1.14	1.50	1.22
	Education: K-12 or college/university with summer session	0.33	0.25	0.35	0.27
	Education: K-12 without summer session	0.16	0.13	0.17	0.14
Climate Zone 3: Houston	Food service: Full-service restaurant	0.75	0.59	0.81	0.63
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.28	1.02	1.37	1.09
	Education: K-12 or college/university with summer session	0.30	0.23	0.33	0.25
	Education: K-12 without summer session	0.15	0.12	0.16	0.12

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 4: Corpus Christi	Food service: Full-service restaurant	0.73	0.56	0.80	0.62
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.21	0.95	1.34	1.06
	Education: K-12 or college/university with summer session	0.29	0.22	0.32	0.24
	Education: K-12 without summer session	0.14	0.11	0.16	0.12
Climate Zone 5: El Paso	Food service: Full-service restaurant	0.83	0.64	0.83	0.65
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.46	1.18	1.47	1.18
	Education: K-12 or college/university with summer session	0.33	0.25	0.33	0.25
	Education: K-12 without summer session	0.17	0.13	0.17	0.13

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.⁴²⁰

⁴²⁰ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- **New construction only:** Total kitchen hood exhaust airflow rate (CFM)
- Kitchen ventilation system exhaust fan horsepower
- Kitchen ventilation makeup air unit fan horsepower, if present
- Presence of dedicated makeup air unit
- Testing and balancing report, if available
- Facility type (Education: K-12, Education: College and university, All other)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 224. DCKV—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	Updated algorithms and corrected table error.
v11.0	10/2023	Aligned building type names across all commercial measures.
v12.0	10/2024	Clarified new construction eligibility, specified reduced operating schedule for education applications, corrected heating interactive effects, updated heating type distribution, and updated corresponding deemed savings tables.
v13.0	10/2025	Updated coincidence factor for Education building types.

2.4.16 Pre-Rinse Spray Valves Measure Overview

TRM Measure ID: NR-FS-SV

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: All commercial kitchens, grocery

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 measure is 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 225 (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 (PRSV) with a flow rate that does not exceed the maximum flow rate per product class as specified in Table 225.⁴²¹

Table 225. 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

⁴²¹ 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.⁴²² 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 225 for the pre-rinse spray valve's respective product class. The sprayer should be capable of the same cleaning ability as the old sprayer.⁴²³

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy and demand savings are calculated using the following algorithms:

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

Equation 163

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

Equation 164

Where:

U	=	Water usage duration (see Table 226)
F_B	=	Baseline sprayer flow rate (GPM) (see Table 225)
F_P	=	PRSV flow rate (GPM), use actual
AOD	=	Facility annual operating days [days/year] (see Table 226)
T_H	=	Average mixed hot water (after spray valve) temperature for prewashing [°F] = 120°F ⁴²⁴

⁴²² "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.

⁴²³ FEMP Performance Requirements for Federal Purchases of Pre-rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-rinse Spray Valves.

⁴²⁴ "CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves," Consortium of Energy Efficiency (CEE). Page 3. <https://cee1.my.site.com/>.

T_C	=	Average supply (cold) water temperature [°F] = 71.4°F ⁴²⁵
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 = 0.98 ⁴²⁶
3,412	=	Constant to convert from Btu to kWh
CF	=	Seasonal peak coincidence factor (see Table 227)
100,000	=	Constant to convert values for easier readability

Table 226. PRSVs—Assumed Variables for Energy and Peak Demand Savings Calculations

Variable	Assumed value
U^{427}	Food service: Full-service restaurant: 105 min/day/unit Food service: Quick-service restaurant: 45 min/day/unit Office: Cafeteria: 210 min/day/unit Education: K-12: 105 min/day/unit Education: College/university: 210 min/day/unit
AOD^{428}	Food service: Full-service restaurant: 360 Food service: Quick-service restaurant: 360 Office: Cafeteria: 360 Education: K-12 ⁴²⁹ : 180 Education ⁴³⁰ : College and university: 260

⁴²⁵ Average calculated input water temperature for five Texas climate zone cities, based on typical meteorological year (TMY) dataset for TMY3: Available at <https://texasefficiency.com/trm-docs/>.

⁴²⁶ Recovery efficiency of electric water heaters as listed on the AHRI Directory of Certified Product Performance. <https://www.ahridirectory.org>.

⁴²⁷ “CEE Commercial Kitchens Initiative Program Guidance on pre-rinse valves”, page 3. Midpoint of typical hours of operation in footnoted building types. <https://cee1.my.site.com/>.

⁴²⁸ For facilities that operate year-round: assume operating days of 360 days/year. For dormitories with few occupants in the summer: 360 x (9/12) = 270.

⁴²⁹ Fisher-Nickel, Inc., “Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report.” Prepared for the California Energy Commission. October 2014. Appendix E.

⁴³⁰ Ibid.

Table 227. PRSV—Seasonal Peak CFs⁴³¹

Climate zone	Summer CF			Winter CF		
	Food service: Full-service restaurant and cafeterias ⁴³²	Food service: Quick-service restaurant	Education: K-12	Food service: Full-service restaurant and cafeterias ⁴³³	Food service: Quick- service restaurant	Education: K-12
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.⁴³⁴

⁴³¹ CFs are developed according to the method described in the Texas TRM Volume 1, using load profiles derived from the American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., ASHRAE Handbook 2019. HVAC Applications. Chapter 50 51 - Service Water Heating, Section 9 – Hot Water Load and Equipment Sizing, Figure 24 – Hourly Flow Profiles for Various Building Types. CF values are multiplied by 100,000 to allow for easier readability of the values.

⁴³² This building type should be used for Food Service: Full-service restaurant, Office: Cafeteria, and Education: College/university cafeteria.

⁴³³ Ibid.

⁴³⁴ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Spray force in ounce-force (ozf)
- Baseline equipment flow-rate
- Retrofit equipment flow-rate
- Building type

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 228. PRSVs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	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	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.

TRM version	Date	Description of change
v9.0	10/2021	General reference checks, updates to input assumptions, and update peak demand savings. Updated EUL reference.
v10.0	10/2022	Formula and variable definition updates.
v11.0	10/2023	Adjusted mixed water hot temperature to match CEE guidance. Aligned building type names across all commercial measures.
v12.0	10/2024	Specified reduced operating schedule for education applications.
v13.0	10/2025	No revision.

2.4.17 Vacuum-Sealing and Packaging Machines Measure Overview

TRM Measure ID: NR-MS-VS

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Supermarket, Grocery, Commercial kitchens

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

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

Eligibility Criteria

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

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

Baseline Condition

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

High-Efficiency Condition

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

Savings Algorithms and Input Variables

Southern California Edison (SCE) and the Food Service Technology Center (FSTC) conducted a field study to evaluate and compare energy savings and demand reduction potential between baseline and on-demand package sealers in supermarkets.⁴³⁵ 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.⁴³⁶ 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 229. 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.⁴³⁷

⁴³⁵ "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.

⁴³⁶ See Volume 1, Section 4.

⁴³⁷ "Useful Life Indices for Equipment Depreciation", University of California Office of the President. <https://controller.ucsf.edu/reference/capital-equipment-accounting/useful-life-indices-equipment-depreciation>.

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 230. Vacuum-Sealing & Packaging Machines—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	No revision.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.4.18 Hand Wrap Machines Measure Overview

TRM Measure ID: NR-FS-HW

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: Supermarket, grocery, commercial kitchens

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit,

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

A commercial hand-wrap machine is an appliance used to wrap and seal food items before being displayed for purchase. A hand-wrap machine consists of a heating bar and a heating platform, rated at approximately 0.05 kW and 0.55 kW, respectively. The heating bar cuts the wrapping film as it comes in contact with itself. The heating platform heats up the wrapping film. When the wrapping film is heated, the film sticks to the package and seals the product. Both heating elements of the conventional (always on) hand-wrap machine are kept at a constant temperature of 280°F.

An on-demand (OD) hand-wrap machine has a more powerful heating platform (rated at approximately 2 kW), which is switched ON/OFF by a controller. Mechanical systems engage a switch when pressure is applied to the heating platform, which activates the heating platform until the switch is disengaged or for a maximum of three seconds. Alternatively, optical systems feature an optical eye to detect that an item is being sealed. When a package is set on the heating platform, light is reflected into the eye, which activates the heating platform until the item is removed or for a maximum of three seconds.

Measure savings result from eliminating standby losses. Although an OD hand-wrap machine has a more powerful heating element than the always-on machine (2 kW compared to 0.55 kW), the total hours of operation are much less.

Eligibility Criteria

Eligible units are defined as new commercial OD hand-wrap machines that use either a mechanical or optical control system. Used or rebuilt hand-wrap machines are not eligible.

Eligible building types include any nonresidential application.

Baseline Condition

The baseline condition is an always-on commercial electric hand-wrap machine.

Generally, new construction is ineligible to claim savings under this measure. However, utilities may work with the EM&V team to determine the baseline standard for new construction applications, if applicable.

High-Efficiency Condition

The high-efficiency condition is a new commercial on-demand hand-wrap machine.

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The annual electric unit energy saving (UES) of this measure were derived from a 2015 field test study conducted by Southern California Edison (SCE) through the Emerging Technologies Program.⁴³⁸ The SCE field test monitored hand wrap machines in the bakery, deli, and meat departments at four supermarket chains across 21 supermarket locations. Both baseline and high-efficiency condition hand wrap machines were monitored for six weeks at ten-second intervals. For each chain, an average unit energy consumption (UEC) was calculated for units in bakery and deli departments, and a separate average UEC was calculated for units in meat departments. The average UEC values for each use type were then averaged together to calculate the overall average UEC and peak demand.

The deemed values are calculated by using the following algorithms:

$$\text{Energy Savings } [\Delta kWh] = kWh_{avg,base} - kWh_{avg,OD}$$

Equation 165

$$\text{Peak Demand Savings } [\Delta kW] = kW_{avg,base} - kW_{avg,OD}$$

Equation 166

Where:

$kWh_{avg,base}$ = Weighted average baseline annual energy consumption [kWh]

$kWh_{avg,OD}$ = Weighted average OD annual energy consumption [kWh]

$kW_{avg,base}$ = Weighted average baseline peak demand energy rate [kW]

$kW_{avg,OD}$ = Weighted average OD peak demand energy rate [kW]

⁴³⁸ "Emerging Products: Commercial Hand Wrap Machines for Food Service Applications Field Test, ET13SCE1190". Southern California Edison (SCE). October 2015.
https://www.caetrm.com/media/reference-documents/SCE_2014_ET13SCE1190_Report.pdf.

Annual kWh_{avg} is calculated the same for both the baseline and efficiency cases, except they require their respective input assumptions relative to measured field data values seen in Table 231.

$$kWh_{avg} = \left(\frac{\sum_{i=1}^4 (kWh_{chain,i} \times N_{HWM,i})}{N_{HWM}} \right)$$

Equation 167

$$kW_{avg} = \left(\frac{\sum_{i=1}^4 (kW_{chain,i} \times N_{HWM,i})}{N_{HWM}} \right)$$

Equation 168

Where:

$kWh_{chain,i}$	=	Measured annual energy consumption [kWh]
$kW_{chain,i}$	=	Measured peak demand energy rate [kW]
$N_{HWM,i}$	=	Number of measured hand wrap machines per supermarket chain
N_{HWM}	=	Total number of measured hand wrap machines

Table 231. Hand Wrap Machines—Savings Calculation Input Assumptions

Supermarket chain	# Chains	Base kWh	OD kWh	Base kW	OD kW
1	6	2,311	412	0.27	0.05
2	7	1,810	395	0.23	0.04
3	6	1,697	452	0.27	0.05
4	2	1,983	361	0.23	0.04
Total/average	21	1,937	413	0.253	0.046

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following table are based on the input assumptions from Table 231.

Table 232 Hand Wrap Machines—Annual Energy and Peak Demand Savings

Energy savings (kWh)	Peak demand savings (kW)
1,524	0.207

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is ten years for EUL ID FoodHandWrap.⁴³⁹

Program Tracking Data and Evaluation Requirements

To ensure that the appropriate incentives, savings, and cost-effectiveness values are applied for each application, the following data must be collected for each application:

- Machine quantity
- Manufacturer and model number
- 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 233. Hand Wrap Machines—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin.
v13.0	10/2025	No revision.

⁴³⁹ “Useful Life Index, G8605: Cutters, Slicers, Saws, Choppers, Graters, Grinders, Universal Mach, Food Prep.” University of California, Office of the President, Purchasing Services. 2018.
<https://www.ucop.edu/procurement-services/for-ucstaff/equipment-management.html>.

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 modulates power supplied to the heaters accordingly. DP inside a building is primarily dependent on the moisture content of outdoor ambient air. Because the outdoor DP varies between 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 ($\text{kWh}_{\text{refrig}}$). These savings are calculated using the following procedures:

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

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

Equation 169⁴⁴⁰

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 42.89°F DP and all on (duty cycle of 100%) at 52.87°F DP for a typical supermarket.⁴⁴¹ Between these values, the door heaters' duty cycle changes proportionally:

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

Equation 170

⁴⁴⁰ 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.

⁴⁴¹ Ibid, "Direct ASH Power", page 6.
42.89°F DP and 52.87°F DP correspond to relative humidity of 35 percent and 50 percent, respectively, for a 72°F indoor space. These relative humidity values are common practice setpoints for a typical supermarket of this temperature.

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 heater⁴⁴² at:

For medium temperature (coolers):

$$kW_{ASH} = 0.109 \text{ per door or } 0.0436 \text{ per horizontal linear foot of door}^{443}$$

Equation 171

For low temperature (freezers):

$$kW_{ASH} = 0.191 \text{ per door or } 0.0764 \text{ per horizontal linear foot of door}^{444}$$

Equation 172

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

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

Equation 173

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

Equation 174

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,⁴⁴⁵ the cooling load contribution from door heaters for each hour of the year can be given by:

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

Equation 175

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.

⁴⁴² 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/bpdeemedavingsmanuav10_evaluationreport.pdf.

⁴⁴³ Ibid.

⁴⁴⁴ Ibid.

⁴⁴⁵ A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

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 0.87.⁴⁴⁶

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 176⁴⁴⁷

Where:

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

⁴⁴⁶ Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas and Electric Company. May 29, 2009. Assumes 15% oversizing.

⁴⁴⁷ San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012.
https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

For low temperature compressors, the following equation is used to determine the EER_{LT} [Btu/hr/watts] 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 177⁴⁴⁸

Where:

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

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 178

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

Equation 179

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 180

⁴⁴⁸ Ibid.

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

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

Equation 181

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;⁴⁴⁹ Table 234 provides these deemed values. Savings are specified per horizontal linear feet of door.

Table 234. 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.⁴⁵⁰

⁴⁴⁹ <https://texasefficiency.com/trm-docs/>.

⁴⁵⁰ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Refrigeration temperature (medium, low)
- Linear feet of door length

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 235. Door Heater Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	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	Correction to state that savings are on a per-linear foot of display case.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	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 176 and Equation 177.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.

TRM version	Date	Description of change
v9.0	10/2021	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	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	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 schools⁴⁵¹

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 (SP) or permanent split capacitor (PSC) 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.

⁴⁵¹ 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

$$\text{Peak Demand Savings } [\Delta kW] = N \times \Delta kW_{\text{peak per unit}} \quad \text{Equation 182}$$

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}})/1,000 \times LF \times DC_{\text{EvapCool}} \times \left(1 + \frac{1}{COP_{\text{cooler}}}\right) \quad \text{Equation 183}$$

$$\text{Energy Savings } [\Delta kWh] = N \times \Delta kWh_{\text{per unit}} \quad \text{Equation 184}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} \times \text{Hours} \times (1 - \%OFF) \quad \text{Equation 185}$$

Freezer

$$\text{Demand Savings } [\Delta kW] = N \times \Delta kW_{\text{peak per unit}} \quad \text{Equation 186}$$

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}})/1,000 \times LF \times DC_{\text{EvapFreeze}} \times \left(1 + \frac{1}{COP_{\text{freezer}}}\right) \quad \text{Equation 187}$$

$$\text{Energy Savings } [\Delta kWh] = N \times \Delta kWh_{\text{per unit}} \quad \text{Equation 188}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} \times \text{Hours} \times (1 - \%OFF) \quad \text{Equation 189}$$

Where:

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

LF	=	Load factor of evaporator fan motor = 0.9 (default) ⁴⁵²
$DC_{EvapCool}$	=	Duty cycle of evaporator fan motor for cooler = 100% (default) ⁴⁵³
$DC_{EvapFreeze}$	=	Duty cycle of evaporator fan motor for freezer = 97.8% (default) ^{454,455}
COP_{cooler}	=	$12/EER_{MT}$, the coefficient of performance of compressor in the cooler
$COP_{freezer}$	=	$12/EER_{LT}$, the coefficient of performance of compressor in the freezer
Hours	=	The annual operating hours are assumed to be 8,760 for coolers and freezers. ^{456,457}
%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%. ⁴⁵⁸
1,000	=	Constant to convert from W to kW

⁴⁵² 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>.

⁴⁵³ Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019. Page 83, footnote 401.

⁴⁵⁴ The December 2018 VT TRM Evaporator Fan Motors measure attributes reduced operating hours to freezers. This is expressed through a reduced duty cycle of approximately $8,567 / 8,760 = 97.8$ percent. <https://puc.vermont.gov/document/ev-technical-reference-manual>.

⁴⁵⁵ “Commercial Refrigeration Loadshape Project Final Report,” The Cadmus Group. Northeast Energy Efficiency Partnerships (NEEP), Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

⁴⁵⁶ The December 2018 VT TRM Evaporator Fan Motors measure attributes reduced operating hours to freezers. This is expressed through a reduced duty cycle of approximately $8,567 / 8,760 = 97.8$ percent. <https://puc.vermont.gov/document/ev-technical-reference-manual>.

⁴⁵⁷ “Commercial Refrigeration Loadshape Project Final Report,” The Cadmus Group. Northeast Energy Efficiency Partnerships (NEEP), Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

⁴⁵⁸ The Massachusetts Technical Reference Manual, 2012 Program Year – Plan Version, “Refrigeration – Evaporator Fan Controls”, October 2011. Page 216, footnote 414 cites the following as the source for this variable:

“The value is an estimate by National Resource Management (NRM) based on extensive analysis of hourly use data. These values are also supported by Select Energy (2004). Cooler Control Measure Impact Spreadsheet User’s Manual. Prepared for NSTAR.”

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

For medium-temperature refrigerated cases, the saturated condensing temperature (SCT_{MT}) is calculated as the design dry-bulb temperature plus 15 degrees. For low-temperature refrigerated cases, the SCT_{LT} is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant of 1/1.15 or approximately 0.87.⁴⁵⁹

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 190⁴⁶⁰

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

⁴⁵⁹ Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas and Electric Company. May 29, 2009. Assumes 15 percent oversizing.

⁴⁶⁰ San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012.
https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

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

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

Equation 191⁴⁶¹

Where:

$$\begin{aligned} a &= 9.86650982829017 \\ b &= -0.230356886617629 \\ c &= 22.905553824974 \\ d &= 0.00218892905109218 \\ e &= -2.48866737934442 \\ f &= -0.248051519588758 \\ g &= -7.57495453950879 \times 10^{-6} \\ h &= 2.03606248623924 \\ i &= -0.0214774331896676 \\ j &= 0.000938305518020252 \\ SCT_{LT} &= T_{db} + 10 \end{aligned}$$

Table 236. ECM Evaporator Fan Motors—Motor Sizes, Efficiencies, and Input Watts^{462,463}

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

⁴⁶¹ Ibid.

⁴⁶² 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.

⁴⁶³ Motor efficiencies: “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Department of Energy. December 2013. Motor efficiencies for the baseline motors are from Table 2.1, which provides peak efficiency ranges for a variety of motors. ECM motor efficiencies is from discussion in Section 2.4.3. <https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>.

Nominal motor size	Motor output (W)	SP eff	SP input (W)	PSC eff	PSC input (W)	ECM eff	ECM input (W)
1/15 HP (49W)	49.0	30%	163	60%	82	70%	70
1/4 HP	186.5	30%	622	60%	311	70%	266
1/3 HP	248.7	30%	829	60%	415	70%	355

Table 237. ECM Evaporator Fan Motors—Cooler & Freezer Compressor COP

Climate zone	Summer design dry-bulb temperature ⁴⁶⁴	EER _{MT}	COP _{cooler}	EER _{LT}	COP _{freezer}
Climate Zone 1: Amarillo	98.6	6.18	1.94	4.77	2.51
Climate Zone 2: Dallas	101.4	5.91	2.03	4.56	2.63
Climate Zone 3: Houston	97.5	6.29	1.91	4.86	2.47
Climate Zone 4: Corpus Christi	96.8	6.36	1.89	4.91	2.44
Climate Zone 5: El Paso	101.1	5.94	2.02	4.58	2.62

Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL IDs GrocDisp-FEEvapFanMtr and GrocWikIn-WEvapFanMtr.⁴⁶⁵

⁴⁶⁴ 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. <http://ashrae-meteo.info/v2.0/>.

⁴⁶⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 238. ECM Evaporator Fan Motors—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measureorigin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	Updated the methodology with cooler and freezer values.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated methodology based on the load shape from original workpaper. Updated EUL reference.
v10.0	10/2022	Added Schools as an eligible building type.
v11.0	10/2023	Clarified duty cycle assumptions and references.
v12.0	10/2024	Clarified baseline condition and documentation requirements.

TRM version	Date	Description of change
v13.0	10/2025	No revision.

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 schools⁴⁶⁶

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.

⁴⁶⁶ 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:

$$\text{Energy Savings } [\Delta kWh] = \Delta kWh_{\text{defrost}} + \Delta kWh_{\text{heat}} \quad \text{Equation 192}$$

$$\Delta kWh_{\text{defrost}} = kW_{\text{defrost}} \times CF \times \text{Hours} \quad \text{Equation 193}$$

Medium temperature:

$$\Delta kWh_{\text{heat}} = \Delta kWh_{\text{defrost}} \times 0.28 \times COP_{MT} \quad \text{Equation 194}$$

Low temperature:

$$\Delta kWh_{\text{heat}} = \Delta kWh_{\text{defrost}} \times 0.28 \times COP_{LT} \quad \text{Equation 195}$$

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{\text{Hours}} \quad \text{Equation 196}$$

Where:

$\Delta kWh_{\text{defrost}}$ = 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 kW⁴⁶⁷

⁴⁶⁷ Efficiency Vermont TRM, 3/16/2015, p. 170. The total defrost element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900 W per fan. <https://puc.vermont.gov/document/ev-technical-reference-manual>.

<i>Hours</i>	=	<i>Number of hours defrost occurs over a year without defrost controls, 487⁴⁶⁸</i>
<i>CF</i>	=	<i>Coincidence factor—percentage reduction in defrosts required per year, see Table 239</i>
<i>0.28</i>	=	<i>Conversion of kW to tons; 3,412 Btuh/kW divided by 12,000 Btuh/ton</i>
<i>COP_{MT}</i>	=	<i>12/EER_{MT}, the coefficient of performance of compressor in the cooler</i>
<i>COP_{LT}</i>	=	<i>12/EER_{LT}, the coefficient of performance of compressor in the freezer</i>

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 0.87.⁴⁶⁹

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 197⁴⁷⁰

Where:

<i>a</i>	=	<i>3.75346018700468</i>
<i>b</i>	=	<i>-0.049642253137389</i>
<i>c</i>	=	<i>29.4589834935596</i>

⁴⁶⁸ 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>.

⁴⁶⁹ Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas and Electric Company. May 29, 2009. Assumes 15 percent oversizing.

⁴⁷⁰ 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.

<i>d</i>	=	0.000342066982768282
<i>e</i>	=	-11.7705583766926
<i>f</i>	=	-0.212941092717051
<i>g</i>	=	-1.46606221890819 × 10 ⁻⁶
<i>h</i>	=	6.80170133906075
<i>i</i>	=	-0.020187240339536
<i>j</i>	=	0.000657941213335828
<i>PLR</i>	=	1/1.15 = 0.87
<i>SCT_{MT}</i>	=	<i>T_{db}</i> + 15
<i>T_{DB}</i>	=	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 198⁴⁷¹

Where:

<i>a</i>	=	9.86650982829017
<i>b</i>	=	-0.230356886617629
<i>c</i>	=	22.905553824974
<i>d</i>	=	0.00218892905109218
<i>e</i>	=	-2.48866737934442
<i>f</i>	=	-0.248051519588758
<i>g</i>	=	-7.57495453950879 × 10 ⁻⁶
<i>h</i>	=	2.03606248623924
<i>i</i>	=	-0.0214774331896676
<i>j</i>	=	0.000938305518020252
<i>SCT_{LT}</i>	=	<i>T_{db}</i> + 10

⁴⁷¹ Ibid.

Table 239. Defrost Controls—Savings Calculation Input Assumptions

Climate zone	CF ⁴⁷²	COP _{MT} ⁴⁷³	COP _{LT} ⁴⁷⁴
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.⁴⁷⁵

Program Tracking Data and Evaluation Requirements

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

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

⁴⁷² 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.heatcraftpd.com/contentAsset/raw-data/aee972cd-cbe8-4912-879e-b69aba4d25e9/fileAsset?bylnode=true>

⁴⁷³ Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPSCNRRN009 (rev.o.2007).

⁴⁷⁴ Ibid.

⁴⁷⁵ GDS Associates, Inc. (June 2007). *Measure Life Report*. Prepared for The New England State Program Working Group (SPWG). https://www.caetrm.com/media/reference-documents/HVAC_Ltg_measure_life_GDS_2007.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://puc.vermont.gov/document/ev-technical-reference-manual>."

- Refrigeration temperature (low temperature or medium temperature)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 240. Defrost Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated methodology based on the load shape from original workpaper.
v10.0	10/2022	Added Schools as an eligible building type.
v11.0	10/2023	No revision.
v12.0	10/2024	Corrected peak factor naming convention.
v13.0	10/2025	No revision.

2.5.4 Evaporator Fan Controls Measure Overview

TRM Measure ID: NR-RF-FC

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools⁴⁷⁶

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.

⁴⁷⁶ 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:

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

Equation 199

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

Equation 200

Where:

kW_{evap}	=	Connected load kW of each evaporator fan, see Table 241
kW_{circ}	=	Connected load kW of the circulating fan, see Table 241
n_{fans}	=	Number of evaporator fans
DC_{comp}	=	Duty cycle of the compressor, see Table 241
DC_{evap}	=	Duty cycle of the evaporator fan, see Table 241
BF	=	Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running, see Table 241
8,760	=	Annual hours per year

Table 241. Evaporator Fan Controls—Savings Calculation Input Assumptions⁴⁷⁷

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWikIn-WEvapFMtrCtrl.⁴⁷⁸

⁴⁷⁷ The Maine Technical Reference Manual was utilized to determine these assumed values. Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019.

- kW_{evap}: Page 78, footnote 366 states this value is determined “based on a weighted average of 80% shaded-pole motors at 132 watts and 20% PSC motors at 88 watts. This weighted average is based on discussions with refrigeration contractors and is considered conservative (market penetration estimated at approximately 10%).”
- kW_{circ}: Page 78, footnote 367 states this value is the “wattage of fan used by Freeaire and Cooltrol”
- DC_{comp}: Page 78, footnote 368 states the reasoning for this value as follows: “A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (35%-65%), Control (35%-65%), Natural Cool (70%), Pacific Gas and Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor.”
- DC_{evap}: 94.4% is equivalent to 8,273 / 8,760 annual operating hours. The assumption of 8,273 is the annual total of the assumption that “a[n] evaporator fan in a cooler runs all the time, but a freezer only runs 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)”, an explanation given on page 82, footnote 401.
- BF: Page 183, Table 45, footnote A summarizes the Bonus Factor (-1 + 1/COP) as “assum[ing] 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.”

⁴⁷⁸ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 242. Evaporator Fan Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	Added Schools as an eligible building type.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.5.5 Night Covers for Open Refrigerated Display Cases Measure Overview

TRM Measure ID: NR-RF-NC

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

Eligible high-efficiency equipment is considered any suitable low-emissivity material sold as a night cover. The night cover must be applied for a period of at least six hours⁴⁷⁹ per day (i.e., average continuous overnight use).

⁴⁷⁹ 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.

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

Equation 201

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 ⁴⁸⁰

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.⁴⁸¹ Vertical and horizontal *open* equipment types were selected for inclusion given the nature of this measure.

⁴⁸⁰ 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”

⁴⁸¹ In 2013, the US DOE conducted an extensive life-cycle cost (LCC) analysis of the commercial refrigeration equipment classes listed in the current federal standard [10 CFR 431.66](#) to determine average annual unit energy consumption per equipment class. In this analysis, 10,000 separate simulations yielded probability distributions for various parameters associated with each equipment class, among them: the efficiency level in kWh/yr. These efficiency levels were then subject to roll-up calculations to determine market shares of each efficiency level, which were then utilized to compute the average consumption for said efficiency level listed in Table 243.

Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, US Department of Energy, September 2013. LCC Summary Statistics: Section 8B2; Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf.

Table 243. Night Covers—Energy and Peak Demand Savings per Lin. Ft.

Temperature ⁴⁸²	Condensing unit configuration	Equipment family	Average annual energy consumption/lin. ft. (kWh _{baseline})	kWh Savings	kW Savings ⁴⁸³
Medium (≥32 ± 2°F)	Remote condensing	Vertical open	1,453	131	–
		Horizontal open	439	40	
	Self-contained	Vertical open	2,800	252	
		Horizontal open	1,350	122	
Low (<32 ± 2°F)	Remote condensing	Vertical open	3,292	296	
		Horizontal open	1,007	91	
	Self-contained	Horizontal open	2,748	247	

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.⁴⁸⁴

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)

⁴⁸² 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-id?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

⁴⁸³ The demand savings for this measure are 0 because energy savings exist at night only.

⁴⁸⁴ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

- Operating temperature (low or medium as defined in Table 243)
- Horizontal linear feet length of refrigerated case

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 244. Night Covers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	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	No revision.
v4.0	10/10/2016	Added more significant digits to the input variables a-j.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	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	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.5.6 Solid and Glass Door Reach-Ins Measure Overview

TRM Measure ID: NR-RF-RI

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of ENERGY STAR or CEE certified vertical or horizontal closed solid and glass (transparent) door reach-in refrigerators and freezers.

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

Eligibility Criteria

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

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

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

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

Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 245.

Table 245. Door Reach-Ins—Baseline Energy Consumption^{485,486}

Baseline standards	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Solid door	$0.10V + 2.04$	$0.40V + 1.38$
Glass door	$0.12V + 3.34$	$0.75V + 4.10$

High-Efficiency Condition

Eligible high-efficiency equipment for solid- or glass-door reach-in refrigerators and freezers must meet ENERGY STAR minimum efficiency requirements, as shown in Table 246.

Table 246. Door Reach-Ins—Efficient Energy Consumption Requirements⁴⁸⁷

Door type	Product volume (cubic feet)	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Vertical closed solid door	$0 < V < 15$	$0.0267V + 0.8$	$0.21V + 0.9$
	$15 \leq V < 30$	$0.05V + 0.45$	$0.12V + 2.248$
	$30 \leq V < 50$		$0.2578V - 1.886$
	$V \geq 50$	$0.025V + 1.6991$	$0.14V + 4.0$
Vertical glass door	$0 < V < 15$	$0.095V + 0.445$	$0.232V + 2.36$
	$15 \leq V < 30$	$0.05V + 1.12$	
	$30 \leq V < 50$	$0.076V + 0.34$	
	$V \geq 50$	$0.105V - 1.111$	
Horizontal closed door (solid or glass)	All volumes	$0.05V + 0.28$	$0.057V + 0.55$

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

⁴⁸⁶ V = Interior volume [ft³] of a refrigerator or freezer (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).

⁴⁸⁷ ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 5.0, US Environmental Protection Agency. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20%28Rev.%20November%20-%202022%29%20Commercial%20Refrigerators%20and%20Freezers%20Specification.pdf>.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy and demand savings of solid and glass door reach-in refrigerators and freezers are calculated using values in Table 245 and Table 246, based on the volume of the units.

The savings calculations are specified as:

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

Equation 202

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

Equation 203

Where:

kWh_{base} = Baseline maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 245)

kWh_{ee} = Efficient maximum daily energy consumption in kWh, based on volume (V) of unit (see Table 246)

V = Chilled or frozen compartment volume [ft³] (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 factor⁴⁸⁸ = 1.0

⁴⁸⁸ The summer peak coincidence factor is assumed equal to 1.0, since the annual kWh savings is divided by the total annual hours (8,760), effectively resulting in the average kW reduction during the peak period.

Deemed Energy and Demand Savings Tables

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

Refrigerator or freezer	Door type	Product volume range (ft ³)	Average product volume ^{489,490}	kWh savings	kW savings
Refrigerator	Vertical closed solid door	0 < V < 15	9.0	693	0.079
		15 ≤ V < 30	20.6	956	0.109
		30 ≤ V < 50	41.7	1,341	0.153
		V ≥ 50	67.5	1,972	0.225
	Vertical closed glass door	0 < V < 15	47.9	1,129	0.129
		15 ≤ V < 30	21.0	1,347	0.154
		30 ≤ V < 50	42.1	1,771	0.202
		V ≥ 50	70.7	2,012	0.230
	Horizontal closed solid door	0 < V < 15	11.4	850	0.097
		15 ≤ V < 30	18.6	982	0.112
		30 ≤ V < 50	30.0	1,190	0.136
		V ≥ 50	50.0	1,555	0.178
	Horizontal closed glass door	0 < V < 15	3.0	1,194	0.136
		15 ≤ V < 30	20.2	1,633	0.186
		30 ≤ V < 50	30.0	1,883	0.215
		V ≥ 50	50.0	2,394	0.273

⁴⁸⁹ Simple average product volume for volume ranges of vertical solid and glass door refrigerators and freezers. ENERGY STAR Certified Commercial Refrigerators and Freezers qualified product listing (August 2023).
<https://www.energystar.gov/productfinder/product/certified-commercial-refrigerators-and-freezers/results>.

⁴⁹⁰ For product types with no ENERGY STAR certified units, the low end of the volume range was used as a placeholder in the event that additional products are certified before the TRM can be updated, with one exception. Horizontal closed glass door units assume the product volume specified for the equivalent refrigerator category to avoid using a volume of zero.

Refrigerator or freezer	Door type	Product volume range (ft ³)	Average product volume ^{489,490}	kWh savings	kW savings
Freezer	Vertical closed solid door	0 < V < 15	9.4	827	0.094
		15 ≤ V < 30	20.0	1,727	0.197
		30 ≤ V < 50	42.3	3,388	0.387
		V ≥ 50	68.8	5,573	0.636
	Vertical closed glass door	0 < V < 15	6.8	1,921	0.219
		15 ≤ V < 30	20.7	4,549	0.519
		30 ≤ V < 50	41.9	8,557	0.977
		V ≥ 50	72.5	14,343	1.637
	Horizontal closed solid door	0 < V < 15	14.2	2,081	0.238
		15 ≤ V < 30	19.1	2,694	0.308
		30 ≤ V < 50	30.0	4,059	0.463
		V ≥ 50	50.0	6,563	0.749
	Horizontal closed glass door	0 < V < 15	3.0	2,055	0.235
		15 ≤ V < 30	15.0	5,090	0.581
		30 ≤ V < 50	30.0	8,884	1.014
		V ≥ 50	50.0	13,943	1.592

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.⁴⁹¹

Program Tracking Data and Evaluation Requirements

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

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

⁴⁹¹ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 248. Solid and Glass Door Reach-Ins—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits. Updated methodology for ENERGY STAR Version 4.0.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	Citation added for average product volumes.
v11.0	10/2023	Updated ENERGY STAR efficiency requirements. Clarified that residential refrigerator and freezer equipment can be installed in commercial applications following the methodology in Volume 2 of the TRM. Updated documentation requirements.
v12.0	10/2024	Minor corrections.
v13.0	10/2025	No revision.

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 methodology⁴⁹², 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:

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

Equation 204

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

Equation 205

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

⁴⁹² 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>.

$$\begin{aligned}
C_{13} &= 6.5459673E+00 \\
^{\circ}R_{Adj} &= \text{Adjacent absolute temperature, } t_{DB,Adj} + 459.67 \text{ (see Table 249)} \\
^{\circ}R_{Refrig} &= \text{Refrigeration box absolute temperature, } t_{DB,Refrig} + 459.67 \\
&\text{(see Table 249)}
\end{aligned}$$

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

$$W_{Adj} = 0.62198 \times \frac{Rh_{Adj} \times P_{ws,Adj}}{14.696 - (Rh_{Adj} \times P_{ws,Adj})} \quad \text{Equation 206}$$

$$W_{Refrig} = 0.62198 \times \frac{Rh_{Refrig} \times P_{ws,Refrig}}{14.696 - (Rh_{Refrig} \times P_{ws,Refrig})} \quad \text{Equation 207}$$

Where:

$$\begin{aligned}
W_{Adj} &= \text{Humidity ratio of the adjacent space} \\
W_{Refrig} &= \text{Humidity ratio of the refrigerated space} \\
Rh_{Adj} &= \text{Relative humidity of the adjacent space (see Table 249)} \\
Rh_{Refrig} &= \text{Relative humidity of the refrigerated space (see Table 249)}
\end{aligned}$$

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

$$h_{Adj} = 0.24 \times t_{DB,Adj} + \left(W_{Adj} \times \left(1061 + (0.444 \times t_{DB,Adj}) \right) \right) \quad \text{Equation 208}$$

$$h_{Refrig} = 0.24 \times t_{DB,Refrig} + \left(W_{Refrig} \times \left(1061 + (0.444 \times t_{DB,Refrig}) \right) \right) \quad \text{Equation 209}$$

Where:

$$\begin{aligned}
h_{Adj} &= \text{Air enthalpy of the adjacent space} \\
h_{Refrig} &= \text{Air enthalpy of the refrigerated space} \\
t_{DB,Adj} &= \text{Dry-bulb temperature of the adjacent space (see Table 249)} \\
t_{DB,Refrig} &= \text{Dry-bulb temperature of the refrigerated space (see Table 249)}
\end{aligned}$$

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

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

Equation 210

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

Equation 211

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

Equation 212

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

Equation 213

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

Equation 214

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

Equation 215

Where:

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

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

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

Equation 216

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

Equation 217

Where:

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

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

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

Equation 218

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

Equation 219

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

Equation 220

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

Equation 221

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

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

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 222

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

Equation 223

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

Equation 224

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

Equation 225

Where:

ΔkW	=	<i>Whole-door demand savings</i>
ΔkWh	=	<i>Whole-door energy savings</i>

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 249. EER variables are calculated as either the simple or weighted average of representative EERs for refrigeration suction groups that correspond to medium temperature (cooler) or low temperature (freezer) multiplex or standalone units; these are detailed in Table 250.

Table 249. Strip Curtains—Savings Calculation Input Assumptions⁴⁹³

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

⁴⁹³ 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>.

⁴⁹⁴ EER is not an independent variable but is rather dependent on Table 250. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 250. Strip Curtains—Default EER by System Configuration⁴⁹⁵

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

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

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

⁴⁹⁵ Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. <https://rtf.nwcouncil.org/measure/strip-curtains>.

Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are shown below in Table 252.

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

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

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWIkIn-StripCrtn.⁴⁹⁶

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

⁴⁹⁶ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 253. Strip Curtains—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Added documentation for calculation methodology. Updated tracking data requirements. Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	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.⁴⁹⁷

High-Efficiency Condition

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

⁴⁹⁷ An open refrigerated case is not a baseline for these existing deemed savings. Contact the evaluation team for preliminary approval of the savings methodology for the application of a zero-energy door to an open refrigerated case.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

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

For medium temperature:

$$kW_{ASH} = 0.109 \text{ per door}^{498}$$

For low temperature:

$$kW_{ASH} = 0.191 \text{ per door}^{499}$$

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

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

Equation 226

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

Equation 227

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,⁵⁰⁰ the cooling load contribution from door heaters can be given by:

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

Equation 228

⁴⁹⁸ Here, “medium temperature” is equivalent to the categorization “coolers”. Pennsylvania TRM, “3.5.6 Controls: Anti-Sweat Heater Controls”. page 383, June 2016. https://www.puc.pa.gov/Electric/pdf/Act129/Act129_TRM-2016_Redlined-Final.pdf.

⁴⁹⁹ Ibid. Here, “low temperature” is equivalent to the categorization “freezers”.

⁵⁰⁰ *A Study of Energy Efficient Solutions for Anti-Sweat Heaters*. Southern California Edison RTTC. December 1999.

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data. The compressor analysis is limited to the cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

For medium temperature refrigerated cases, the saturated condensing temperature (SCT) is calculated as the design dry-bulb temperature plus 15 degrees. For low temperature refrigerated cases, the SCT is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant or 1/1.15 or approximately 0.87.⁵⁰¹

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

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

Equation 229⁵⁰²

Where:

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

⁵⁰¹ *Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls*. Pacific Gas and Electric Company. May 29, 2009. Assumes 15% oversizing.

⁵⁰² San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012.
https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

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

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

Equation 230⁵⁰³

Where:

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

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

Climate zone	T_{DB}^{504}	SCT_{MT}	SCT_{LT}	EER_{MT}	EER_{LT}
Climate Zone 1: Amarillo	98.6	113.6	108.6	6.18	4.74
Climate Zone 2: Dallas	101.4	116.4	111.4	5.91	4.56
Climate Zone 3: Houston	97.5	112.5	107.5	6.29	4.86
Climate Zone 4: Corpus Christi	96.8	111.8	106.8	6.36	4.91
Climate Zone 5: El Paso	101.1	116.1	111.1	5.94	4.58

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

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

Equation 231

⁵⁰³ Ibid.

⁵⁰⁴ 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. <http://ashrae-meteo.info/v2.0/>.

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

Equation 232

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

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

Equation 233

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

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

Equation 234

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

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

Equation 235

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

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ZeroHtDrs.⁵⁰⁵

⁵⁰⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Program Tracking Data and Evaluation Requirements

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

- Refrigeration temperature range

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 256. Zero-Energy Doors—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	Updated savings methodology to be consistent with the door heater controls measure.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Clarified energy and demand savings are in kilowatt/door rather than kilowatt/feet. Updated EUL reference.
v10.0	10/2022	Added clarification for baseline condition.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

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

Measure Overview

TRM Measure ID: NR-RF-DG

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

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

Measure Description

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

Eligibility Criteria

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

Baseline Condition

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets with at least six inches of damage for reach-in units and at least two feet of damage for walk-in units.⁵⁰⁶ An average baseline gasket efficacy⁵⁰⁷ of 90 percent is assumed for this measure.

⁵⁰⁶ Musgrave, Dwight. Emerson Design Services Network. "Study of Typical Gasket Deterioration", Feb 27, 2008, Slide 24. <https://slideplayer.com/slide/4525301/>.

⁵⁰⁷ Gasket efficacy is defined as the ratio of the gasket length that was removed by the installers to the gasket length that was replaced. A 90 percent gasket efficacy translates to an average of 10 percent of missing, badly damaged or ineffective gasket by length replaced.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

The energy savings assumptions are based on DEER 2005 analysis performed by Southern California Edison (SCE) and an evaluation of a Pacific Gas and Electric (PG&E) direct install refrigeration measures for program year 2006-2008.^{508,509} The results from the PG&E evaluation were used as the foundation for establishing the energy savings for the refrigeration gasket measures. The energy savings achievable for new gaskets replacing baseline gaskets were found during this study to be dependent almost entirely on the leakage through the baseline gaskets. Therefore, the energy savings attributable to door gaskets were derived for various scenarios regarding baseline gasket efficacies and are shown in Table 257 below.

Table 257. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. of Installed Door Gasket)⁵¹⁰

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

As the PG&E analysis was performed in California with different climate zones as compared to those in Texas, an analysis was conducted to develop an adjustment factor to associate the savings in the table above to Texas anticipated results. The PG&E study could not be used to determine these effects, as insufficient climate zones were researched. Therefore, the SCE study was utilized as savings in this study were determined for each of the 16 climate zones in California and were similar⁵¹¹ to those assessed within the PG&E results at 90 percent efficacy. A comparison was completed between the SCE energy savings and the typical meteorological year 3 (TMY3) data⁵¹² to establish a cooling degree day (CDD) correlation across the 16 California climate zones. Figure 3 provides a summary comparison for coolers and Figure 4 for freezers.

⁵⁰⁸ Southern California Edison (SCE). WPCSNRRN0013—Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases and Solid Doors of Reach-in Coolers and Freezers. 2007.

⁵⁰⁹ Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010.

http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.

⁵¹⁰ Ibid., Table 5-3.

⁵¹¹ The SCE ex-ante savings as reported in the PG&E report were 10.2 and 21.7 kWh/linear foot for coolers and freezers respectively.

Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. Table 5-3.

http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.

Modeled savings as reported in the SEC report for climate zone 4 were approximately 6 and 15 kWh/linear foot for coolers and freezers respectively.

⁵¹² <http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>

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

Figure 3. Door Gaskets—Comparison of Projected Annual Energy Savings to CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Coolers)

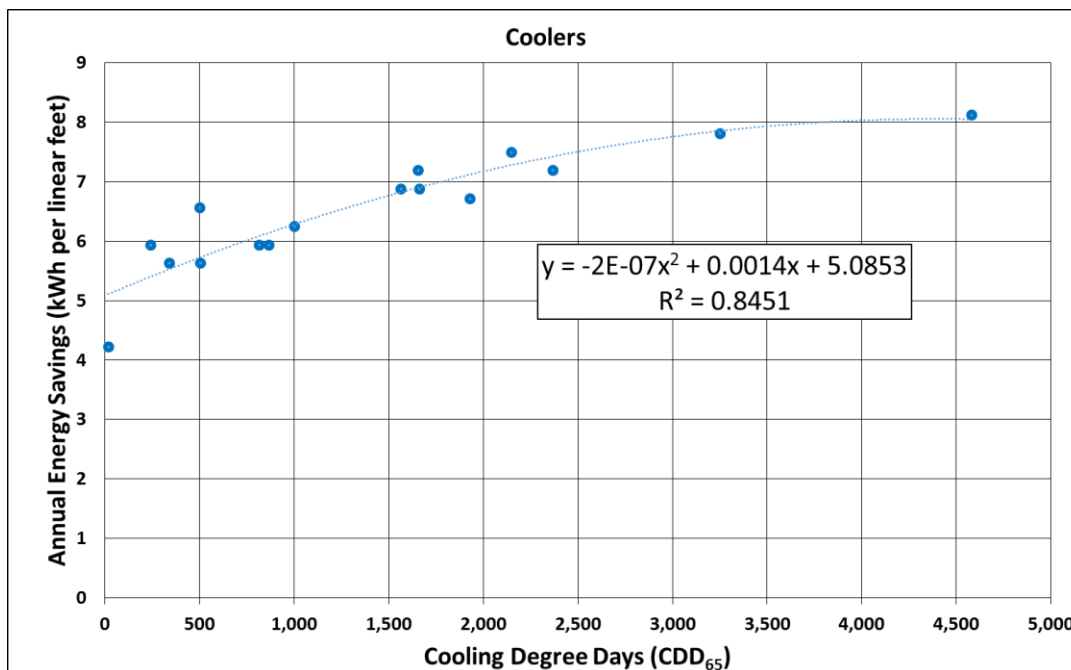
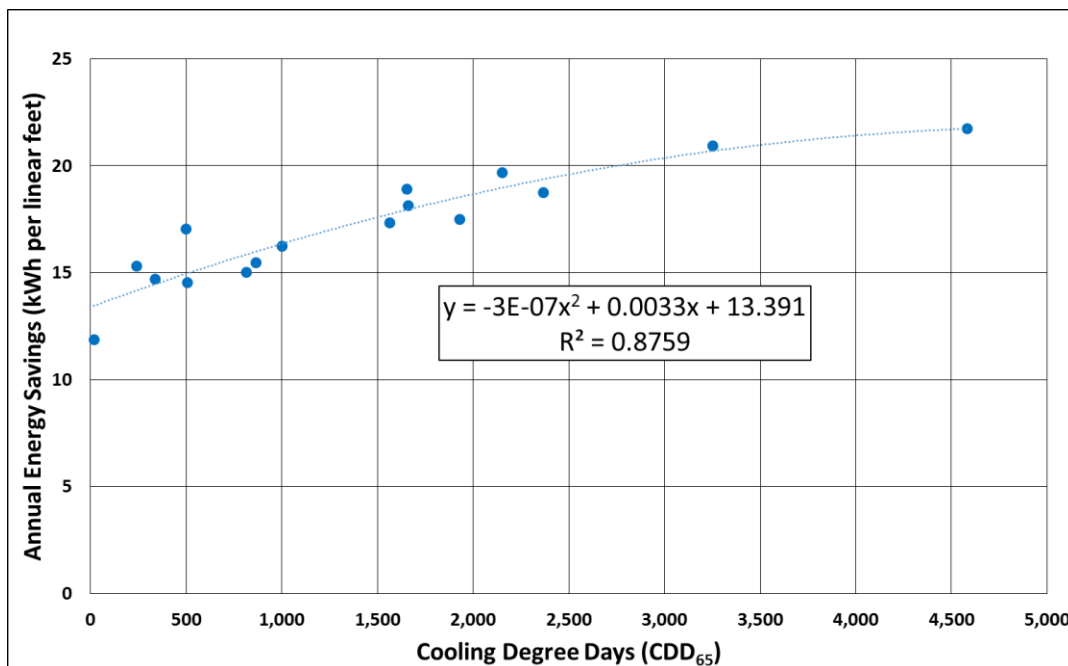


Figure 4. Door Gaskets—Comparison of Projected Annual Energy Savings to Cooling Degree CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Freezers)



These correlations were used to adjust the energy savings and TMY3 CDDs in California to TMY3 CDDs in Texas to determine an average energy savings of 7.4 and 20.0 kWh/linear feet for coolers and freezers in Texas. Comparing the average energy savings between California and Texas, the CDD adjustment results in a 113 percent adjustment factor for coolers and a 117 percent adjustment factor for freezers. For simplicity, an average adjustment factor of 115 percent (the midpoint of 113% and 117% TX vs. CA energy savings values) was applied to the PG&E results at 90 percent efficacy (as shown in Table 257 above), resulting in Texas-based annual energy savings values for coolers of 3.5 kWh/linear feet and freezers of 26.5 kWh/linear feet. These results are summarized in Table 258 below.

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

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

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

Savings Algorithms and Input Variables

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

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

Equation 236

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

Equation 237

Where:

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

L = Total gasket length (ft.)

Deemed Energy and Demand Savings Tables

Table 259. Door Gaskets—Energy and Peak Demand Savings per Lin. Ft. of Door Gasket

Refrigerator type	$\Delta kW/ft$	$\Delta kWh/ft$
Walk-in or reach-in cooler	0.0004	3.5
Walk-in or reach-in freezer	0.0030	26.5

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 3 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDrGask.⁵¹³

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

⁵¹³ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Document Revision History

Table 260. Door Gaskets—Revision History

TRM version	Date	Description of change
v6.0	10/2018	Measure origin.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	General reference checks and text edits. Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.5.10 High-Speed Doors for Cold Storage Measure Overview

TRM Measure ID: NR-RF-HS

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: All commercial with cold storage

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithms

Savings Methodology: Algorithms

Measure Description

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

Eligibility Criteria

Eligible equipment includes high-speed doors with a minimum opening rate of 32 inches per second, a minimum closing rate of 24 inches per second, and a means to automatically reclose the door, as defined by the Door and Access Systems Manufacturers' Association, International (DASMA).⁵¹⁴ The high-speed doors must be installed for access to a cold storage area either from exterior conditions, such as a loading dock, or from a conditioned area, such as a non-refrigerated warehouse.

Baseline Condition

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

High-Efficiency Condition

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

⁵¹⁴ DASMA Standard Specification for High Speed Doors and Grilles, definition 2.6 for High Speed Door. <https://www.dasma.com/wp-content/uploads/pubs/Standards/DASMA403.pdf>.

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

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

Equation 238

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

Equation 239

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

Equation 240

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

Equation 241

Where:

w	=	Width of the door opening (ft.)
h	=	Height of the door opening (ft.)
EF	=	The outcome of Equation 239 based on climate zone and cold storage application, see Table 261 and Table 262
CF	=	The outcome of Equation 241 based on climate zone and cold storage application, see Table 263, Table 264, and Table 265
hours	=	Operating hours, 3,798 ⁵¹⁵

⁵¹⁵ Operating hours taken from TRM Volume 3, Table 8, hours for refrigerated warehouse.

3,790	=	Constant ⁵¹⁶
q_s/A	=	Sensible heat load of infiltration air per square foot of door opening, ton/ft ² , see Table 266
R_s	=	Sensible heat ratio of the infiltration air heat gain, see Table 267
ΔD_t	=	Change in percent of time the doorway is open, 0.33 ⁵¹⁷
DFF	=	Doorway flow factor, varies based on temperature delta between cold room and infiltration air, 0.8 for delta $T \geq 20^\circ\text{F}$, 1.1 for delta $T < 20^\circ\text{F}$ ⁵¹⁸
ΔE	=	Change in door effectiveness, 0.2 ⁵¹⁹
COP	=	Coefficient of performance, assume 2.8 COP ⁵²⁰
3,412	=	Constant to convert from Btu to kWh and from Btuh to kW

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

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

⁵¹⁶ From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

⁵¹⁷ From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes; assume baseline door open-close time is 15 seconds, and high-speed door open-close time is 10 seconds, for a difference in percent of time the door is open of $(15-10)/15 = 0.33$.

⁵¹⁸ ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 17 notes.

⁵¹⁹ ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes. ASHRAE provides a range of doorway effectiveness, stating 0.95 for newly installed doors though that may quickly decrease to 0.8 or 0.85 depending on door use frequency and maintenance. Air curtain effectiveness ranges from very poor to more than 0.7. The input assumptions for this measure are conservatively estimated for baseline door effectiveness of 0.7 and high-speed door effectiveness of 0.9.

⁵²⁰ Air cooled chiller efficiency from IECC 2009.

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

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

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

Climate zone	All temperatures
All climate zones	1.0

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

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

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

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

Table 266. High-Speed Doors—Sensible Heat Load of Infiltration Air⁵²¹

Cold room temperature	Climate zone							
	Z1-2, winter peak	Z3-5, winter peak	Z1, annual	Z2, Z5, annual	Z3-4, annual	Z4, summer peak	Z1, Z5, summer peak	Z2-3, summer peak
	Infiltration air temperature							
	15°F	30°F	63°F	70°F	75°F	96°F	99°F	103°F
-20°F	0.2	0.40	0.85	0.94	1.02	1.31	1.38	1.45
0°F	–	0.18	0.55	0.62	0.68	0.95	1.03	1.08
20°F	–	0.08	0.30	0.35	0.42	0.65	0.70	0.76
40°F	–	–	0.13	0.17	0.30	0.38	0.45	0.50

Table 267. High-Speed Doors—Sensible Heat Ratio of Infiltration Air⁵²²

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

⁵²¹ From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, figure 9. Values in table are summarized to reflect average annual and summer and winter peak infiltration air Temperatures. Where infiltration air Temperatures are not shown on ASHRAE figure 9, $\frac{q_s}{A}$ is estimated by extrapolation. Values for infiltration air temperature of 75°F are used to calculate energy and demand factors for doorways between cold room and conditioned space.

⁵²² Sensible heat ratio determined from psychrometric chart, using values for the air properties of dry bulb Temperature and relative humidity. Relative humidity of the cold room is estimated at 90 percent based on ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, Table 9. Energy factor values for unconditioned space are the average annual values between the expected operating hours of 8 a.m. to 6 p.m. using TMY3 data. Demand factor values for unconditioned space are taken using the highest probability temperatures from TRM Volume 1 and their associated relative humidity from TMY3 data. Energy and demand factor values for conditioned space assume conditioned air temperature of 75°F and 45 percent RH.

Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

The utilization of the high-speed doors coincident with the peak demand period is uncertain, an average of the total savings over the operating hours per facility type is used (the absence of *hours* in Equation 241 implies Equation 238 can be divided by *hours* to yield *kW savings*).

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 16 years based on Navigant's 2018 ComEd Effective Useful Life Research Report.⁵²³

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

⁵²³ "ComEd Effective Useful Life Research Report." Navigant. May 14, 2018. Table A-4.
<https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf>.

Document Revision History

Table 268. High-Speed Doors—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	General reference checks and text edits.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	Updated EUL from 5 to 16 years to match recommendations from 2018 Navigant report.
v13.0	10/2025	No revision.

2.5.11 Retrofit Doors for Open Refrigerated Display Cases Measure Overview

TRM Measure ID: NR-RF-RD

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any commercial retail facility, such as supermarkets, grocery stores, 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

Open display cases are typically found in grocery and convenience stores and have been a preference of store owners because they allow customers a clear view and easy access to refrigerated products. This measure is retrofitting existing, open, refrigerated display cases by adding and installing doors. The baseline equipment is an open vertical or horizontal display case with no doors or covering. The efficient equipment is the installation of solid doors on the existing display case. Replacement of open display cases with new display cases with doors is not covered under this measure characterization.

Energy savings are based on air infiltration reduction from the addition of doors to the open display cases. The air infiltration reductions assume a reduced heat gain and subsequent reduced load on the refrigeration compressors. Both radiant and conduction heat losses were factored into the analysis as well. Energy savings are based on a per linear foot of display case.

Interactive HVAC energy savings were also included in the measure savings analysis. The HVAC interactive effects calculation assesses the measure's impact on the heating and cooling equipment. With adding a door to an open refrigerated display case, excess cold air leaking into the conditioned space no longer has to be treated by the heating system, resulting in additive savings. Similarly, the reduction in cold air from the open refrigerated display case no longer supplements the efforts of the space cooling equipment, which results in an overall increase in its consumption.

Eligibility Criteria

High, medium, and low temperature cases are eligible for this measure; however, the measure assumptions detailed in this characterization are based on medium temperature display cases, with the installation of zero energy doors, as it was deemed the most likely candidate for participation in this measure.

Baseline Condition

The baseline efficiency case is an open, refrigerated, display case without any covering.

High-Efficiency Condition

The high-efficiency condition is retrofitting an existing open, refrigerated, display case by adding doors.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The savings calculations are specified as:

$$\begin{aligned} \text{Energy Savings } [\Delta kWh] &= \left(\frac{(\Delta HG \times CL)}{(EER \times 1,000) \times 8,760} \right) + \left(MMBtu_{HVAC \text{ Cool}} \times CL \times \left(\frac{1}{SEER} \right) \times 1,000 \right) \\ &\quad - kWh_{Night \text{ Covers}} - kWh_{Added \text{ Lights}} \end{aligned}$$

Equation 242

$$\begin{aligned} \text{Peak Demand Savings } [\Delta kW] &= \left(\frac{(\Delta HG \times CL)}{EER \times 1,000} - kW_{Added \text{ Lights}} \right) \times CF_{Refrigeration} \\ &\quad + \left(\left(\frac{MMBtu_{HVAC \text{ Cool}}}{Hours_{Cool}} \times CL \times \left(\frac{1}{SEER} \right) \times 1,000 \right) \times CF_{Cool} \right) \end{aligned}$$

Equation 243

Where:

ΔHG	=	Heat Gain, the decreased load or the reduced heat gain on the open refrigerated display case with the installation of a door [Btu/hr-linear foot]; =1,172 Btu/h-ft for vertical cases and =202.3 Btu/h-ft for horizontal cases ⁵²⁴
CL	=	Case length, refrigerated case length in feet [ft]
EER	=	Energy efficiency ratio, display case compressor efficiency [Btu/hr-watt]; =11.36 Btu/hr-watt ⁵²⁵
1,000	=	Conversion from watts to kilowatts (W/kW)

⁵²⁴ 2025 IL TRM v13.0 Vol 2 Section 4.6.13 Add Doors to Open Refrigerated Display Cases.

⁵²⁵ Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications. The efficiency analysis and product review is sourced from the Efficiency Vermont TRM, which utilizes data from Emerson Climate Technology software. Medium temperature cases have an EER value of 11.36

8,760 = Annual operating hours of the refrigerated display case⁵²⁶

$MMBtu_{HVAC\ Cool}$ = Total cooling load increase on the HVAC equipment per linear foot of display case. Varies by climate zone, please see Table 269

Table 269. Retrofit Doors—Cooling Load Increase per linear foot by Climate Zone⁵²⁷

Climate Zone	$MMBtu_{HVAC\ Cool\ Vertical}$	$MMBtu_{HVAC\ Cool\ Horizontal}$
Zone 1: Amarillo	-4.66	-0.80
Zone 2: Dallas	-6.45	-1.11
Zone 3: Houston	-7.40	-1.28
Zone 4: Corpus Christi	-8.08	-1.39
Zone 5: El Paso	-5.99	-1.03

SEER = Seasonal energy efficiency ratio, HVAC equipment operating efficiency = 13.4⁵²⁸ [Btu/hr-watt]

$kWh_{Night\ Covers}$ = Reduction in energy savings if existing display case utilizes night covers, refer to Table 275; = 0 [kWh/linear-ft] if existing case has no night covers.

$kWh_{Added\ Lights}$ = Reduction in energy savings if new lighting is added to the case (kWh/linear-ft), refer to Table 243; = 0 if no lighting is added, or if lighting is added but existing lighting is removed. If lighting is retrofit, determine case lighting savings using '2.1.1 Lamps and Fixtures'.

$kW_{Added\ Lights}$ = Reduction in demand savings if new lighting is added to the case (kWh/linear-ft), refer to Table 243; = 0 if no lighting is added, or if lighting is added but existing lighting is removed. If lighting is retrofit, determine case lighting savings using '2.1.1 Lamps and Fixtures'

$Hours_{cool}$ = Total combined hours the site is providing cooling, see Table 270

⁵²⁶ The measure assumes the baseline equipment is not employing night covers or any other covering but is in fact left open for the duration of its operation.

⁵²⁷ The MMBtu increase on the HVAC cooling equipment is based on an outdoor air temperature bin analysis, the total hours of operation of the cooling system, the building's overall loss of additional cooling as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain amount of conditioned air has to be treated to replace the air previously cooled by the display case. A 25% disabling factor was also applied for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment.

⁵²⁸ This is the code value for packaged units that are less than 5.42 tons and less than 5 years old.

Table 270. Retrofit Doors—Hours the Cooling System is Operational

Climate Zone	Hours _{cool}
Zone 1: Amarillo	3,974
Zone 2: Dallas	5,507
Zone 3: Houston	6,316
Zone 4: Corpus Christi	6,891
Zone 5: El Paso	5,111

$CF_{Refrigeration}$ = Summer peak coincidence factor for the refrigerated display case
= 0.964⁵²⁹

CF_{Cool} = Summer peak coincidence factor for the HVAC cooling system.
This is the summer system peak coincidence factor for commercial cooling (during system peak hours), see Table 271

Table 271. Retrofit Doors—HVAC System Coincidence Factors

Climate Zone	CF_{Cool}	
	Supermarket	Convenience
Zone 1: Amarillo	0.29	0.73
Zone 2: Dallas	0.58	1.0
Zone 3: Houston	0.60	1.0
Zone 4: Corpus Christi	0.54	0.94
Zone 5: El Paso	0.38	0.76

Deemed Energy and Demand Savings Tables

The per-linear foot deemed energy and demand savings for open-case, no added lights baseline condition are shown in Table 272 and Table 273. The per-linear foot deemed energy and demand reduction for added lighting is shown in Table 243, and the per-linear foot deemed energy reduction for a night cover baseline is shown in Table 275.

Table 272. Retrofit Doors—Deemed Energy and Demand Savings for Supermarkets per Linear Foot For Open Case Baseline

Climate Zone	Vertical		Horizontal	
	kW/ft	kWh/ft	kW/ft	kWh/ft
Zone 1: Amarillo	0.074	556	0.013	96
Zone 2: Dallas	0.049	422	0.008	73
Zone 3: Houston	0.047	351	0.008	61
Zone 4: Corpus Christi	0.052	301	0.009	52

⁵²⁹ IL TRM Measure 4.6.13 Add Doors to Open Refrigerated Cases

Climate Zone	Vertical		Horizontal	
	kW/ft	kWh/ft	kW/ft	kWh/ft
Zone 5: El Paso	0.066	457	0.011	79

Table 273. Retrofit Doors—Deemed Energy and Demand Savings for Convenience Stores per Linear Foot for Open Case Baseline

Climate Zone	Vertical		Horizontal	
	kW/ft	kWh/ft	kW/ft	kWh/ft
Zone 1: Amarillo	0.036	556	0.006	96
Zone 2: Dallas	0.012	422	0.002	73
Zone 3: Houston	0.012	351	0.002	61
Zone 4: Corpus Christi	0.017	301	0.003	52
Zone 5: El Paso	0.033	457	0.006	79

Table 274. Retrofit Doors—Energy and Demand Savings Reduction per Lin. Ft. for Added Lighting⁵³⁰

Climate Zone	kWh _{Added Lights}	kW _{Added Lights}	
		Supermarket	Convenience
Zone 1: Amarillo	-24	-0.001	-0.004
Zone 2: Dallas		-0.003	-0.005
Zone 3: Houston		-0.003	-0.005
Zone 4: Corpus Christi		-0.003	-0.005
Zone 5: El Paso		-0.002	-0.004

Table 275. Retrofit Doors—Energy Savings Reduction per Lin. Ft. for Night Cover Baseline

Condensing unit configuration	Equipment family	kWh _{NightCovers} ⁵³¹
Remote condensing	Vertical open	-130
	Horizontal open	-39
Self-contained	Vertical open	-252
	Horizontal open	-121

⁵³⁰ 2025 IL TRM v13.0 Vol 2 Section 4.5.4 LED Bulbs and Fixtures, 4 watts per ft for LED Display Case lighting.

⁵³¹ See Volume 3 Section 2.5.5 Night Covers for Open Refrigerated Cases, Medium Temperature Savings.

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.⁵³²

Program Tracking Data and Evaluation Requirements

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

- Building Type (Supermarket, Convenience Store)
- Climate zone or county
- Baseline Condition (open case, night covers)
- Refrigerated case length
- Display case equipment type:
 - Equipment family (vertical, horizontal)
 - Condensing unit configuration (night cover baseline only)
- Retrofit door lighting condition (no lighting, lighting added, existing lighting replaced)

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 276. Retrofit Doors—Revision History

TRM version	Date	Description of change
v13.0	11/25/2025	Measure origin.

⁵³² The measure life is sourced from the PG&E Workpaper, “Add Doors to Open Medium Temperature Cases – PGE3PREF116 R3”, June 2019.

2.6 NONRESIDENTIAL: WATER HEATING

2.6.1 Heat Pump Water Heaters Measure Overview

TRM Measure ID: C-WH-HW

Market Sector: Commercial

Measure Category: Water heating

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

Fuels Affected: Electricity and gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the replacement of an electric storage water heater with an ENERGY STAR compliant heat pump water heater (HPWH) in a commercial application.

Eligibility Criteria

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

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

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency uniform energy factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with

tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.⁵³³

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.⁵³⁴ The TRM will add an early retirement baseline after the effective date for the new standard.

Table 277. HPWHs—Federal Standard for Consumer Electric Storage Water Heaters

Rated storage volume	Draw pattern	FHR ^{535,536}	UEF ⁵³⁷
≥ 20 gal and ≤ 55 gal	Very small usage	$0 \leq \text{FHR} < 18$	$0.8808 - (0.0008 \times V_r)$
	Low usage	$18 \leq \text{FHR} < 51$	$0.9254 - (0.0003 \times V_r)$
	Medium usage	$51 \leq \text{FHR} < 75$	$0.9307 - (0.0002 \times V_r)$
	High usage	$75 \leq \text{FHR}$	$0.9349 - (0.0001 \times V_r)$
> 55 gal and ≤ 120 gal	Very small usage	$0 \leq \text{FHR} < 18$	$1.9236 - (0.0011 \times V_r)$
	Low usage	$18 \leq \text{FHR} < 51$	$2.0440 - (0.0011 \times V_r)$
	Medium usage	$51 \leq \text{FHR} < 75$	$2.1171 - (0.0011 \times V_r)$
	High usage	$75 \leq \text{FHR}$	$2.2418 - (0.0011 \times V_r)$

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

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 278.⁵³⁸

⁵³³ 10 CFR Part 430.32 Energy and water conservation standards and their effective dates.

www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8.

⁵³⁴ Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. <https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063>.

⁵³⁵ “The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs” presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. <https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf>.

⁵³⁶ Assume FHR equal to that of installed water heater.

⁵³⁷ V_r is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

⁵³⁸ ENERGY STAR HPWH Key Product Criteria. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.

Table 278. HPWHs—ENERGY STAR Specification

Criteria		ENERGY STAR requirement
UEF	Integrated HPWH	UEF $\geq$ 3.30
	Integrated HPWH, 120 volt/15 amp circuit	UEF $\geq$ 2.20
	Split-system HPWHT	UEF $\geq$ 2.20
First-hour rating		FHR $\geq$ 45 gallons per hour
Warranty		Warranty $\geq$ 6 years on sealed system
Safety		UL 174 and UL 1995 or UL 60335-2-40
Lower compressor cut-off temperature (reporting requirement only)		Report ambient temperature below which the compressor cuts off and electric-resistance-only operation begins

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.⁵³⁹

HPWHs depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces where temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.⁵⁴⁰

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

HPWH savings are calculated on a per-unit basis. Deemed savings are calculated utilizing the standard algorithms outlined below for water heating. Consumption in gallons per year is estimated using data from Building America Performance Analysis Procedures for Existing Homes.⁵⁴¹ Temperature data are based on TMY3 dataset.⁵⁴² The area served by the HPWH may only be a portion of a commercial building, the area served by the water heater must be

⁵³⁹ ENERGY STAR-certified water heaters qualified product listing.
https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

⁵⁴⁰ Heat Pump Water Heaters. Department of Energy, May 2012.
<http://energy.gov/energysaver/articles/heat-pump-water-heaters>

⁵⁴¹ Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. <https://www.nrel.gov/docs/fy06osti/38238.pdf>.

⁵⁴² TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, <https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here: <https://texasefficiency.com/trm-docs/>.

documented. Alternately, the daily demand per unit in the table may also be used to estimate consumption and translated to annual consumption.

Energy Savings Algorithm

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

Equation 244

Where:

ρ	=	Water density [lbs/gal] = 8.33
C_p	=	Specific heat of water [Btu/lb·°F] = 1
GPY/SF	=	Estimated annual hot water use intensity [gal/year/sf] (see Table 279)

Table 279. HPWHs—Water Heater Consumption (Gal/Year)⁵⁴³

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

A	=	Building square footage served by the water heater [sf]
DD	=	Daily demand per unit per day (see Table 279)
$Quantity$	=	Necessary number of units (HPWHs) per 1,000 sq ft. depending on the building type (see Table 279)

⁵⁴³ Osman S, & Koomey, J. G J 1995, National Laboratory 1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting. Table 2.
<https://escholarship.org/uc/item/2j42t2c3>.

T_{setpoint}	=	Water heater setpoint temperature [°F] ⁵⁴⁴ = 120
$T_{\text{supply,annual}}$	=	Average annual supply water temperature [°F] (see Table 280)
UEF_{pre}	=	Baseline uniform energy factor (calculate per Table 277)
UEF_{post}	=	Uniform energy factor of new water heater
3,412	=	Constant to convert from Btu to kWh

Table 280. HPWHs—Water Mains Temperature (°F)⁵⁴⁵

Climate zone	$T_{\text{supply,annual}}$	$T_{\text{supply,seasonal}}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

Demand Savings Algorithm

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

Equation 245

Where:

$T_{\text{supply,seasonal}}$	=	Seasonal supply water temperature [°F] (see Table 280)
$CF_{S/W}$	=	Seasonal peak coincidence factor (see Table 281)

⁵⁴⁴ 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.” Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

⁵⁴⁵ Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, <https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here: <https://texasefficiency.com/trm-docs/>.

Table 281. HPWHs—Seasonal Peak CFs

Building type	Commercial ⁵⁴⁶		Lodging ⁵⁴⁷	
Climate zone	Summer	Winter	Summer	Winter
Zone 1: Amarillo	0.059	0.039	0.039	0.073
Zone 2: Dallas	0.060	0.039	0.035	0.075
Zone 3: Houston	0.063	0.039	0.038	0.080
Zone 4: Corpus Christi	0.064	0.042	0.038	0.068
Zone 5: El Paso	0.064	0.040	0.028	0.069

Deemed Energy Savings Tables

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

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Upstream/Midstream Delivery

For upstream/midstream program designs where the building type is known, use the GPY identified in Table 279 associated with the proper building type and the area of the building must be reported.

⁵⁴⁶ Probability weighted seasonal peak CFs are calculated according to the method in Section 4 of Texas TRM Vol. 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Commercial Water Heating. Peak Season, Peak Weekday values are used for summer calculations. Off Peak Season, Peak Weekday values are used for winter calculations.
<https://loadshape.epri.com/enduse>

⁵⁴⁷ Building America Performance Analysis Procedures for Existing Homes: Shower, Bath, and Sink Hot Water Use Profile.

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 13 years.⁵⁴⁸

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

⁵⁴⁸ 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, “Heat Pump Water Heaters and American Homes: A Good Fit?” p 9-74.
<https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf>.

Document Revision History

Table 282. Commercial Heat Pump Water Heaters—Revision History

TRM version	Date	Description of change
v11.0	10/2023	Measure origin.
v12.0	10/2024	Cleaned up table column labels and equation parameter definitions. Updated building type names to align with Volume 3 naming convention.
v13.0	10/2025	Revised seasonal peak coincidence factors.

2.6.2 Central Domestic Hot Water Controls Measure Overview

TRM Measure ID: NR-WH-DC

Market Sector: Commercial

Measure Category: Water heating

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

Circulation Pump Savings Algorithm

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

Equation 246

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

Equation 247

Where:

kW_{pump}	=	The demand used by the circulation pump, obtained from the project site; if unknown, assume 0.075 kW
$\text{Pump}_{\%On\_base}$	=	Baseline pump operation as percentage of time, 100%
$\text{Pump}_{\%On\_eff}$	=	Efficient pump operation as percentage of time, 7% ⁵⁴⁹
Hours	=	Hours per year = 8,760
CF	=	Seasonal peak coincidence factor, see Table 283

Table 283. Central DHW Controls—Seasonal Peak CFs⁵⁵⁰

Building type	Commercial		Lodging ⁵⁵¹	
	Summer	Winter	Summer	Winter
Climate Zone 1: Amarillo	0.00016	0.00011	0.00012	0.00015
Climate Zone 2: Dallas	0.00017	0.00011	0.00012	0.00014
Climate Zone 3: Houston	0.00016	0.00011	0.00012	0.00015

⁵⁴⁹ A 93 percent pump runtime reduction is assumed based on the average runtime reduction of field studies conducted at multiple sites: “Evaluation of New DHW System Controls in Hospitality and Commercial Buildings,” Minnesota Department of Commerce, average reduction of 87 percent; and “Energy-Efficiency Controls for Multifamily Domestic Hot Water Systems,” New York State Energy Research and Development Authority, average reduction of 99 percent.

⁵⁵⁰ Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations.
<https://loadshape.epri.com/enduse>.

⁵⁵¹ For the purposes of this measure, the lodging building type applies to all buildings where lodging takes place, including multifamily, hotels, nursing homes, dormitories, prisons, and similar.

Building type	Commercial		Lodging ⁵⁵¹	
Climate zone	Summer	Winter	Summer	Winter
Climate Zone 4: Corpus Christi	0.00016	0.00011	0.00012	0.00015
Climate Zone 5: El Paso	0.00018	0.00011	0.00012	0.00014

Thermal Distribution Savings Algorithm

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

Equation 248

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

Equation 249

Where:

- # Units* = The number of dwelling units at the project site
- kWh_{reference}* = Annual kWh energy savings from reference study (see Table 284)
- HDD Adjustment* = Climate adjustment for Texas heating degree days (see Table 285)

Table 284. Central DHW Controls—Reference kWh by Water Heater and Building Type⁵⁵²

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

Table 285. Central DHW Controls—HDD Adjustment Factors⁵⁵³

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

⁵⁵² Reference kWh are the annual energy savings per dwelling unit from the Southern California Edison Company Work Paper SCE13WP002, Demand Control for Centralized Water Heater Recirculation Pump for California Climate Zone 13.

⁵⁵³ HDD Adjustment factors for DHW controls are derived by dividing the HDD for each Texas climate zone by the HDD from the reference climate zone (California Climate Zone 13).

Deemed Energy Savings Tables

Table 286 presents the energy savings (kWh) for a range of pump sizes for all climate zones. The deemed savings are provided for convenience, but the algorithm may be used for pump sizes that differ from the assumed wattage listed in the tables.

Table 286. Central DHW Controls—Circulation Pump Energy Savings

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

Table 287 presents the thermal energy savings (kWh) per dwelling unit for all climate zones. Thermal energy savings only apply to lodging building types where lodging takes place (multifamily, hotels, nursing homes, dormitories, prisons, and similar). For commercial applications, please follow a custom approach.

Table 287. Central DHW Controls—Thermal Distribution Energy Savings per Dwelling Unit

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

Deemed Summer and Winter Demand Savings Tables

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

Table 288. Central DHW Controls—Circulation Pump Peak Demand Savings

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

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

Table 289. Central DHW Controls—Thermal Distribution Peak Demand Savings per Dwelling Unit

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Climate Zone 1: Amarillo	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Climate Zone 2: Dallas	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Climate Zone 3: Houston	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Climate Zone 4: Corpus Christi	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Climate Zone 5: El Paso	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Time clock.⁵⁵⁴

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

⁵⁵⁴ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

Document Revision History

Table 290. Central DHW Controls—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.6.3 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: NR-WH-SV

Market Sector: Commercial

Measure Category: Water heating

Applicable Building Types: Lodging

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)⁵⁵⁵ between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95°F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

⁵⁵⁵ A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

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

Equation 250

Where:

<i>SHFR</i>	=	<i>Showerhead flow rate, gallons per minute [gpm] (see Table 291)</i>
<i>BW</i>	=	<i>Behavioral waste, minutes per shower (see Table 291)</i>
<i>n_s</i>	=	<i>Number of showers per occupied room per day (see Table 291)</i>
<i>365</i>	=	<i>Constant to convert days to years (see Table 291)</i>
<i>OCC</i>	=	<i>Occupancy rate (see Table 291)</i>
<i>n_{SH}</i>	=	<i>Number of showerheads per room (see Table 291)</i>

Applying the formula to the values used for Texas from Table 291 returns the following values for baseline behavioral waste in gallons per showerhead per year:

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

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

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

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

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 291.

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

Equation 251

Where:

$HW\%$ = Hot water percentage (see Table 291)

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

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

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

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

Table 291. Showerhead TSRVs—Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower) ⁵⁵⁶	1.742			
Showers/occupied room/day ⁵⁵⁷	1.756			
Occupancy rate ⁵⁵⁸	65.9%			
Showerheads/room ⁵⁵⁹	1.0			
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water ⁵⁶⁰	80-85%, or 82.5% on average			
Hot water saved/year (gal)	1,516	1,213	1,062	910

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

Equation 252

⁵⁵⁶ Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

⁵⁵⁷ Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

⁵⁵⁸ 2001-2021 US hotel occupancy rates from Statista. <https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/>. Used average of last 5 pre-COVID years (2015-2019).

⁵⁵⁹ Assuming industry standard for standard one-bathroom rooms.

⁵⁶⁰ Average percent hot water from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

Where:

ρ	=	Water density [lb/gal] = 8.33
C_p	=	Specific heat of water [Btu/lb°F] = 1
V	=	Hot water saved per year per showerhead [gal] (see Table 291)
T_{Setpoint}	=	Water heater setpoint [°F] ⁵⁶¹ = 120
$T_{\text{Supply,Avg}}$	=	Average supply water temperature [°F] (see Table 292)
RE	=	Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric-resistance water heaters, or 2.2 for heat-pump water heaters. ⁵⁶²
3,412	=	Constant to convert from Btu to kWh

Demand Savings Algorithms

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

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

Equation 253

Where:

$T_{\text{Supply,Seasonal}}$	=	Seasonal supply water temperature (see Table 292)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 293)

⁵⁶¹ 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs” October 2010, page 99. Data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

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

Table 292. Showerhead TSRVs—Water Mains Temperatures

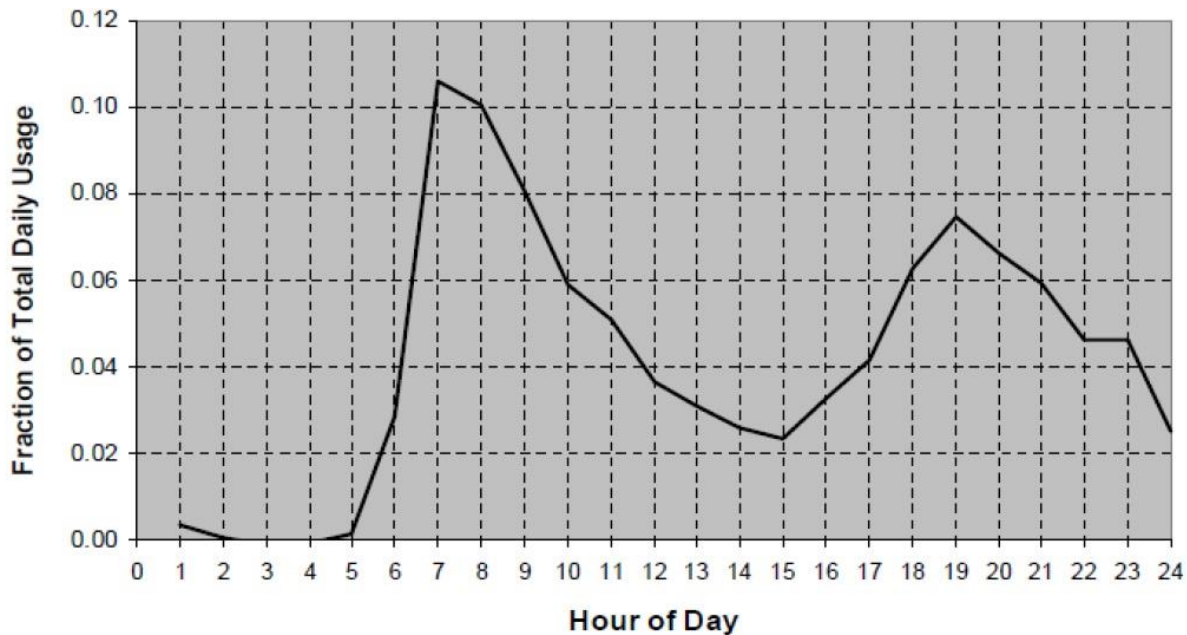
Climate zone	Water mains temperature (°F) ⁵⁶³		
	T _{SupplyAverage}	T _{SupplySeasonal}	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 293. Showerhead TSRVs—Peak Coincidence Factors

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

⁵⁶³ Based on typical meteorological year (TMY) dataset for TMY3: <https://sam.nrel.gov/weather-data.html>.

Figure 5. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile⁵⁶⁴



Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

⁵⁶⁴ Building America Performance Analysis Procedures for Existing Homes.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.⁵⁶⁵ This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).⁵⁶⁶

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 294. Showerhead TSRVs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁵⁶⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

⁵⁶⁶ 2014 California Database for Energy Efficiency Resources. <http://www.deeresources.com/>.

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

TRM Measure ID: NR-WH-TV

Market Sector: Commercial

Measure Category: Water heating

Applicable Building Types: Lodging

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of replacing existing tub spouts and showerheads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV)⁵⁶⁷ between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95°F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

Eligibility Criteria

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

Baseline Condition

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

⁵⁶⁷ A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

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

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

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

Equation 254

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

Equation 255

Where:

$\%WUE_{SH}$	=	Showerhead percentage of warm-up events (see Table 295)
$\%WUE_{TS}$	=	Tub spout percentage of warm-up events (see Table 295)
$SHFR$	=	Showerhead flow rate, gallons per minute (gpm) (see Table 295)
$TSFR$	=	Tub spout flow rate, gallons per minute (gpm) (see Table 295)
BW	=	Behavioral waste, minutes per shower (see Table 295)
n_S	=	Number of showers per occupied room per day (see Table 295)
365	=	Constant to convert days to years (see Table 295)
OCC	=	Occupancy rate (see Table 295)
n_{SH}	=	Number of showerheads per room (see Table 295)

Applying the formula to the values from Table 295 returns the following values:

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

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

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

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

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

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

$$\text{Annual Diverter Waste} = \text{DLR} \times t_s \times n_s \times 365 \frac{\text{days}}{\text{year}} \times \frac{\text{OCC}}{n_{SH}}$$

Equation 256

Where:

DLR = Diverter leakage rate (gpm) (see Table 295)

t_s = Shower time (min/shower) (see Table 295)

Applying the formula to the values used for Texas from Table 295 returns the following values:

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

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percentage of hot water from Table 295.

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

Equation 257

Where:

SHBW = Showerhead behavioral waste (gal)

TSBW = Tub-spout behavioral waste (gal)

DW = Diverter waste (gal)

$HW\%_{SH,TS}$ = Showerheads and tub-spout hot water percentage
(see Table 295)

$HW\%_D$ = Diverter hot-water percentage (see Table 295)

Applying the formula to the values from Table 295 returns the following values:

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

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

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

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

Table 295. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction

Description	Part 1—Behavioral waste		Part 2— Diverter leakage	Part 3— Total
	Showerhead warm-up	Tub spout warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			—
Tub-spout flow rate (gpm) ⁵⁶⁸	—	5.0		—
Percentage of warm-up events ⁵⁶⁹	60%	40%		—
Average behavioral waste (minutes per shower) ⁵⁷⁰		1.742		—
Average diverter leakage-rate (gpm) ⁵⁷¹		—	0.80	—
Average shower time (minutes) ⁵⁷²		—	7.8	—
Showers/occupied room/day ⁵⁷³				1.756
Occupancy rate ⁵⁷⁴				65.9%

⁵⁶⁸ Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

⁵⁶⁹ Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

⁵⁷⁰ Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

⁵⁷¹ Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diversers.

⁵⁷² Cadmus and Opinion Dynamics Evaluation Team, “Memorandum: Showerhead and Faucet Aerator Meter Study”. Prepared for Michigan Evaluation Working Group.

⁵⁷³ Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

⁵⁷⁴ 2001–2021 US hotel occupancy rates from Statista. <https://www.statista.com/statistics/200161/us-annual-accommodation-and-lodging-occupancy-rate/>. Used average of last five pre-COVID years (2015–2019).

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Showerheads/room ⁵⁷⁵	1.0			
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	662	1,471	2,634	4,766
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	772			4,877
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	882			4,987
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	1,103			5,207
Percentage hot water ⁵⁷⁶	80-85%, or 82.5% average		73.7%	—
Gallons of hot water saved per year (1.5 gpm)	—			3,700
Gallons of hot water saved per year (1.75 gpm)	—			3,791
Gallons of hot water saved per year (2.0 gpm)	—			3,882
Gallons of hot water saved per year (2.5 gpm)	—			4,064

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

Equation 258

Where:

ρ	=	Water density [lb/gal] = 8.33
C_p	=	Specific heat of water [Btu/lb°F] = 1
V	=	Hot water saved per year per showerhead [gal] (see Table 295)

⁵⁷⁵ Assuming industry standard for standard one-bathroom rooms.

⁵⁷⁶ Average percentage of hot water for warm-up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

$T_{Setpoint}$	=	Water heater setpoint [$^{\circ}\text{F}$] ⁵⁷⁷ = 120
$T_{Supply,Avg}$	=	Average supply water temperature [$^{\circ}\text{F}$] (see Table 296)
RE	=	Recovery efficiency (or in the case of heat-pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, or 2.2 for heat-pump water heaters ⁵⁷⁸
3,412	=	Constant to convert from Btu to kWh

Demand Savings Algorithms

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

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

Equation 259

Where:

$T_{Supply,Seasonal}$	=	Seasonal-supply water temperature (see Table 296)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 297)

Table 296. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature ($^{\circ}\text{F}$) ⁵⁷⁹		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5

⁵⁷⁷ 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs” October 2010, page 99. Data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

⁵⁷⁸ Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. <https://www.ahridirectory.org/>.

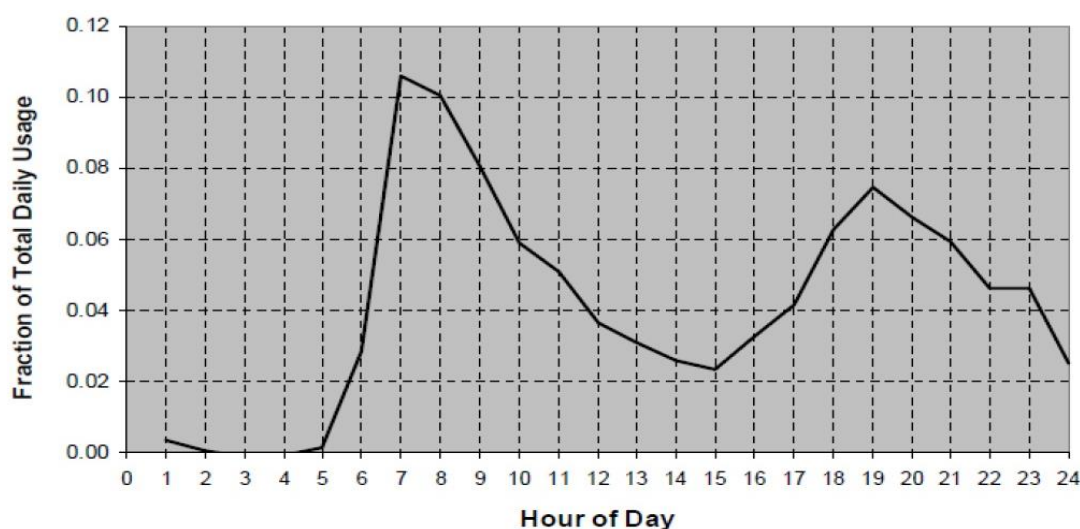
⁵⁷⁹ Based on typical meteorological year (TMY) dataset for TMY3: <https://sam.nrel.gov/weather-data.htmlhttps://nsrdb.nrel.gov/about/tmy.html>.

Climate zone	Water mains temperature (°F) ⁵⁷⁹		
	T _{SupplyAverage}	T _{SupplySeasonal}	
		Summer	Winter
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 297. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors

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

Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile⁵⁸⁰



Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

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

⁵⁸⁰ Building America Performance Analysis Procedures for Existing Homes.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.⁵⁸¹

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 298. Tub Spout/Showerhead TSRVs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁵⁸¹ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

2.7 NONRESIDENTIAL: MISCELLANEOUS

2.7.1 Variable Frequency Drives for Water Pumping Measure Overview

TRM Measure ID: NR-MS-WP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

Baseline Technology⁵⁸²:

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

Equation 260

Where:

%GPM = Percentage flow rate (see Table 299)

i = Each hour of the year

Table 299. Water Pumping VFDs—Water Demand Profile⁵⁸³

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

VFD Technology⁵⁸⁴:

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

Equation 261

⁵⁸² PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

⁵⁸³ NREL, Development of Standardized Domestic Hot Water Event Schedules for Residential Buildings, Fig. 2 Combined domestic hot water use profile for the Benchmark, representing average use.
<https://www.nrel.gov/docs/fy08osti/40874.pdf>.

⁵⁸⁴ PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

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

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

Equation 262

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

Equation 263

Where:

$\%power_i$	=	Percentage of full load pump power needed at the i^{th} hour calculated by an equation based on the control type
kW_{full}	=	Fan motor demand operating at typical design conditions
kW_i	=	Pump real-time power at the i^{th} hour of the year
HP	=	Rated horsepower of the motor
LF	=	Load factor—ratio of the operating load to the nameplate rating of the motor; default assumption is 75%
0.746	=	Constant to convert from hp to kW
η	=	Motor efficiency of a standard efficiency motor (see Table 300)

Table 300. Water Pumping VFDs—Motor Efficiencies⁵⁸⁵

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

⁵⁸⁵ Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors.
https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

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

Hourly and Peak Demand Savings Calculations

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

Equation 264

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

Equation 265

Where:

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

Energy Savings are calculated in the following manner:

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

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

Equation 266

Where:

8,760 = Total number of hours in a year

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

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

Equation 267

Deemed Energy and Demand Savings Tables

Table 339 presents the deemed summer and winter peak kilowatt savings per motor horsepower.

Table 301. Water Pumping VFDs—Energy and Peak Demand Savings per Motor HP

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

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

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12.5 years, which is the average EUL for pump VSD applications as specified in the California Database of Energy Efficiency Resources (DEER) READI tool.⁵⁸⁶

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Unit quantity
- Motor horsepower

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 302. Water Pumping VFDs—Revision History

TRM version	Date	Description of change
v9.0	10/2021	Measure origin.
v10.0	10/2022	General text edits.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁵⁸⁶ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

2.7.2 Premium Efficiency Motors Measure Overview

TRM Measure ID: NR-MS-PM

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All commercial

Fuels Affected: Electricity

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

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

To qualify for early retirement, the premium efficiency unit must replace an existing, full-size unit with a maximum age of 16 years. To determine the remaining useful life of an existing unit, see Table 307. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Baseline and High-Efficiency Conditions

New Construction or Replace-on-Burnout

EISA 2007 Sec 313 adopted new federal standards for motors manufactured in the United States from December 19, 2010, to before June 1, 2016, with increased efficiency requirements for 250-500 hp motors as of June 1, 2016. These standards replace legislation commonly referred to as EP Act 1992 (the Federal Energy Policy Act of 1992). The standards can also be found in section 431.25 of the Code of Federal Regulations (10 CFR Part 431).⁵⁸⁷

⁵⁸⁷ Federal Standards for Electric Motors, Table 1: Nominal Full-load Efficiencies of General Purpose Electric Motors (Subtype I), Except Fire Pump Electric Motors, <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>. Accessed July 2020.

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

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

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

Under these legislative changes, 200-500 hp and subtype II motor baselines will be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EAct)⁵⁸⁸ (see Table 306) and are thus no longer equivalent to pre-1992/pre-EAct defaults.

Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EAct)⁵⁸⁹, as listed in Table 308.

NEMA premium efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for replacement motors for both replace-on-burnout and early retirement projects exceeds that listed in Table 306.

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

⁵⁸⁸ Federal Standards for Electric Motors, Table 4: Nominal Full-load Efficiencies of NEMA Design B General Purpose Electric Motors (Subtype I and II), Except Fire Pump Electric Motors, <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>.

⁵⁸⁹ Federal Standards for Electric Motors, Tables 3 (≤ 200 hp), and 4 (> 200 hp), <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Actual motor operating hours are expected to be used to calculate savings. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 303 or Table 304 can be used.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

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

Equation 268

Demand Savings Algorithms

HVAC Applications:

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

Equation 269

Industrial Applications⁵⁹⁰:

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

Equation 270

Where:

HP	=	Nameplate horsepower data of the motor
0.746	=	Constant to convert from hp to kWh ⁵⁹¹
LF	=	Estimated load factor (if unknown, see Table 303 or Table 304)

⁵⁹⁰ Assumes three-shift operating schedule

⁵⁹¹ US DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 10.2.2.1 Motor Capacity". Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

$\eta_{baseline,ROB}$	=	Assumed original motor efficiency [%] (see Table 306) ⁵⁹²
η_{post}	=	Efficiency of the newly installed motor [%]
Hrs	=	Estimated annual operating hours (if unknown, see Table 303 or Table 304)
CF	=	Peak coincidence factor (see Table 303)
$kWh_{savings,ROB}$	=	Total energy savings for a new construction or ROB project
$kW_{savings,ROB}$	=	Total demand savings for a new construction or ROB project

Table 303. Premium Motors—HVAC Input Assumptions

Building type	Load factor ⁵⁹³	CF ⁵⁹⁴	HVAC fan hours ⁵⁹⁵
Education: K-12 school	0.75	1.0	4,173
Education: College/university			4,590
Food service: Quick-service restaurant			6,716
Food service: Full-service restaurant			5,256
Healthcare: Inpatient			8,760
Mercantile: All retail			5,548
Office: Large (>30k sq. ft.)			4,424
Office: Small (≤30k sq. ft.)			4,006

⁵⁹² In the case of rewind motors, in-situ efficiency may be reduced by a percentage as found in Table 305.

⁵⁹³ Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. <https://cedars-2.cpuc.ca.gov/deer-resources/deer-versions/archive/file/1544/download/>

⁵⁹⁴ Commercial Prototype Building Models HVAC operating schedules for hours ending 15-18. US Department of Energy. https://www.energycodes.gov/development/commercial/prototype_models

⁵⁹⁵ Factors are equivalent to Table 90 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 304. Premium Motors—Industrial Input Assumptions

Industrial processing	Load factor ⁵⁹⁶	Hours ⁵⁹⁷					
		Chem	Paper	Metals	Petroleum refinery	Food production	Other
1-5 hp	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20 hp	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50 hp	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100 hp	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200 hp	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500 hp	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000 hp		7,495	7,255	7,750	5,934	5,260	8,157
> 1,000 hp		7,693	8,294	7,198	6,859	6,240	2,601

Table 305. Premium Motors—Rewound Motor Efficiency Reduction Factors⁵⁹⁸

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

Table 306. Premium Motors—NC/ROB Baseline Efficiencies by Motor Size (%)^{587,591,603}

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

⁵⁹⁶ United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

⁵⁹⁷ United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

⁵⁹⁸ US DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 8.2.2.1 Annual Energy Consumption”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

hp	Open motors: $\eta_{\text{baseline, ROB}}$			Closed motors: $\eta_{\text{baseline, ROB}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	95.8	95.8	94.0	95.8	96.2	95.8
300	95.8	95.8	95.4	95.8	96.2	95.8
350	95.8	95.8	95.4	95.8	96.2	95.8
400	–	95.8	95.8	–	96.2	95.8
450	–	96.2	96.2	–	96.2	95.8
500	–	96.2	96.22	–	96.22	95.8

Early Retirement

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

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

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

Where:

RUL = Remaining useful life (see Table 307); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.0 years

EUL = Estimated useful life = 15 years

Table 307. Premium Motors—RUL of Early Retirement Motors⁵⁹⁹

Age of replaced motor (years)	RUL (years)	Age of replaced motor (years)	RUL (years)
1	13.9	10	5.0
2	12.9	11	4.2
3	11.9	12	3.6
4	10.9	13	3.0
5	9.9	14	2.5
6	8.9	15	2.0
7	7.9	16	1.0
8	6.9	17 ⁶⁰⁰	0.0
9	5.9		

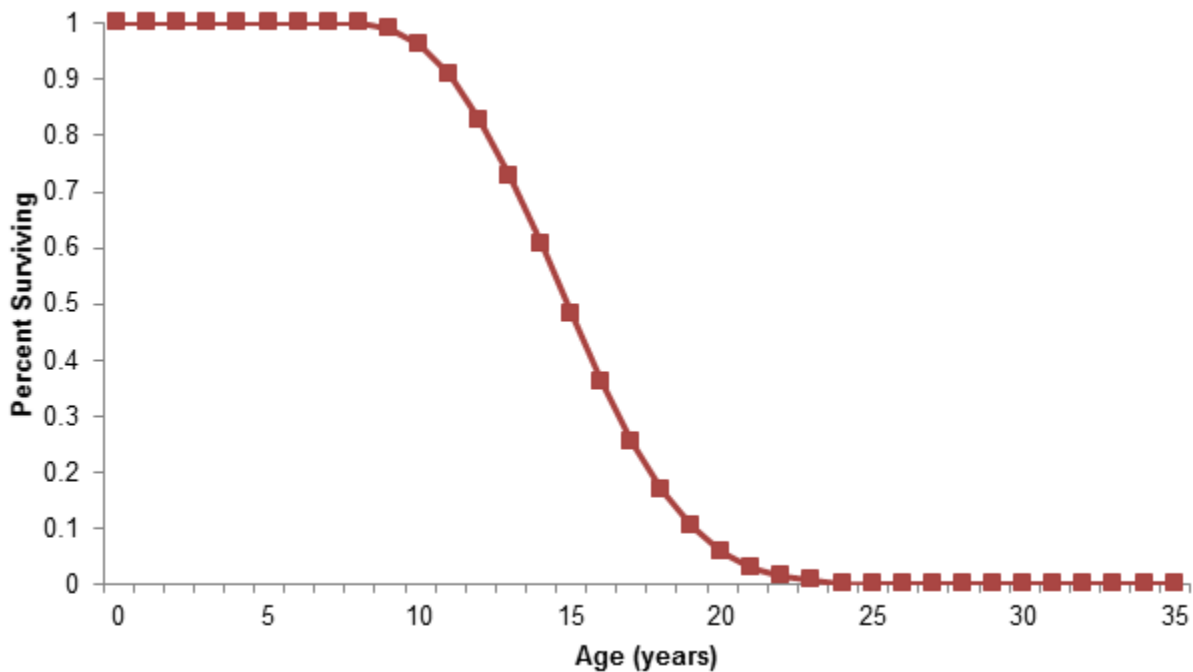
Derivation of RULs

Premium Efficiency Motors have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the motors installed in a given year will no longer be in service, as described by the survival function for a general fan or air compressor application in Figure 7.

⁵⁹⁹ Current federal standard effective date is 12/19/2010. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead.

⁶⁰⁰ RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see Figure 7). Systems older than 17 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

Figure 7. Premium Motors—Survival Function for Premium Efficiency Motors⁶⁰¹



The method to estimate the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 7. The age of the motor being replaced is found on the horizontal axis, and the corresponding percentage of surviving motors is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a motor being replaced is 15 years old (the estimated useful life). The corresponding percent surviving value is approximately 50 percent. Half of 50 percent is 25 percent. The age corresponding to 25 percent on the chart is approximately 17 years. Therefore, the RUL of the motor being replaced is $(17 - 15) = 2$ years.

Energy Savings Algorithms

For the RUL time period:

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

Equation 271

⁶⁰¹ Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011.

http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project.

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

Equation 272

It follows that total lifetime energy savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations:

$$kWh_{savings,ER} = kWh_{savings,RUL} \times RUL + kWh_{savings,EUL} \times (EUL - RUL)$$

Equation 273

Demand Savings Algorithms

To calculate demand savings for the early retirement of a motor, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

HVAC Applications

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{Hrs} \times CF$$

Equation 274

Industrial Applications

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8,760 \text{ hours}}$$

Equation 275

For the remaining time in the EUL period., calculate annual savings as you would for a replace-on-burnout project:

HVAC Applications

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{Hrs} \times CF$$

Equation 276

Industrial Applications

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8,760 \text{ hours}}$$

Equation 277

Annual deemed peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

$$kW_{savings,ER} = kW_{savings,RUL} \times RUL + kW_{savings,EUL} \times (EUL - RUL)$$

Equation 278

Where:

- $\eta_{baseline,ER}$ = Assumed original motor efficiency for remaining EUL time period (Table 308 or Table 309)⁶⁰²
- $kWh_{savings,RUL}$ = Energy savings for RUL time period in an ER project
- $kWh_{savings,EUL}$ = Energy savings for remaining EUL time period in an ER project
- $kW_{savings,RUL}$ = Demand savings for RUL time period in an ER project
- $kW_{savings,EUL}$ = Demand savings for remaining EUL time period in an ER project
- $kWh_{savings,ER}$ = Total energy savings for an ER project
- $kW_{savings,ER}$ = Total demand savings for an ER project

Table 308. Premium Motors—ER Baseline Efficiencies by Motor Size (%)^{589,603}

hp	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7

⁶⁰² Ibid.

⁶⁰³ For unlisted motor horsepower values, round down to the next lowest horsepower value.

hp	Open motors: $\eta_{\text{baseline, ER}}$			Closed motors: $\eta_{\text{baseline, ER}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0
250	95.4	95.4	94.5	95.0	95.0	95.4
300	95.4	95.4	95.0	95.0	95.4	95.4
350	95.4	95.4	95.0	95.0	95.4	95.4
400	—	95.4	95.4	—	95.4	95.4
450	—	95.8	95.8	—	95.4	95.4
500	—	95.8	95.8	—	95.8	95.4

Table 309. Premium Motors—ER Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)^{604,605}

hp	Open motors: $\eta_{\text{baseline, ER}}$			Closed motors: $\eta_{\text{baseline, ER}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
250	95.4	95.4	94.5	95.0	95.0	95.4
300	95.4	95.4	95.0	95.0	95.4	95.4
350	95.4	95.4	95.0	95.0	95.4	95.4
400	—	95.4	95.4	—	95.4	95.4
450	—	95.8	95.8	—	95.4	95.4
500	—	95.8	95.8	—	95.8	95.4

Deemed Energy and Demand Savings Tables

Not applicable.

⁶⁰⁴ Federal Standards for Electric Motors, Table 4.

⁶⁰⁵ For unlisted motor horsepower values, round down to the next lowest horsepower value.

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.⁶⁰⁶

Program Tracking Data and Evaluation Requirements

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

- Unit quantity
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Horsepower
- Estimated annual operating hours and estimated load factor
- Number of poles in and horsepower of original motor
- Newly-installed motor efficiency (%)
- Description of motor service application
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

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.

⁶⁰⁶ US DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>

Document Revision History

Table 310. Premium Motors—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. Replace-on-burnout and Early Retirement clarifications.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
v12.0	10/2024	TRM v12.0 update. Updated early retirement age eligibility.
v13.0	10/2025	TRM v13.0 update. No revision.

2.7.3 Pump-Off Controllers Measure Overview

TRM Measure ID: NR-MS-PC

Market Sector: Commercial

Measure Category: Controls

Applicable Building Types: Industrial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Field study, engineering algorithms, and estimates

Measure Description

Pump-off controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions (i.e., when the fluid in the well bore is insufficient to warrant continued pumping). These controllers are used to shut down the pump when the fluid falls below a certain level and “fluid pounding”⁶⁰⁷ occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number⁶⁰⁸ prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a *conventional* well (above ground or vertical, with a standard induction motor of 480V or less).

Baseline Condition

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

⁶⁰⁷ Fluid pounding occurs when the downhole pump rate exceeds the production rate of the formation.

The pump strikes the top of the fluid column on the down stroke causing extreme shock loading of the components which can result in premature equipment failure.

⁶⁰⁸ The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*⁶⁰⁹ (SPE 16363), which identified a relationship between volumetric efficiency and pump run times and the *2006-2008 Evaluation Report for PG&E Fabrication, Process, and Manufacturing Contract Group*,⁶¹⁰ which showed a reduction in savings from the SPE 16363 paper. These two methods were the basis of the current savings calculations and deemed inputs listed below. To develop Texas-specific stipulated values, field and metering data will be collected when there is sufficient uptake in the measure and used to calibrate and update the savings calculation methods and input variables for a future version of the TRM.⁶¹¹

Savings Algorithms and Inputs

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

$$\text{Energy Savings } [\Delta kWh] = kW_{avg} \times (\text{TimeClock}\%On - \text{POC}\%On) \times 8,760$$

Equation 279

$$\text{Demand Savings } [\Delta kW] = \frac{kWh_{savings}}{8,760}$$

Equation 280⁶¹²

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

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

Equation 281

⁶⁰⁹ Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production*", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

⁶¹⁰ *2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group*. CALMAC Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.

⁶¹¹ The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

⁶¹² The equations in the petition for peak demand simplify to the equation shown.

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

Equation 282⁶¹³

Where:

kW_{avg}	=	The demand used by each rod pump
HP	=	Rated pump-motor horsepower
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor—ratio of average demand to maximum demand (see Table 311)
ME	=	Motor efficiency, based on NEMA Standard Efficiency Motor (see Table 312)
SME	=	Mechanical efficiency of sucker-rod pump (see Table 311)
Time Clock%On	=	Stipulated-baseline time clock setting (see Table 311)
$Run_{constant}$, $Run_{coefficient}$	=	8.336, 0.956, derived from SPE 16363 ⁶¹⁴
VolumetricEfficiency%	=	Average well gross production divided by theoretical production (provided on rebate application)
8,760	=	Total hours per year

⁶¹³ This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is $(Run_{constant} + Run_{coefficient} \times VolumetricEfficiency\%)$ with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25 percent).

⁶¹⁴ Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production, (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

Deemed Energy and Demand Savings Tables

Table 311. Pump-Off Controllers—Savings Calculation Input Assumptions

Variable	Deemed values
LF (Load factor)	25% ⁶¹⁵
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95% ⁶¹⁶
Time clock%On	65% ⁶¹⁷

Table 312. Pump-Off Controllers—NEMA Premium Efficiency Motor Efficiencies⁶¹⁸

Motor hp	Nominal full-load efficiency					
	Open motors (ODP)			Enclosed motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%

⁶¹⁵ Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011. Adjusted based on Field Measurements provided by ADM Associates, based on 2010 custom projects.

⁶¹⁶ Engineering estimate for standard gearbox efficiency.

⁶¹⁷ A Time Clock%On of 80 percent is typical from observations in other jurisdictions, but that was adjusted to 65 percent for a conservative estimate. This value will be reevaluated once Texas field data is available.

⁶¹⁸ DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I]
https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=6&action=viewlive.

Claimed Peak Demand Savings

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8,760 hours) is used, as shown in Equation 280.

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.⁶¹⁹

Program Tracking Data and Evaluation Requirements

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

- Motor manufacturer
- Motor model number
- Rated motor horsepower
- Motor type (TEFC or ODP)
- Rated motor RPM
- Baseline control type and time clock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times⁶²⁰

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

⁶¹⁹ CPUC 2006-2008 Industrial Impact Evaluation "SCIA_06-08_Final_Report_Appendix_D-5": An EUL of 15 years was used for the ex-post savings, consistent with the SPC—Custom Measures and System Controls categories in the CPUC Energy Efficiency Policy Manual (Version 2) and with DEER values for an energy management control system.

⁶²⁰ Per PUCT Docket 42551, Southwestern Public Service Company (SPS)/Xcel Energy has agreed to collect field data in 2015 on post-run times for a sample of wells to improve the accuracy of POC saving estimates.

Document Revision History

Table 313. Pump-Off Controllers—Revision History

TRM version	Date	Description of change
v2.1	01/30/2015	Measure origin.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	General reference checks and text edits.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.7.4 ENERGY STAR® Pool Pumps Measure Overview

TRM Measure ID: NR-MS-PP

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: All commercial

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa⁶²¹.

Multi-speed pool pumps are not permitted. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.⁶²² The default pump curves provided in the ENERGY STAR Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

⁶²¹ These pump products are ineligible for ENERGY STAR v3.0 certification:
<https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification.pdf>

⁶²² Hunt, A. and Easley, S., "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), US DOE. May 2012.
<http://www.nrel.gov/docs/fy12osti/54242.pdf>.

Baseline Condition

The baseline is assumed to be a new pool pump that is compliant with the current federal standard, effective July 19, 2021.⁶²³ Weighted energy factor (WEF) requirements are based on rated hydraulic horsepower (hhp).

Table 314. Baseline Condition—Federal Standard Effective July 19, 2021

Pump Subtype	Size class	Baseline WEF
Self-priming (inground) pool pumps	Extra Small (hhp ≤ 0.13)	WEF = 5.55
	Small (hhp > 0.13 to < 0.711)	WEF = -1.30 x ln(hhp) + 2.90
	Standard (hhp ≥ 0.711)	WEF = -2.30 x ln(hhp) + 6.59

High-Efficiency Condition

The high-efficiency condition is a 1 to 5 hp variable speed pool pump that is compliant with the current ENERGY STAR Version 3.1 Specification, effective July 19, 2021.⁶²⁴

Table 315. ENERGY STAR Pool Pumps—Energy Efficiency Level

Pump Subtype	Size class	ENERGY STAR WEF
Self-priming (inground) pool pumps	Extra small (hhp ≤ 0.13)	WEF ≥ 13.40
	Small (hhp > 0.13 to < 0.711)	WEF ≥ -2.45 x ln(hhp) + 8.40
	Standard (hhp ≥ 0.711)	

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR Pool Pump Savings Calculator with Texas selected as the applicable location, so Texas-specific assumptions were used.⁶²⁵

⁶²³ Federal standard for dedicated purpose pool pumps.
<https://www.ecfr.gov/current/title-10/section-431.465>.

⁶²⁴ ENERGY STAR Program Requirements Product Specification for Pool Pumps
<https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification.pdf>

⁶²⁵ The ENERGY STAR Pool Pump Savings Calculator, updated April 2020, can be found on the ENERGY STAR website at: <https://www.energystar.gov/productfinder/product/certified-pool-pumps/results>.

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

Equation 283

Where:

kWh_{conv} = Conventional single-speed pool pump energy [kWh]

kWh_{ES} = ENERGY STAR variable-speed pool pump energy [kWh]

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times \text{hours} \times \text{days}}{WEF_{conv} \times 1,000}$$

Equation 284

$$kWh_{ES} = \frac{V \times TO \times \text{days}}{WEF_{ES} \times 1,000}$$

Equation 285

Where:

PFR_{conv} = Conventional single-speed pump flow rate [gal/min]
(see Table 316)

WEF_{conv} = Conventional single-speed pump weighted energy factor
[gal/W·hr] (see Table 316)

WEF_{ES} = ENERGY STAR weighted energy factor [gal/W·hr]
(see Table 317)

hours = Conventional single-speed pump daily operating hours
(see Table 316)

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

V = Pool volume [gal] (use actual or see Table 317)

TO = Turnovers per day, number of times the volume of the pool is run
through the pump per day (see Table 317)

60 = Constant to convert between minutes and hours

1,000 = Constant to convert from kilowatts to watts

Table 316. Pool Pumps—Conventional Pump Input Assumptions⁶²⁶

New pump hp	Reference hp	Reference hhp ⁶²⁷	Hours, limited ⁶²⁸	Hours, 24/7	PFR _{conv} (gal/min)
≤ 1.25	1.0	0.533	12	24	75.5000
1.25 < hp ≤ 1.75	1.5	0.800			78.1429
1.75 < hp ≤ 2.25	2.0	1.066			88.6667
2.25 < hp ≤ 2.75	2.5	1.333			93.0910
2.75 < hp ≤ 5	3.0	1.599			101.6667

Table 317. Pool Pumps—ENERGY STAR Pump Input Assumptions^{629,630}

New pump hp	TO, limited	TO, 24/7	V [gal]
≤ 1.25	2.7	5.4	20,000
1.25 < hp ≤ 1.75	2.8	5.6	20,000
1.75 < hp ≤ 2.25	2.9	5.8	22,000
2.25 < hp ≤ 2.75	2.7	5.4	25,000
2.75 < hp ≤ 5	2.6	5.2	28,000

Demand Savings Algorithms

$$\text{Peak Demand Savings } [\Delta kW] = \frac{kWh_{conv} - kWh_{ES}}{\text{hours}} \times \frac{CF_{S/W}}{\text{days}}$$

Equation 286

Where:

$CF_{S/W}$ = Summer/winter seasonal peak coincidence factor (see Table 318)

⁶²⁶ Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR Pool Pump Savings Calculator. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

⁶²⁷ Hhp not available in ENERGY STAR calculator. Assumed hhp calculated as follows: Reference horsepower x AF. AF = 0.533 based on ratio of hhp to hp from ENERGY STAR QPL.

⁶²⁸ Limited hours assumes that pump operating hours are 12 hours per day, based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

⁶²⁹ ENERGY STAR turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

⁶³⁰ Turnovers calculated as TO = hours x 60 x PFR_{conv} ÷ V.

Table 318. Pool Pumps—Coincidence Factors⁶³¹

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

Deemed Energy and Demand Savings Tables

Table 319. Pool Pumps—Energy Savings⁶³²

New pump hp	Year-round operation		Seasonal operation (7 months)
	24/7 operation	Limited hours	
	kWh savings	kWh savings	kWh savings
≤ 1.25	6,682	3,341	1,948
1.25 < hp ≤ 1.75	1,191	596	347
1.75 < hp ≤ 2.25	1,580	790	461
2.25 < hp ≤ 2.75	1,895	947	552
2.75 < hp ≤ 5	2,327	1,163	678

Table 320. Pool Pumps—Summer Peak Demand Savings

New pump hp	All schedules
≤ 1.25	0.763
1.25 < hp ≤ 1.75	0.136
1.75 < hp ≤ 2.25	0.180
2.25 < hp ≤ 2.75	0.216
2.75 < hp ≤ 5	0.266

⁶³¹ Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

⁶³² The results in this table may vary slightly from results produced by the ENERGY STAR® Calculator because of rounding of default savings coefficients throughout the measure and pool volume.

Table 321. Pool Pumps—Winter Peak Demand Savings

New pump hp	24/7	Limited and seasonal
≤ 1.25	0.763	0.381
1.25 < hp ≤ 1.75	0.136	0.068
1.75 < hp ≤ 2.25	0.180	0.090
2.25 < hp ≤ 2.75	0.216	0.108
2.75 < hp ≤ 5	0.266	0.133

Claimed Peak Demand Savings

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

Additional Calculators and Tools

ENERGY STAR Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR website at <https://www.energystar.gov/productfinder/product/certified-pool-pumps/results>.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.⁶³³

Program Tracking Data and Evaluation Requirements

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

- For all projects
 - Climate zone or county
 - Pool pump rated horsepower
 - Proof of purchase including quantity, make, and model information
 - Copy of ENERGY STAR certification
 - Facility operation type: 24/7, year-round limited hours, seasonal
 - Pool volume in gallons (only required when calculating site-specific savings in lieu of deemed savings)

⁶³³ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

- For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs)
 - Items listed above for all projects
 - Decision/action type: early retirement, replace-on-burnout, or new construction
 - Rated horsepower of existing pool pump
 - Existing and new pump operating hours

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 322. Pool Pumps—Revision History

TRM version	Date	Description of change
v5.0	10/2017	Measure origin.
v6.0	10/2018	No revision.
v7.0	10/2019	Added ineligible products list. Updated program tracking requirements.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	General text edits. Corrected turnovers/day values in the assumptions table.
v10.0	10/2022	Updated for ENERGY STAR Version 3.0 Specification. Increased upper limit for pump horsepower to 5 to better reflect product availability.
v11.0	10/2023	No revision.
v12.0	10/2024	Updated baseline condition and deemed savings to reflect current federal standard.
v13.0	10/2025	Updated heading to include new construction application, as baseline was updated to federal standard in TRM v12.

2.7.5 Lodging Guest Room Occupancy-Sensor Controls Measure Overview

TRM Measure ID: NR-MS-LC

Market Sector: Commercial

Measure Category: HVAC, indoor lighting

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling

Measure Description

This measure, commonly referred to as a guest room energy management (GREM) system, captures the potential energy and demand savings resulting from occupancy sensor control of HVAC and lighting in unoccupied hotel/motel guest rooms. Hotel and motel guest room occupancy schedules are highly variable, and guests often leave HVAC equipment and lighting on when they leave the room. Installation of occupancy controls can reduce the unnecessary energy consumption in unoccupied guest rooms. Savings have also been developed for the use of this measure in college dormitories.⁶³⁴

Eligibility Criteria

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

Baseline Condition

The baseline condition is an existing guest room or dorm room without occupancy controls. New construction applications are eligible for HVAC only.⁶³⁵

⁶³⁴ The original petition also includes savings for HVAC-only control in master-metered multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is significantly different from the transitory occupation of hotel/motels and even dormitories. This measure is not currently being implemented and is not likely to be used in the future, but it can be added to a future TRM if warranted.

⁶³⁵ IECC 2015 Section C405.2.4 Specific Application Controls mandates occupancy sensors for lighting.

High-Efficiency Condition

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

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

Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies⁶³⁶ and prototypical ASHRAE 90.1-1999 occupancy schedules were used in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system, which was compared to the baseline models.⁶³⁷

Savings Algorithms and Inputs

A building simulation approach was used to produce savings estimates.

Deemed Energy and Demand Savings Tables

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

⁶³⁶ HVAC occupancy rates appear to be based on a single HVAC study of three hotels, but not dorms or multifamily buildings. For the lighting study, a typical guest room layout was used as the basis for the savings analysis. Hotel guest rooms are quite different from either dorms or multifamily units.

⁶³⁷ A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 323. Lodging Occupancy Sensors—Motel per Room Energy and Peak Demand Savings

Climate zone ⁶³⁸	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Climate Zone 1: Amarillo	0.059	267	0.075	380	0.059	341	0.075	441
Climate Zone 2: Dallas	0.076	315	0.091	443	0.076	365	0.091	485
Climate Zone 3: Houston	0.082	324	0.097	461	0.082	351	0.097	484
Climate Zone 4: Corpus Christi	0.086	354	0.103	500	0.086	369	0.103	513
Climate Zone 5: El Paso	0.063	251	0.078	379	0.063	283	0.078	406
10-degree setup/setback offset								
Climate Zone 1: Amarillo	0.111	486	0.126	598	0.111	627	0.126	726
Climate Zone 2: Dallas	0.146	559	0.161	686	0.146	640	0.161	761
Climate Zone 3: Houston	0.151	559	0.166	695	0.151	602	0.166	735
Climate Zone 4: Corpus Christi	0.163	617	0.179	761	0.163	650	0.179	792
Climate Zone 5: El Paso	0.118	432	0.133	561	0.118	482	0.133	607

⁶³⁸ Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo was “Panhandle”, Dallas-Ft Worth was “North”, Houston was “South Central”, El Paso was “Big Bend”, and Corpus Christi was “Rio Grande Valley” using McAllen as a reference city.

Table 324. Lodging Occupancy Sensors—Hotel per Room Energy and Peak Demand Savings

Climate zone ⁶³⁸	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Climate Zone 1: Amarillo	0.053	232	0.072	439	0.053	303	0.072	530
Climate Zone 2: Dallas	0.073	258	0.093	452	0.073	303	0.093	505
Climate Zone 3: Houston	0.074	242	0.094	430	0.074	260	0.094	450
Climate Zone 4: Corpus Christi	0.081	260	0.102	451	0.081	267	0.102	459
Climate Zone 5: El Paso	0.056	178	0.075	360	0.056	196	0.075	380
10-degree setup/setback offset								
Climate Zone 1: Amarillo	0.102	426	0.121	568	0.102	557	0.121	684
Climate Zone 2: Dallas	0.134	452	0.154	617	0.134	517	0.154	676
Climate Zone 3: Houston	0.136	423	0.156	599	0.136	446	0.156	621
Climate Zone 4: Corpus Christi	0.149	467	0.169	652	0.149	483	0.169	667
Climate Zone 5: El Paso	0.106	312	0.126	479	0.106	338	0.126	501

Table 325. Lodging Occupancy Sensors—Dormitory per Room Energy and Peak Demand Savings

Climate zone ⁶³⁸	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Climate Zone 1: Amarillo	0.034	136	0.061	319	0.034	152	0.061	316
Climate Zone 2: Dallas	0.048	214	0.076	425	0.048	223	0.076	428
Climate Zone 3: Houston	0.051	242	0.078	461	0.051	244	0.078	462
Climate Zone 4: Corpus Christi	0.053	265	0.081	492	0.053	266	0.081	492
Climate Zone 5: El Paso	0.031	110	0.059	327	0.031	110	0.059	326
10-degree setup/setback offset								
Climate Zone 1: Amarillo	0.073	261	0.084	404	0.073	289	0.084	417
Climate Zone 2: Dallas	0.078	293	0.105	505	0.078	304	0.105	511
Climate Zone 3: Houston	0.081	326	0.108	543	0.081	328	0.108	545
Climate Zone 4: Corpus Christi	0.088	368	0.114	591	0.088	370	0.114	593
Climate Zone 5: El Paso	0.045	151	0.060	448	0.045	153	0.060	450

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study⁶³⁹. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

⁶³⁹ Energy and Resource Solutions (2005). *Measure Life Study*. Prepared for the Massachusetts Joint Utilities; Table 1-1, Prescriptive Common Measure Life Recommendations, Large C&I retrofit, HVAC Controls, EMS.

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 326. Lodging Occupancy Sensors—Revision History

TRM version	Date	Description of change
v2.0	04/18/2014	Measure origin.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	General reference checks and text edits.
v9.0	10/2021	No revision.
v10.0	10/2022	Changed Climate Zone 4 reference city from McAllen to Corpus Christi.

TRM version	Date	Description of change
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	Cited new construction code requirement.

2.7.6 Vending Machine Controls Measure Overview

TRM Measure ID: NR-MS-VC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All building types

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

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

Eligibility Criteria

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

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

Baseline Condition

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

High-Efficiency Condition

The high-efficiency condition is a 120-volt single-phase refrigerated beverage or non-refrigerated-snack vending machine with occupancy controls and compliant with the current federal standard, effective January 8, 2019.⁶⁴⁰

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Deemed Energy and Demand Savings Tables

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

Table 327. Vending Controls—Refrigerated Cold Drink Energy and Peak Savings⁶⁴¹

Climate zone	kWh savings	Summer kW savings ⁶⁴²	Winter kW savings
Climate Zone 1: Amarillo	1,612	0.023	0.060
Climate Zone 2: Dallas		0.021	0.063
Climate Zone 3: Houston		0.022	0.060
Climate Zone 4: Corpus Christi		0.022	0.064
Climate Zone 5: El Paso		0.015	0.068

⁶⁴⁰ Appliance Standards for Refrigerated Beverage Vending Machines.

https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

⁶⁴¹ Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

⁶⁴² Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56.

https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper.pdf.

Table 328. Vending Controls—Refrigerated Reach-In Energy and Peak Demand Savings⁶⁴³

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

Table 329. Vending Controls—Non-Refrigerated Snack Energy and Peak Demand Savings⁶⁴⁴

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Plug-VendCtrler.⁶⁴⁵

Program Tracking Data and Evaluation Requirements

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

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

⁶⁴³ Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

⁶⁴⁴ Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

⁶⁴⁵ DEER READI (Remote Ex-Ante Database Interface). <https://cedars.cpuc.ca.gov/deer-resources/>.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 330. Vending Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	Measure origin.
v2.0	04/18/2014	No revision.
v3.0	04/10/2015	No revision.
v4.0	10/10/2016	No revision.
v5.0	10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	Clarified baseline condition and updated demand savings for compliance with current peak definition.
v9.0	10/2021	General text edits.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.7.7 Computer Power Management Measure Overview

TRM Measure ID: NR-MS-CP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All building types

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed value (per machine)

Savings Methodology: Algorithms

Measure Description

This measure presents deemed savings for implementation of computer power management strategies. Computer power management includes the use of operational settings that automate the power management features of computer equipment, including automatically placing equipment into a low power mode during periods of inactivity. This may be done either with built-in features integral to the computer operating system or through an add-on software program. Typically, this measure is implemented across an entire network of computers.

Eligibility Criteria

To be eligible for this measure, computers must not have any automatic sleep or other low power setting in place. Both conventional and ENERGY STAR computer equipment are eligible for this measure. Applicable building types include offices and schools.

Baseline Condition

The baseline conditions are the estimated number of hours that the computer spends in active, sleep, and off modes before the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default baseline hours are taken from the ENERGY STAR modeling study assumptions contained in the Low Carbon IT Savings Calculator⁶⁴⁶, and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.⁶⁴⁷

⁶⁴⁶ ENERGY STAR Low Carbon IT Calculator available for download at:
https://portfoliomanager.energystar.gov/buildingEmissionsCalculator/?_gl=1*wckxoe*_ga*OTc2NjQxMjk2LjE3NDAwMzEwNTg.*_ga_S0KJTVVLQ6*cze3NTI3MTgxMDYkbzExJGcxJHQxNzUyNzI1MTcxJGoyJGwwJGgw.

⁶⁴⁷ Based on 2015 custom project metering from El Paso Electric.

High-Efficiency Condition

The efficient conditions are the estimated number of hours that the computer spends in active, sleep, and off modes after the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default efficient hours are taken from the ENERGY STAR modeling study assumptions contained in the Low Carbon IT Savings Calculator and assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.⁶⁴⁸

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings [ΔkWh]

$$= \frac{W_{active}(Hrs_{active,pre} - Hrs_{active,post}) + W_{sleep}(Hrs_{sleep,pre} - Hrs_{sleep,post}) + W_{off}(Hrs_{off,pre} - Hrs_{off,post})}{1,000}$$

Equation 287

$$\text{Summer Peak Demand Savings } [\Delta kW] = (W_{active} - W_{sleep}) \times CF_{inactive,S}$$

Equation 288

$$\text{Winter Peak Demand Savings } [\Delta kW] = 0$$

Equation 289

Where:

W_{active}	=	Total wattage of the equipment, including computer and monitor, in active/idle mode (see Table 331)
$Hrs_{active,pre}$	=	Annual number of hours the computer is in active/idle mode before computer management software is installed (see Table 332)
$Hrs_{active,post}$	=	Annual number of hours the computer is in active/idle mode after computer management software is installed (see Table 332)
W_{sleep}	=	Total wattage of the equipment, including computer and monitor, in sleep mode (see Table 331)
$Hrs_{sleep,pre}$	=	Annual number of hours the computer is in sleep mode before computer management software is installed (see Table 332)
$Hrs_{sleep,post}$	=	Annual number of hours the computer is in sleep mode after computer management software is installed (see Table 332)

⁶⁴⁸ Based on 2015 custom project metering from El Paso Electric.

W_{off}	=	Total wattage of the equipment, including computer and monitor, in off mode (see Table 331)
$Hrs_{off,pre}$	=	Annual number of hours the computer is in off mode before computer management software is installed (see Table 332)
$Hrs_{off,post}$	=	Annual number of hours the computer is in off mode after computer management software is installed (see Table 332)
1,000	=	Constant to convert from W to kW
$CF_{inactive,S}$	=	Inactive summer peak coincidence factor (see Table 333)

Table 331. Computer Power Management—Equipment Wattages⁶⁴⁹

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional monitor ⁶⁵⁰	18.3	0.30	0.30
Conventional computer	48.11	2.31	0.96
Conventional notebook (including display)	14.82	1.21	0.61
ENERGY STAR monitor	15.0	0.26	0.26
ENERGY STAR computer	27.11	1.80	0.81
ENERGY STAR notebook (including display)	8.61	0.89	0.46

Table 332. Computer Power Management—Operating Hours⁶⁵¹

Building activity type	$Hrs_{active,pre}$	$Hrs_{active,post}$	$Hrs_{sleep,pre}$	$Hrs_{sleep,post}$	$Hrs_{off,pre}$	$Hrs_{off,post}$
Typical office (8 hours/day, 5 days/week, 22 non-workdays/year)	4,650	1,175	—	2,105	4,110	5,480
Typical school (8 hours/day, 5 days/week, 113 non-school days/year)	4,213	727	—	1,970	4,547	6,063

⁶⁴⁹ Equipment wattages taken from the ENERGY STAR Office Equipment Calculator, updated October 2016. Available for download at <https://www.energystar.gov/buildings/save-energy-commercial-buildings/ways-save/energy-efficient-products>.

⁶⁵⁰ Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR® Office Equipment Calculator.

⁶⁵¹ Hours taken from assumptions in the ENERGY STAR calculator. Hours_{pre} assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night. Hours_{post} assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.

Table 333. Computer Power Management—Coincidence Factors

Climate zone	Summer CF		Winter CF	
	Active	Inactive	Active	Inactive
Climate Zone 1: Amarillo	0.65	0.35	0.11	0.89
Climate Zone 2: Dallas	0.62	0.38	0.12	0.88
Climate Zone 3: Houston	0.66	0.34	0.12	0.88
Climate Zone 4: Corpus Christi	0.62	0.38	0.14	0.86
Climate Zone 5: El Paso	0.75	0.25	0.28	0.72

Deemed Energy and Demand Savings Tables

Energy and demand savings are deemed values for conventional and ENERGY STAR equipment, based on the input assumptions listed in Table 331, Table 332, and Table 333. The following tables provide these deemed values.

Table 334. Computer Power Management—Energy Savings for Offices & Schools

Equipment	kWh Savings
Conventional LCD monitor	62.6
Conventional computer	161.4
Conventional notebook	48.2
ENERGY STAR monitor	51.3
ENERGY STAR computer	89.5
ENERGY STAR notebook	27.5

Table 335. Computer Power Management—Peak Demand Savings for Offices & Schools

Equipment	Climate Zone 1: Amarillo		Climate Zone 2: Dallas		Climate Zone 3: Houston		Climate Zone 4: Corpus Christi		Climate Zone 5: El Paso	
	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)
Conventional LCD monitor	0.006	—	0.007	—	0.006	—	0.007	—	0.004	—
Conventional computer	0.016	—	0.017	—	0.015	—	0.017	—	0.011	—
Conventional notebook	0.005	—	0.005	—	0.005	—	0.005	—	0.003	—
ENERGY STAR monitor	0.005	—	0.006	—	0.005	—	0.006	—	0.004	—
ENERGY STAR computer	0.009	—	0.010	—	0.009	—	0.010	—	0.006	—
ENERGY STAR notebook	0.003	—	0.003	—	0.003	—	0.003	—	0.002	—

Claimed Peak Demand Savings

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

Winter demand savings are not specified for this measure based on an assumption that the reduced operating hours are not achieved during the winter peak period.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of this measure is 3 years, based on the useful life of the computer equipment being controlled.⁶⁵²

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.

- Equipment type
 - Conventional or ENERGY STAR
 - Monitor, computer, or notebook
- Application type (office, school)

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 336. Computer Power Management—Revision History

TRM version	Date	Description of change
v7.0	10/2019	Measure origin.
v8.0	10/2020	General reference checks and text edits. Incorporated version 2 baseline adjustments and revised savings.

⁶⁵² Internal Revenue Service, 1.35.6.10, Property and Equipment Capitalization, Useful life for Laptop and Desktop Equipment. July 2016. https://www.irs.gov/irm/part1/irm_01-035-006.

TRM version	Date	Description of change
v9.0	10/2021	Updated peak demand savings coefficients and deemed savings. Added application type to documentation requirements. Eliminated winter demand savings.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.7.8 ENERGY STAR® Electric Vehicle Supply Equipment Measure Overview

TRM Measure ID: NR-MS-EV

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

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 measure applies to the installation of electric vehicle supply equipment (EVSE) meeting the specifications of ENERGY STAR Level 2 at a commercial site. EVSE is the infrastructure that enables plug-in electric vehicles (PEV) to charge onboard batteries. Level 2 EVSE require 240-volt electrical service. This measure provides deemed savings for the energy efficiency improvement of an ENERGY STAR EVSE over a standard or non-ENERGY STAR EVSE.

Eligibility Criteria

Eligible equipment includes ENERGY STAR compliant Level 2 EVSE installed in a commercial application, which includes public, multifamily, workplace, and fleet locations. Public locations are sites where an EVSE is intended to be used by the public or visitors to the site. This includes locations such as retail, education, municipal, hospitality, and other similar locations. For the purposes of this measure, multifamily sites are public locations. Workplace locations include sites where an EVSE is intended to be used by employees to charge their personal vehicles when reporting to the workplace site. Fleet locations include sites where an EVSE is intended to be used to charge a fleet of company vehicles. The EVSE may be installed for use on either an all-battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV). Savings estimates for this measure are based on studies of light duty vehicles; EVSE for charging heavy duty vehicles should pursue custom M&V.

Baseline Condition

The baseline condition is a non-ENERGY STAR compliant Level 2 EVSE.

High-Efficiency Condition

The high-efficiency condition is a Level 2 EVSE compliant with ENERGY STAR Version 1.1 Specification, effective March 31, 2021.⁶⁵³

Energy and Demand Savings Methodology

Savings for EVSE come from efficiency gains of the ENERGY STAR equipment during operating modes when the vehicle is plugged in but not charging and when not plugged in. Deemed savings are calculated according to the following algorithms.

Savings Algorithms and Input Variables

$$\begin{aligned} & \text{ENERGY STAR Idle Consumption [kWh]} \\ = & \frac{(Hrs_{plug} \times W_{plug} + Hrs_{unplug,C} \times W_{unplug}) \times days_C + Hrs_{unplug,NC} \times W_{unplug} \times days_{NC}}{1,000} \end{aligned}$$

Equation 290

$$\text{Baseline Idle Consumption [kWh]} = \frac{\text{ENERGY STAR Idle Consumption}}{0.6}$$

Equation 291

$$\text{Energy Savings [\Delta kWh]} = \text{Baseline Idle Consumption} - \text{ENERGY STAR Idle Consumption}$$

Equation 292

$$\text{Peak Demand Savings [\Delta kW]} = \frac{\Delta kWh}{Hrs_{unplug,C} \times days_C + Hrs_{unplug,NC} \times days_{NC}} \times PDPF$$

Equation 293

Where:

$$\begin{aligned} Hrs_{plug} &= \text{Time per day the vehicle is plugged into the EVSE and not charging [hours]}^{654} = 2.8 \\ W_{plug} &= \text{Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging [W]}^{655} = 6.9 \text{ W} \end{aligned}$$

⁶⁵³ ENERGY STAR Program Requirements for Electric Vehicle Supply Equipment Eligibility Criteria v1.1. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20DC%20EVSE%20Final%20Specification_0.pdf.

⁶⁵⁴ National Renewable Energy Laboratory (NREL), February 2018, "Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio," page 26, Table 8: Charging Statistics by Location Type and Level, ChargePoint Data. Average across all location types, dwell time minus charging duration.

⁶⁵⁵ Average Idle Mode Input Power from ENERGY STAR certified EVSE product list as of July 13, 2020.

$Hrs_{unplug,C}$	= Time per day the vehicle is not plugged into the EVSE on a charging day [hours] ⁶⁵⁶ = 19
$Hrs_{unplug,NC}$	= Time per day the vehicle is not plugged into the EVSE on a non-charge day [hours] = 24
W_{unplug}	= Wattage of the EVSE when the vehicle is not plugged into the EVSE [W] ⁶⁵⁷ = 3.3
$days_C$	= Number of charging days per year [days] ⁶⁵⁸ = 204
$days_{NC}$	= Number of non-charging days per year [days] = 161
1,000	= Constant to convert from W to kW
0.6	= Efficiency adjustment factor ⁶⁵⁹
PDPF	= Peak demand probability factor (see Table 337)

Table 337. EVSE—Peak Demand Probability Factors⁶⁶⁰

Location type	Public		Workplace		Fleet	
Climate zone	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF
Climate Zone 1: Amarillo	0.46526	0.46032	0.87484	0.75271	0.27206	0.44421
Climate Zone 2: Dallas	0.45808	0.47380	0.86213	0.75558	0.22867	0.42040
Climate Zone 3: Houston	0.46134	0.42544	0.87173	0.68222	0.26507	0.34306
Climate Zone 4: Corpus Christi	0.46892	0.49816	0.87553	0.77324	0.25862	0.50077
Climate Zone 5: El Paso	0.42680	0.51324	0.80969	0.92091	0.15042	0.57715

⁶⁵⁶ NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 26, Table 8; 24 hours per day minus average dwell time.

⁶⁵⁷ Average No Vehicle Mode Input Power from ENERGY STAR certified EVSE product list.

⁶⁵⁸ NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 25; 0.56 charging sessions per day per plug in Austin, Texas. $365 \times 0.56 = 204$.

⁶⁵⁹ ENERGY STAR Electric Vehicle Chargers Buying Guidance: “ENERGY STAR certified EV charger... on average use 40% less energy than a standard EV charger when the charger is in standby mode (i.e., not actively charging a vehicle).” https://www.energystar.gov/products/ev_chargers.

⁶⁶⁰ Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 27, Figure 21: Daily distribution of ChargePoint charging events by EVSE type and day of the week.

Deemed Energy and Demand Savings Tables

Table 338 presents the deemed annual energy savings per EVSE.

Table 338. EVSE—Energy Savings

kWh Savings (all location types)
19.7

Table 339 presents the deemed summer and winter peak kW savings per EVSE.

Table 339. EVSE—Peak Demand Savings

Location type	Public		Workplace		Fleet	
Climate zone	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
Climate Zone 1: Amarillo	0.0012	0.0012	0.0022	0.0019	0.0008	0.0012
Climate Zone 2: Dallas	0.0012	0.0012	0.0022	0.0019	0.0006	0.0012
Climate Zone 3: Houston	0.0012	0.0011	0.0022	0.0017	0.0007	0.0010
Climate Zone 4: Corpus Christi	0.0012	0.0013	0.0022	0.0020	0.0007	0.0014
Climate Zone 5: El Paso	0.0011	0.0013	0.0021	0.0023	0.0004	0.0016

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for an EVSE is assumed to be 10 years.⁶⁶¹

⁶⁶¹ US Department of Energy Vehicle Technologies Office, November 2015, "Costs Associated with Non-Residential Electric Vehicle Supply Equipment" p. 21.
https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Location Type (public, workplace, or fleet)⁶⁶²
- EVSE quantity
- EVSE manufacturer and model number

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 340. EVSE—Revision History

TRM version	Date	Description of change
v8.0	10/2020	Measure origin.
v9.0	10/2021	General reference checks and text edits.
v10.0	10/2022	Added reference for ENERGY STAR version.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁶⁶² Refer to Eligibility Criteria section for location type definitions.

2.7.9 Industrial High-Frequency Battery Chargers Overview

TRM Measure ID: NR-MS-BC

Market Sector: Commercial

Measure Category: Other/miscellaneous

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

Industrial electric vehicle fleets used for material handling, or forklifts, use battery charging systems to convert AC source power into DC power required to charge the vehicle batteries. Traditional charging systems include Ferro resonant (FR) and silicon-controlled rectifier (SCR) charging equipment. This measure is for a single high-frequency battery charger that converts AC to DC power more efficiently than traditional systems due to switch mode operation that reduces heat and power loss throughout the system.

Baseline Condition

The baseline condition is a typical FR or SCR charging system operating in an industrial warehouse setting to power forklifts.

High-Efficiency Condition

There is no federal standard for large industrial battery chargers. Therefore, the efficient condition is the energy efficiency standard for large battery systems in California Appliance Efficiency Regulations, Title 20, which is detailed in the following table.

Table 341. Battery Chargers—Efficiency Requirements⁶⁶³

Performance factor		Requirement
Charge return factor	100 percent, 80 percent depth of discharge	≤ 1.10
	40% depth of discharge	≤ 1.15
Power conversion efficiency		≥ 89%
Power factor		≥ 90%
No battery mode power		≤ 10 W

Energy and Demand Savings Methodology

Battery charger systems operate in three modes: *charge*, *maintenance*, and *no battery*. In *charge* mode, the battery is accumulating charge. *Maintenance* mode occurs when the battery is fully charged, and the charger is simply supplying energy to counteract natural discharge. *No battery* mode indicates that the battery has been fully disconnected from the charger.

Savings Algorithms and Input Variables

The deemed savings values area calculated using the following algorithms:

$$hours = DC \times 8,760$$

Equation 294

$$\begin{aligned}
 \text{Energy Savings } [kWh_{\text{savings}}] &= hours_C \times \frac{W_{C,pre} - W_{C,post}}{1,000} + hours_M \times \frac{W_{M,pre} - W_{M,post}}{1,000} \\
 &+ hours_{NC} \times \frac{W_{NC,pre} - W_{NC,post}}{1,000}
 \end{aligned}$$

Equation 295

$$\text{Summer Peak Demand Savings } [kW_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_S$$

Equation 296

$$\text{Winter Peak Demand Savings } [kW_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_W$$

Equation 297

⁶⁶³ California Appliance Efficiency Regulations, Title 20, Section 1605.3 State Standards for Non-Federally-Regulated Appliances, (w) Battery Chargers and Battery Charger Systems.
<https://energycodeace.com/content/reference-ace-t20-tool>.

Where:

8,760	=	Annual hours per year
$DC_{C/M/NB}$	=	Duty cycle in charging, maintenance, and no battery mode (see Table 342)
$hours_{C/M/NB}$	=	Annual number of hours in charging, maintenance, and no battery mode (see Table 342)
$W_{C/M/NB}$	=	Wattage draw in charging, maintenance, and no battery mode (see Table 343)
$CF_{S/W}$	=	Seasonal peak coincidence factor (see Table 344)
1,000	=	Conversion constant for W to kW

Table 342. Battery Chargers—Charging and Idle Hours Assumptions⁶⁶⁴

Equipment	DC_C	DC_M	DC_{NB}	$hours_C$	$hours_M$	$hours_{NB}$
Single phase	45%	31%	24%	3,942	2,716	2,102
Three phase	94%	—	6%	8,234	—	526

Table 343. Battery Chargers—Pre/Post Charging and Idle Wattage Assumptions⁶⁶⁵

Equipment	$W_{C,pre}$	$W_{M,pre}$	$W_{NB,pre}$	$W_{C,post}$	$W_{M,post}$	$W_{NB,post}$
Single phase	2,000	50	50	1,767	10	10
Three phase	5,785	89	34	5,111	10	10

Table 344. Battery Charging System—Coincidence Factors⁶⁶⁶

Equipment	Summer	Winter
Single phase	0.19	—
Three phase	1.00	—

Deemed Energy and Peak Demand Savings Tables

The deemed energy and seasonal peak savings values are presented in the following table.

⁶⁶⁴ “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 6. https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf.

⁶⁶⁵ “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. W_{pre} : Table 7, W_{post} : Table 10. https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf.

⁶⁶⁶ “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 7 and Table 10. https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf.

Table 345. Battery Chargers—Deemed Energy and Demand Savings per Charger

Equipment	kWh savings	Summer kW savings	Winter kW savings
Single phase	1,111	0.02	—
Three phase	5,562	0.63	—

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 high efficiency battery chargers is 15 years.⁶⁶⁷

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:

- Battery charger quantity
- Battery charger manufacturer and model number
- Charger type (single phase, three phase)
- Depth of discharge
- Charge return factor
- Power conversion efficiency
- Power factor
- No battery mode power (W)

Document Revision History

Table 346. Battery Chargers—Revision History

TRM version	Date	Description of change
v11.0	10/2023	Measure origin
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁶⁶⁷ “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 18. https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf.

2.7.10 Steam Trap Repair and Replacement Measure Overview

TRM Measure ID: NR-MS-ST

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

Faulty steam traps that allow steam to leak require makeup water to re-generate the lost steam. This measure applies to the replacement or repair of faulty mechanical (thermostatic, thermodynamic, bucket, or fixed orifice) steam traps in industrial and commercial facilities. The measure also covers annual maintenance of venturi steam traps after their deemed 20-year measure life.

Eligibility Criteria

The measure is applicable to failed steam traps in commercial and industrial applications less than 300 pounds per square in gauge (psig). Residential, multifamily, and heating radiator applications are not eligible to claim savings under the methods in this measure.

Baseline Condition

The baseline condition is a faulty (blocked, leaking, or blow-through) mechanical steam trap in need of replacement or repair.

High-Efficiency Condition

The high-efficiency condition is the repair of a faulty steam trap, replacement with a venturi steam trap installed in compliance with ASME PTC 39-2005, or annual maintenance of a venturi steam trap.

A venturi steam trap removes condensate from steam systems by utilizing the thermodynamic pressure properties of water passing through a fixed venturi orifice rather than by the moving parts found in traditional steam traps. There are numerous steam system parameters that influence operating pressure, system load, and system operations. Venturi steam traps are an engineering solution that must be designed and sized by a qualified professional based on specific site conditions.

Annual maintenance of a venturi steam trap after exhausting its deemed 20-year measure life with savings awarded on a year-to-year basis includes the removal, cleaning, and replacement of the trap strainer. Some traps may contain an integrated strainer blowdown valve for improved maintenance.

Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy associated with makeup required to replace water lost due to steam leaks. Savings are presented per trap.

Savings Algorithms and Input Variables

$$\text{Energy Savings } [\Delta kWh] = \Delta Water \text{ (gallons)} / 1,000,000 \times E_{\text{water supply}}$$

Equation 298

$$\Delta Water = \frac{S_L \text{ (lb/hr)}}{8.33 \text{ (lbs/gal)}} \times \text{Hours} \times L$$

Equation 299

$$S_L = 24.24 \times P_{ia} \times D^2 \times A \times FF$$

Equation 300

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

Equation 301

Where:

$E_{\text{water supply}}$	=	Water supply energy factor: 2,300 kWh/million gallons
S_L	=	Average steam loss per trap (lb/hr) (see Table 347)
Hours	=	Annual hours when steam system is operational, equal to heating degree days by climate zone (see Table 348)
L	=	Percentage leakage, 1 per each leaking trap with a system audit to document leaks; for full system replacement without a system audit, use default values from Table 347
24.24	=	Constant lb/(hr-psia-in ²)
P_{ia}	=	Average steam trap inlet pressure, absolute (psia), $P_{ig} + P_{atm}$
P_{ig}	=	Average steam trap inlet pressure, gauge (psig) (see Table 347)
P_{atm}	=	Atmospheric pressure, 14.7 psia

<i>D</i>	=	<i>Diameter of orifice (inches), use actual if possible, or defaults in Table 347</i>
<i>A</i>	=	<i>Adjustment factor: 50% for all steam systems; this factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor)</i>
<i>FF</i>	=	<i>Flow factor for medium- and high-pressure steam systems to address industrial float and thermodynamic style traps where additional blockage is possible</i>
<i>CF</i>	=	<i>Peak coincidence factor, assume value of 1 for industrial and process steam applications; for commercial heating applications, see Table 35 through Table 39 in Section 2.2.2; for commercial dry cleaners, use CF for stand-alone retail</i>

Table 347. Steam Traps—Savings Calculation Input Assumptions⁶⁶⁸

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, S _L (lb/hr/trap)	Hours	L
Commercial dry cleaners	82.8	0.125	100%	18.5	2,425	0.27
Industrial or process low pressure < 15 psig	—	—		6.9	8,282	0.16
Industrial or process medium pressure > 15 and < 30 psig	16	0.1875	50%	6.5	8,282	0.16
Industrial or process medium pressure > 30 and < 75 psig	47	0.2500		23.4	8,282	0.16
Industrial or process high pressure > 75 and < 125 psig	101			43.8	8,282	0.16
Industrial or process high pressure > 125 and < 175 psig	146			60.9	8,282	0.16
Industrial or process high pressure > 175 and < 250 psig	202			82.1	8,282	0.16
Industrial or process high pressure > 250 and < 300 psig	263			105.2	8,282	0.16
Commercial space heating low pressure steam (LPS)	—	—	100%	6.9	Table 348	0.27

⁶⁶⁸ Default inputs for the steam trap measure are sourced from the Illinois TRM version 9.0, Volume 2, measure 4.4.16 Steam Trap Replacement or Repair. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf

Table 348. Steam Traps—Commercial Heating Hours

Climate zone	Hours (HDD) ⁶⁶⁹
Climate Zone 1: Amarillo	4,565
Climate Zone 2: Dallas	2,567
Climate Zone 3: Houston	1,686
Climate Zone 4: Corpus Christi	1,129
Climate Zone 5: El Paso	2,677

Deemed Energy and Demand Savings Tables

Table 349. Steam Traps—Energy Savings

Steam system	Climate zone	Annual kWh savings (per trap, without audit)	Annual kWh savings (per trap with audit)
Commercial dry cleaners	All	3.3	12.4
Industrial or process low pressure < 15 psig	All	2.5	15.8
Industrial or process medium pressure > 15 and < 30 psig	All	2.4	15.0
Industrial or process medium pressure > 30 and < 75 psig	All	8.6	53.4
Industrial or process high pressure > 75 and < 125 psig	All	16.0	100.2
Industrial or process high pressure > 125 and < 175 psig	All	22.3	139.2
Industrial or process high pressure > 175 and < 250 psig	All	30.0	187.7
Industrial or process high pressure > 250 and < 300 psig	All	38.5	240.5
Commercial space heating low pressure steam (LPS)	1 Amarillo	2.3	8.7
	2 DFW	1.3	4.9
	3 Houston	0.9	3.2
	4 Corpus	0.6	2.2
	5 El Paso	1.4	5.1

⁶⁶⁹ Heating degree days are calculated from TMY3 Hourly Weather Data by Climate Zone, available at <https://texasefficiency.com/trm-docs/>.

Claimed Peak Demand Savings

Table 350. Steam Traps—Peak Demand Savings, Without Audit

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Commercial dry cleaners	Mercantile	Stand-alone retail	1.36E-03	7.57E-04	5.92E-04	3.03E-04	3.58E-04
Low pressure ≤ 15 psig	All	Industrial or process	3.05E-04	3.05E-04	3.05E-04	3.05E-04	3.05E-04
Medium pressure > 15 and < 30 psig	All	Industrial or process	2.89E-04	2.89E-04	2.89E-04	2.89E-04	2.89E-04
Medium pressure ≥ 30 and < 75 psig	All	Industrial or process	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03
High pressure ≥ 75 and < 125 psig	All	Industrial or process	1.94E-03	1.94E-03	1.94E-03	1.94E-03	1.94E-03
High pressure ≥ 125 and < 175 psig	All	Industrial or process	2.69E-03	2.69E-03	2.69E-03	2.69E-03	2.69E-03
High pressure ≥ 175 and < 250 psig	All	Industrial or process	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03
High pressure ≥ 250 and < 300 psig	All	Industrial or process	4.65E-03	4.65E-03	4.65E-03	4.65E-03	4.65E-03
Commercial space heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	2.21E-04	3.39E-04	2.57E-04	1.54E-04	1.90E-04
		Secondary school	2.21E-04	3.03E-04	2.78E-04	1.80E-04	2.21E-04
	Food sales	Convenience store	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Commercial space heating LPS	Food service	Full-service restaurant	2.21E-04	2.57E-04	2.26E-04	1.80E-04	1.44E-04
		24-hour full-service restaurant	2.21E-04	2.52E-04	2.26E-04	1.85E-04	1.39E-04
		Quick-service restaurant	2.47E-04	3.14E-04	2.62E-04	1.75E-04	1.34E-04
		24-hour quick-service restaurant	2.47E-04	3.09E-04	2.57E-04	1.75E-04	1.34E-04
	Healthcare	Inpatient	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient	1.39E-04	1.44E-04	1.49E-04	4.12E-05	2.06E-05
	Large multifamily	Midrise apartment	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lodging	Large hotel	4.42E-04	4.22E-04	1.70E-04	1.08E-04	1.08E-04
		Nursing home	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Small hotel/motel	1.85E-04	2.16E-04	9.77E-05	5.14E-05	3.09E-05
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	3.70E-04	3.39E-04	2.16E-04	1.23E-04	1.39E-04
		Small office	1.49E-04	2.06E-04	1.44E-04	7.20E-05	7.72E-05
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Commercial space heating LPS	Retail	Stand-alone retail	5.09E-04	2.83E-04	2.21E-04	1.13E-04	1.34E-04
		24-hour retail	2.21E-04	2.93E-04	2.11E-04	1.29E-04	1.44E-04
		Strip mall	2.01E-04	2.83E-04	2.16E-04	1.08E-04	1.39E-04
	Service	Service (non-food)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	1.39E-04	1.44E-04	9.77E-05	4.12E-05	2.06E-05

Table 351. Steam Traps—Peak Demand Savings, With Audit

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Commercial dry cleaners	Mercantile	Stand-alone retail	5.05E-03	2.80E-03	2.19E-03	1.12E-03	1.33E-03
Low pressure ≤ 15 psig	All	Industrial or process	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03
Medium pressure > 15 and < 30 psig	All	Industrial or process	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03
Medium pressure ≥ 30 and < 75 psig	All	Industrial or process	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03
High pressure ≥ 75 and < 125 psig	All	Industrial or process	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02
High pressure ≥ 125 and < 175 psig	All	Industrial or process	1.68E-02	1.68E-02	1.68E-02	1.68E-02	1.68E-02
High pressure ≥ 175 and < 250 psig	All	Industrial or process	2.27E-02	2.27E-02	2.27E-02	2.27E-02	2.27E-02

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
High pressure ≥ 250 and < 300 psig	All	Industrial or process	2.90E-02	2.90E-02	2.90E-02	2.90E-02	2.90E-02
Commercial space heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	8.19E-04	1.26E-03	9.53E-04	5.72E-04	7.05E-04
		Secondary school	8.19E-04	1.12E-03	1.03E-03	6.67E-04	8.19E-04
	Food sales	Convenience store	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	8.19E-04	9.53E-04	8.38E-04	6.67E-04	5.33E-04
		24-hour full-service restaurant	8.19E-04	9.34E-04	8.38E-04	6.86E-04	5.14E-04
		Quick-service restaurant	9.14E-04	1.16E-03	9.72E-04	6.48E-04	4.95E-04
		24-hour quick-service restaurant	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	Inpatient	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient	5.14E-04	5.33E-04	5.52E-04	1.52E-04	7.62E-05
	Large multifamily	Midrise apartment	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lodging	Large hotel	1.64E-03	1.56E-03	6.29E-04	4.00E-04	4.00E-04
		Nursing home	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Small hotel/motel	6.86E-04	8.00E-04	3.62E-04	1.91E-04	1.14E-04

Steam type	Building type	Principal building activity	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	1.37E-03	1.26E-03	8.00E-04	4.57E-04	5.14E-04
		Small office	5.52E-04	7.62E-04	5.33E-04	2.67E-04	2.86E-04
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Retail	Stand-alone retail	1.89E-03	1.05E-03	8.19E-04	4.19E-04	4.95E-04
		24-hour stand-alone retail	8.19E-04	1.09E-03	7.81E-04	4.76E-04	5.33E-04
		Strip mall	7.43E-04	1.05E-03	8.00E-04	4.00E-04	5.14E-04
	Service	Service: Excluding food	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	5.14E-04	5.33E-04	3.62E-04	1.52E-04	7.62E-05

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 6 years for standard steam traps and 20 years for venturi steam traps.⁶⁷⁰

Program Tracking Data and Evaluation Requirements

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

- Application type of steam system
- Climate zone or county if application is commercial heating
- Steam trap quantity
- Type of measure undertaken for each trap: repaired, replaced, or maintained
- Audit documentation, if conducted, including count of leaking or faulty steam traps
- Maintenance documentation, if conducted, indicating strainer maintenance activities undertaken

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 352. Steam Traps—Revision History

TRM version	Date	Description of change
v9.0	10/2021	Measure origin.
v10.0	10/2022	No revision.
v11.0	10/2023	Aligned building type names across all commercial measures.
v12.0	10/2024	Building types realigned in tables.
v13.0	10/2025	No revision.

⁶⁷⁰ EULs for the steam trap measure are sourced from the Illinois TRM 9.0, volume 2, measure 4.4.16 Steam Trap Replacement or Repair. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf

2.7.11 Hydraulic Gear Lubricants Measure Overview

TRM Measure ID: NR-MS-HL

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithm

Savings Methodology: Engineering algorithms and estimates

Measure Description

Hydraulic gear lubricants are used in manufacturing. Energy efficient hydraulic gear lubricants offer reduced energy consumption over standard lubricants because they have a lower coefficient of friction which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which in turn reduces the energy requirements. Additionally, efficient lubricants have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures which optimizes volumetric and mechanical efficiency.

Eligibility Criteria

The measure is applicable to manufacturing and industrial sites using hydraulic gear lubricants for gearboxes.

Baseline Condition

The baseline condition is a gearbox using standard hydraulic lubricants.

High-Efficiency Condition

The high-efficiency condition is a gearbox using energy-efficiency hydraulic lubricants which have a higher viscosity index than standard lubricants.

Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

Savings Algorithms and Input Variables

$$\text{Energy Savings } [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times \text{hours} \times EI$$

Equation 302

Where:

HP_{motor}	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor ⁶⁷¹ = 75%
η	=	Motor efficiency (use default from Table 353 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase = 1.0% per gear mesh ⁶⁷²

Table 353. Hydraulic Gear Lubricants—Motor Efficiencies⁶⁷³

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

Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

⁶⁷¹ Assume motor is designed to operate at maximum efficiency, neat 75% of rated load. See DOE Motor Challenge Fact Sheet available at <https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf>. Accessed August 2021.

⁶⁷² Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf. Accessed September 2022.

⁶⁷³ Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

Claimed Peak Demand Savings

There are no demand savings for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the equipment that the lubricant is used with.⁶⁷⁴

Program Tracking Data and Evaluation Requirements

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

- Quantity
- Motor horsepower
- Motor operating hours

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 354. Hydraulic Gear Lubricants—Revision History

TRM version	Date	Description of change
v9.0	10/2021	Measure origin.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁶⁷⁴ US DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

2.7.12 Hydraulic Oils Measure Overview

TRM Measure ID: NR-MS-HO

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithm

Savings Methodology: Engineering algorithms and estimates

Measure Description

Hydraulic oils are lubricants used in manufacturing. Energy-efficient hydraulic oil lubricants offer reduced energy consumption over standard oils because they have a lower coefficient of friction, which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which, in turn, reduces the energy requirements. Additionally, efficient oils have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures, optimizing volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient hydraulic oils reduce the operating temperature of the hydraulic system.

Eligibility Criteria

The measure is applicable to manufacturing and industrial sites using hydraulic oil lubricants for hydraulic equipment performance.

Baseline Condition

The baseline condition is hydraulic equipment using standard hydraulic oils.

High-Efficiency Condition

The high-efficiency condition is hydraulic equipment using energy-efficient hydraulic oils which have a higher viscosity index than standard oils.

Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

Savings Algorithms and Input Variables

$$\text{Energy Savings } [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times \text{hours} \times EI$$

Equation 303

Where:

HP_{motor}	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor, 75% ⁶⁷⁵
η	=	Motor efficiency (use default from Table 355 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase ⁶⁷⁶ = 3.2%

Table 355. Hydraulic Oils—Motor Efficiencies⁶⁷⁷

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

⁶⁷⁵ Assume motor is designed to operate at maximum efficiency, neat 75% of rated load. See DOE Motor Challenge Fact Sheet available at <https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf>. Accessed August 2021.

⁶⁷⁶ Focus on Energy Lubricant Study, <https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study>.

⁶⁷⁷ Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominical Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

Claimed Peak Demand Savings

There are no demand savings for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the motor that the oil is used with.⁶⁷⁸

Program Tracking Data and Evaluation Requirements

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

- Quantity
- Motor horsepower
- Motor operating hours

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 356. Hydraulic Oils—Revision History

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

⁶⁷⁸ US DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>

TRM version	Date	Description of change
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

2.7.13 Hand Dryers Measure Overview

TRM Measure ID: NR-MS-HD

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the methodology for calculating the savings realized from installing efficient hand dryers, which save energy by drying with air movement using motion sensors, thus reducing hand-drying time.

Eligibility Criteria

Existing hand dryer must be push-button-operated and rated at more than 1,500 W. New hand dryers must be motion-sensor-operated and rated at 1,500 W or less.

Baseline Condition

The baseline efficiency case is a push-button-activated hand dryer rated at more than 1,500 W.

High-Efficiency Condition

Eligible high-efficiency equipment is a motion-sensor-operated hand dryer with a nominal input power of 1,500 W or less.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of efficient hand dryers are due to a decrease in power and runtime of the efficient hand dryers over the pre-retrofit equipment. The energy and demand savings are calculated using the following equations.

AOH and CF match assumptions from the nonresidential lighting measure.⁶⁷⁹

$$\Delta Wh = \frac{(W_{Base} \times CT_{Base}) - (W_{Eff} \times CT_{Eff})}{3,600}$$

Equation 304

$$Energy\ Savings\ [\Delta kWh] = \frac{UPD \times AOD \times \Delta Wh}{1,000}$$

Equation 305

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{UPD \times AOD \times \Delta Wh}{1,000 \times AOH} \times CF$$

Equation 306

Where:

W_{Base}	=	Baseline equipment nominal power ⁶⁸⁰ = 2,155 W
CT_{Base}	=	Cycle time of baseline equipment ⁶⁸¹ = 34 seconds
W_{Eff}	=	Efficient equipment nominal power ⁶⁸² = 1,329 W
CT_{Eff}	=	Cycle time of efficient equipment ⁶⁸³ = 17 seconds
3,600	=	Constant to convert from seconds to hours
UPD	=	Number of uses per day ⁶⁸⁴ (see Table 357)
AOD	=	Number of days the facility operates per year ⁶⁸⁵ (see Table 357)
AOH	=	Annual building operating hours (see Table 357)
CF	=	Peak coincidence factor (see Table 357)

⁶⁷⁹ See Volume 3, 2.1.1 Lamps and Fixtures. It is assumed building occupancy with respect to lighting is an appropriate proxy for occupant utilization of hand dryers.

⁶⁸⁰ Baseline and efficient nominal power and cycle times are averages of 48 surveyed individual hand dryer units by CLEAResult in Arkansas.

⁶⁸¹ Ibid.

⁶⁸² Ibid.

⁶⁸³ Ibid.

⁶⁸⁴ IL TRM 12 Volume 2, Section 4.8.26.

⁶⁸⁵ Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995. Table 2. <https://eta-publications.lbl.gov/sites/default/files/lbnl-37398e.pdf>.

Deemed Energy and Demand Savings Tables

The deemed energy and demand savings for hand dryers with a stipulated number of operating days per year, base/efficient cycle times, and base/efficient unit wattages are shown in Table 357.

Table 357. Hand Dryers—Savings Calculation Input Assumptions

Usage level	Building type	UPD ⁶⁸⁶	AOD ⁶⁸⁷	AOH ⁶⁸⁸	Coincidence factor ⁶⁸⁹				
					Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus	Climate Zone 5: El Paso
Low	Office	50	250	3,737	0.87	0.88	0.86	0.90	0.90
	Warehouse	50	250	3,501	0.79	0.81	0.79	0.80	0.85
Medium/moderate	Food sales: Non-24-hour supermarket or convenience store	125	365	4,706	0.90	0.90	0.90	0.90	0.90
	Food service: Full-service restaurant	125	365	4,368	0.90	0.90	0.90	0.90	0.90
	Food service: Quick-service restaurant	125	365	6,188	0.90	0.90	0.90	0.90	0.90
	Mercantile: Stand-alone retail	125	365	3,668	0.90	0.90	0.90	0.90	0.90
	Mercantile: Strip mall	125	365	3,965	0.90	0.90	0.90	0.90	0.90
High	Education: College, university, vocational, and day care	250	200	3,577	0.90	0.90	0.90	0.90	0.90
	Education: K-12 ⁶⁹⁰	250	200	3,177	0.42	0.39	0.90	0.90	0.57
	Food sales: 24-hour supermarket or convenience store	375	365	6,900	0.90	0.90	0.90	0.90	0.90
	Mercantile: Enclosed mall	375	365	4,813	0.90	0.90	0.90	0.90	0.90
	Public assembly	250	250	2,638	0.65	0.65	0.65	0.65	0.65
Heavy duty/extreme	Transportation center	750	365	8,760	1.00	1.00	1.00	1.00	1.00

⁶⁸⁶ IL TRM 12 Volume 2, Section 4.8.26.

⁶⁸⁷ Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995. Table 2. <https://eta-publications.lbl.gov/sites/default/files/lbnl-37398e.pdf>.

⁶⁸⁸ From 2.1.1 Lamps and Fixtures measure.

⁶⁸⁹ Ibid.

⁶⁹⁰ Assuming K–12 with partial summer session.

Table 358. Hand Dryers—Deemed Energy and Peak Demand Savings

Usage level	Building type	kWh	Summer kW				
			Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Low	Office	176	0.04	0.04	0.04	0.04	0.04
	Warehouse	176	0.04	0.04	0.04	0.04	0.04
Medium/moderate	Food sales: Non-24-hour supermarket or convenience store	642	0.12	0.12	0.12	0.12	0.12
	Food service: Full-service restaurant	642	0.13	0.13	0.13	0.13	0.13
	Food service: Quick-service restaurant	642	0.09	0.09	0.09	0.09	0.09
	Mercantile: Stand-alone retail	642	0.16	0.16	0.16	0.16	0.16
	Mercantile: Strip mall	642	0.15	0.15	0.15	0.15	0.15
High	Education: College, university, vocational, and day care	703	0.18	0.18	0.18	0.18	0.18
	Education: K-12	703	0.09	0.09	0.20	0.20	0.13
	Food sales: 24-hour supermarket or convenience store	1,926	0.25	0.25	0.25	0.25	0.25
	Mercantile: Enclosed mall	1,926	0.36	0.36	0.36	0.36	0.36
	Public assembly	879	0.22	0.22	0.22	0.22	0.22
Heavy duty/extreme	Transportation center	3,851	0.44	0.44	0.44	0.44	0.44

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 ten years⁶⁹¹ for efficient hand dryers.

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:

⁶⁹¹ Based on studies conducted by two separate parties; Comparative Environmental Life Cycle Assessment of Hand Drying Systems by Quantis (pg. 2) and Guidelines to Reduce/Eliminate Paper Towel Use by Installing Electric Hand Dryers by Partners in Pollution Prevention P3 (pg. 17).

- Climate zone or county
- Building type
- Installed quantity
- Efficient hand dryer make and model
- Efficient hand dryer nominal input power (W)
- Proof of purchase

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 359. Hand Dryers—Revision History

TRM version	Date	Description of change
v10.0	10/2022	Measure origin
v11.0	10/2023	No revision.
v12.0	10/2024	Updated building type naming convention. Updated peak demand calculation, savings calculation input assumptions, and deemed savings.
v13.0	10/2025	Removed Interactive effects factors from Demand and energy savings calculations. Updated deemed savings tables based on updated calculations

2.7.14 Laser Projectors Measure Overview

TRM Measure ID: NR-LT-LP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Motion picture theaters

Fuels Affected: Electricity

Decision/Action Types: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the replacement of a lamp-based projector with a laser projector. The conversion from a traditional lamp-based projector system to a laser projector benefits from reduced energy consumption via electricity savings and HVAC savings. With advancements in solid-state technology, laser projectors typically require half the electricity to obtain the equivalent light and resolution output as lamp-based projectors. Due to this reduced electricity consumption, laser projectors also benefit from HVAC savings, with significantly less energy wasted as heat. Another benefit of laser projectors is that they do not require the use of lamps, which can be costly from an equipment and operations standpoint.

Despite the various ways laser projectors result in energy savings, this measure solely focuses on the electricity savings for operating the projector. Due to interactive effects unique to each site, this measure will not consider the corresponding HVAC savings, so annual savings estimates are conservative.

Eligibility Criteria

This measure applies to the replacement of any motion picture theater lamp-based projector. At this time, this measure is limited to retrofit applications where the baseline lamp wattage is specified to match site conditions. Eligibility may be extended to new construction applications once sufficient program implementation data can be collected to establish an appropriate baseline.

Baseline Condition

There is no federal standard applicable to lamp-based projectors. The baseline condition is any commercial cinema lamp-based projector that is replaced by a laser projector. The measure does not consider home, office, venue or any projector replacements that are outside of a professional cinema setting.

High-Efficiency Condition

The high-efficiency condition is a professional commercial cinema laser projector with an equivalent (or no greater than 110%) lumen output of the baseline projector being replaced.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for laser projectors.

Energy Savings Algorithms

Energy savings for this measure are determined to be the difference in maximum operating input rate for the baseline and efficient projector multiplied by the total yearly operating hours for the facility.

$$\text{Energy Savings [kWh]} = (kW_{pre} - kW_{installed}) \times \text{Hours}$$

Equation 307

$$\text{Summer Peak Demand Savings [kW}_S] = (kW_{pre} - kW_{installed}) \times CF_S$$

Equation 308

$$\text{Winter Peak Demand Savings [kW}_W] = (kW_{pre} - kW_{installed}) \times CF_W$$

Equation 309

Where:

kW_{pre}	=	Total kW of existing lamp-based projector
$kW_{installed}$	=	Total kW of efficient laser projector
Hours	=	Annual operating hours = 3,653 hours ⁶⁹² (use actual hours if known)
CF_S	=	Summer peak coincidence factor = 0.65 (all climate zones) ⁶⁹³
CF_W	=	Winter peak coincidence factor = 0 (all climate zones) ⁶⁹⁴

⁶⁹² "HVAC considerations for lamp and laser projectors in cinema," Barco. July 26, 2021. The reference uses 11.5 hours per day (or 4,200 hours) as an example. This measure assumes 10 hr/day as a conservative assumption, but allows for the use of custom hours based on site conditions. Default hours are calculated as 10 hr/day x 365.25 day/year = 3,653 hours.

⁶⁹³ Refer to Lamps and Fixtures measure for the public assembly building type, which is applicable to motion picture theaters.

⁶⁹⁴ Ibid.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for cinema laser projectors.^{695,696,697}

Program Tracking Data and Evaluation Requirements

The program database should specify and track the list of primary inputs and contextual data provided below. This will inform the evaluation process and ensure proper application of the savings.

- Building type
- Baseline lamp-based projector manufacturer and model number
- Baseline projector lamp wattage
- Baseline lamp-based projector nameplate photo
- New laser projector manufacturer and model number
- New laser projector wattage
- New projector nameplate photo
- Proof of purchase: invoice showing model number and quantity purchased

Document Revision History

Table 360. Laser Projectors—Revision History

TRM version	Date	Description of change
v11.0	10/2023	Measure origin
v12.0	10/2024	No revision.
v13.0	10/2025	No revision.

⁶⁹⁵ Average rated life of 18 Barco and Christie cinema laser projectors = 41,667 hours. Dividing by annual operating hours yields EUL.

⁶⁹⁶ Barco cinema projector product listing. <https://www.barco.com/en/products/projection/overview?facets=barco-dxp%3Aproduct%2Fproduct-category%2Fprojection%2Fcinema-projectors>.

⁶⁹⁷ Christie cinema projector product listing. <https://www.christiedigital.com/products/cinema/projection/>.

2.7.15 Water Pumps Measure Overview

TRM Measure ID: NR-MS-WP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

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

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

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

Baseline Condition

The baseline condition for this measure is a clean water pump with a PEI rating specified in Table 361 below. Under Title 10 Section 431.462, the US Department of Energy (DOE) developed the Energy Conservation Standard (ECS) for commercial, industrial, and agricultural clean water pumps.⁶⁹⁸ As of January 2020, all clean water pumps sold are required to have an ECS label with a PEI rating of ≤ 1.0 .

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

High-Efficiency Condition

The high-efficiency condition is a constant speed or variable speed clean water pump that meets or exceeds the conditions in Table 361 below.

Table 361. Water Pumps—Baseline and High-Efficiency Conditions

Pump motor hp	Control strategy	Baseline PEI	Efficient PEI
$1 \leq \text{hp} \leq 15$	Variable Speed	0.47	≤ 0.45
$1 \leq \text{hp} \leq 15$	Constant Speed	0.94	≤ 0.92
$15 < \text{hp} \leq 50$	Variable Speed	0.49	≤ 0.47
$15 < \text{hp} \leq 50$	Constant Speed	0.94	≤ 0.92
$50 < \text{hp} \leq 250$	Variable Speed	0.49	≤ 0.47
$50 < \text{hp} \leq 250$	Constant Speed	0.95	≤ 0.93

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

The energy savings analysis was adopted from the pump savings analysis approved by the Regional Technical Forum (RTF) for the Northwest Energy Efficiency Alliance (NEEA) Efficient Commercial and Industrial Pumps (ECIP) Project.⁶⁹⁹ This analysis was approved in April 2022, and included extensive pump modeling, DOE database information, and customer/vendor field data.

⁶⁹⁸ Code of Federal Regulations at 10 CFR Subpart Y. <https://www.caetrm.com/media/reference-documents/CFR-2018-title10-vol3-sec431-462.pdf>.

⁶⁹⁹ RTF. 2016. "Research Strategy for Efficient Pumps." December 6.

The energy savings from retrofitting a base case pump to a more efficient measure case pump is based on the NEEA modification of the HI pump energy savings calculation.⁷⁰⁰ The HI energy savings calculation assumes a conservative base case efficiency scenario and does not include adjustment factors to account for pump nominal power and actual pump performance variances. The NEEA modifications of the HI calculation considered baseline market average pump efficiencies and adjustment factors that consider nominal versus actual power draw and actual pump system curves.

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

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

Equation 310

Where:

HRS_{OPYr}	=	Annual operating hours, see Table 337
AF_{OPHr}	=	Final load profile adjustment factors by application and speed control case, see Table 337
P_{Pump}	=	Nominal pump size in horsepower (hp)
P_{Motor}	=	Nominal motor size in horsepower (hp)
PEI_{base}	=	Base PEI of the pump, see Table 361
PEI_{Eff}	=	Efficient PEI of the pump
AOH	=	Annual operating hours, see Table 337
AF	=	Final load profile adjustment factors by application and speed control case, see Table 337
0.746	=	Constant to convert from hp to kW

Table 362. Water Pumps—Annual Operating Hours and Adjustment Factors⁷⁰¹

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

⁷⁰⁰ <https://www.caetrm.com/measure/SWWP004/03/>.

⁷⁰¹ Pacific Gas and Electric Company (PG&E). 2023. "SWWP004 Savings_and_Cost_Analysis_12-14-2023.xlsm"

Summer Peak Demand Savings

There are no summer peak demand savings for this measure.

Winter Peak Demand Savings

There are no winter peak demand savings for this measure.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years as specified in Database of Energy Efficiency Resources (DEER) 2008.⁷⁰²

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

⁷⁰² www.deeresources.com

Relevant Standards and Reference Sources

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

Document Revision History

Table 363. Water Pumps—Revision History

TRM version	Date	Description of change
v12.0	10/2024	Measure origin
v13.0	10/2025	No revision.

APPENDIX A: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

The following appendix describes the method to calculate savings for any dual baseline measure, including all early retirement measures. This supersedes the previous Measure Life Savings found in PUCT Dockets 40083 and 40885 and is revised to clarify the understanding of the measure life calculations and reduce any misrepresentation of net present value (NPV) of early retirement projects.

Option 1 provides reduced savings claimed over the full EUL. Option 2 provides higher savings claimed over a reduced EUL. The lifetime savings are the same for both options 1 and 2. Option 1 calculations were originally provided in Docket [43681].

Option 1—Weighting Savings and Holding Measure Life Constant

Step 1: Determine the measure life for first-tier (FT) and second-tier (ST) components of the calculated savings:

$$\text{First Tier (FT) Period} = ML_{FT} = RUL$$

Equation 311

$$\text{Second Tier (ST) Period} = ML_{ST} = EUL - RUL$$

Equation 312

Where:

RUL = The useful life corresponding with the first tier-savings; for early retirement projects, *RUL* is the remaining useful life determined from lookup tables based on the age of the replaced unit (or default age when actual age is unknown)

EUL = The useful life corresponding with the second-tier savings; for early retirement projects, *EUL* is the estimated useful life as specified in applicable measure from Texas TRM (or approved petition)

Step 2: Calculate the FT demand and energy savings and the ST demand and energy savings:

$$\Delta kW_{FT} = kW_{retired} - kW_{installed}$$

Equation 313

$$\Delta kW_{ST} = kW_{baseline} - kW_{installed}$$

Equation 314

$$\Delta kWh_{FT} = kWh_{retired} - kWh_{installed}$$

Equation 315

$$\Delta kWh_{ST} = kWh_{baseline} - kWh_{installed}$$

Equation 316

Where:

ΔkW_{FT}	=	First-tier demand savings
ΔkW_{ST}	=	Second-tier demand savings
$kW_{retired}$	=	Demand of the first-tier baseline system, usually the retired system ⁷⁰³
$kW_{baseline}$	=	Demand of the second-tier baseline system, usually the baseline ROB system ⁷⁰⁴
$kW_{installed}$	=	Demand of the replacement system ⁷⁰⁵
ΔkWh_{FT}	=	First-tier energy savings
ΔkWh_{ST}	=	Second-tier energy savings
$kWh_{retired}$	=	Energy usage of the first-tier baseline system, usually the retired system ⁶⁸⁶
$kWh_{baseline}$	=	Energy usage of the second-tier baseline system, usually the baseline ROB system ⁶⁸⁷
$kWh_{installed}$	=	Energy usage of the replacement system ⁶⁸⁸

Step 3: Calculate the avoided capacity and energy cost contributions of the total NPV for both the ER and ROB components:

$$NPV_{FT,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{FT}} \right\} \times \Delta kW_{FT}$$

Equation 317

$$NPV_{ST,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kW_{ST}$$

Equation 318

$$NPV_{FT,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{FT}} \right\} \times \Delta kWh_{FT}$$

Equation 319

$$NPV_{ST,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kWh_{ST}$$

⁷⁰³ Retired system refers to the existing equipment that was in use before the retrofit had occurred.

⁷⁰⁴ Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the early retirement project (as specified in the applicable measure).

⁷⁰⁵ Replacement system refers to the installed equipment that was in place after the retrofit had occurred.

Where:

$NPV_{FT, kW}$	=	Net Present Value (kW) of first-tier projects
$NPV_{ST, kW}$	=	Net Present Value (kW) of second-tier projects
$NPV_{FT, kWh}$	=	Net Present Value (kWh) of first-tier projects
$NPV_{ST, kWh}$	=	Net present value (kWh) of second-tier projects
e	=	Escalation rate ⁷⁰⁶
d	=	Discount rate weighted average cost of capital (per utility) ⁶⁸⁹
AC_{kW}	=	Avoided cost per kW (\$/kW) ⁶⁸⁹
AC_{kWh}	=	Avoided cost per kWh (\$/kWh) ⁶⁸⁹
ML_{FT}	=	First-tier measure life (calculated in Equation 311)
ML_{ST}	=	Second-tier measure life (calculated in Equation 312)

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total, kW} = NPV_{FT, kW} + NPV_{ST, kW}$$

Equation 321

$$NPV_{Total, kWh} = NPV_{FT, kWh} + NPV_{ST, kWh}$$

Equation 322

Where:

$NPV_{Total, kW}$	=	Total capacity contributions to NPV of both first-tier and second-tier component
$NPV_{Total, kWh}$	=	Total energy contributions to NPV of both first-tier and second-tier component

Step 5: Calculate the capacity and energy cost contributions to the NPV without weighting by demand and energy savings for a scenario using the original EUL:

$$NPV_{EUL, kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{EUL} \right\}$$

Equation 323

$$NPV_{EUL, kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{EUL} \right\}$$

⁷⁰⁶ The exact values to be used each year for the escalation rate, discount rate, and avoided costs are established by the PUC in Substantive Rule §25.181 and updated annually, as applicable. Please note that the discount rates are based on a utility's weighted average cost of capital and, as such, will vary by utility and may change each year.

Equation 324

Where:

$NPV_{EUL, kW}$ = Capacity contributions to NPV without weighting, using original EUL

$NPV_{EUL, kWh}$ = Energy contributions to NPV without weighting, using original EUL

Step 6: Calculate the weighted demand and energy savings by dividing the combined capacity and energy cost contributions from the ER and ROB scenarios by the non-savings weighted capacity and energy cost contributions from the single EUL scenario. These weighted savings are claimed over the original measure EUL:

$$\text{Weighted } kW = \frac{NPV_{Total\ kW}}{NPV_{EUL, kW}} = \frac{\left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RUL} \right) \times (kW_{retired} - kW_{installed}) \right] + \left[\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL-RUL} \right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kW_{baseline} - kW_{installed}) \right]}{\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL} \right)}$$

Equation 325

$$\text{Weighted } kWh = \frac{NPV_{Total\ kWh}}{NPV_{EUL, kWh}} = \frac{\left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RUL} \right) \times (kWh_{retired} - kWh_{installed}) \right] + \left[\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL-RUL} \right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kWh_{baseline} - kWh_{installed}) \right]}{\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL} \right)}$$

Equation 326

Where:

Weighted kW = Weighted lifetime demand savings

Weighted kWh = Weighted lifetime energy savings

$NPV_{Total, kW}$ = Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 321

$NPV_{Total, kWh}$ = Total energy contributions to NPV of both ER and ROB component, calculated in Equation 322

$NPV_{EUL, kW}$ = Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 323

$NPV_{EUL, kWh}$ = Energy contributions to NPV without weighting, using original EUL, calculated in Equation 324

Option 2—Weighting Measure Life and Holding First Year Savings Constant

Repeat Step 1 through Step 4 from Option 1.

Step 5: Reverse calculate the EUL for the capacity and energy contributions to the NPV for a scenario using the first-tier savings:

$$EUL_{kW} = \frac{\ln \left[\frac{NPV_{Total,kW} \times (d - e)}{\Delta kW_{FT} \times AC_{kW} \times (1 + e)} \right]}{\ln \left[\frac{(1 + e)}{(1 + d)} \right]}$$

Equation 327

$$EUL_{kWh} = \frac{\ln \left[\frac{NPV_{Total,kWh} \times (d - e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1 + e)} \right]}{\ln \left[\frac{(1 + e)}{(1 + d)} \right]}$$

Equation 328

Where:

EUL_{kW} = EUL for capacity contribution to NPV using first-tier savings

EUL_{kWh} = EUL for energy contribution to NPV using first-tier savings

Step 6: Confirm that capacity EUL and energy EUL are equivalent. First-tier savings are claimed over this weighted EUL.