

# Public Utility Commission of Texas

**Texas Technical Reference Manual**

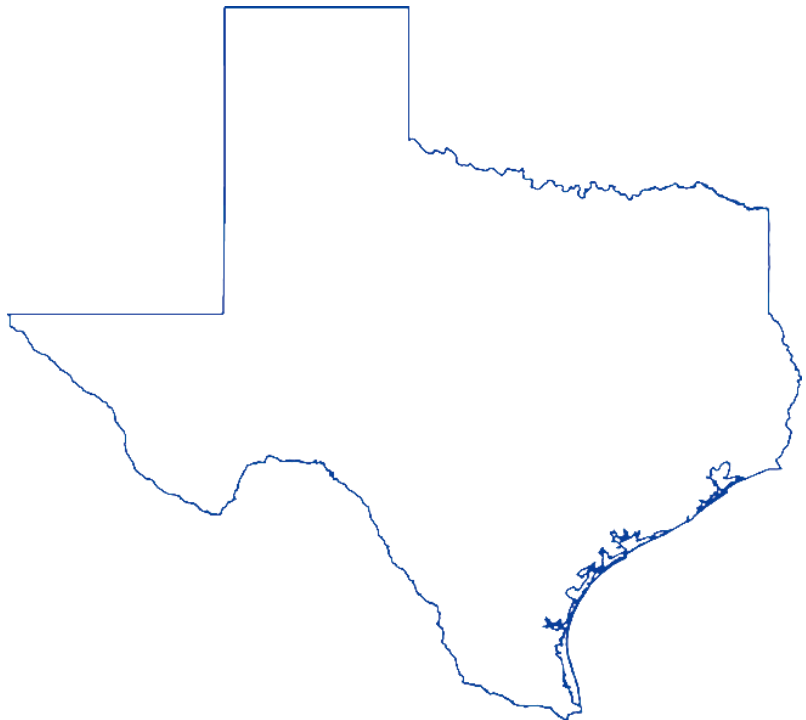
**Version 11.0**

**Volume 3: Nonresidential Measures**

**Program Year 2024**

**Last Revision Date:**

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## Acknowledgments

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## TRM Technical Support

Technical support and questions can be emailed to the EM&V project manager ([lark.lee@tetrattech.com](mailto:lark.lee@tetrattech.com)) and PUCT staff ([therese.harris@puc.texas.gov](mailto:therese.harris@puc.texas.gov)).



# 1. INTRODUCTION

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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	11.0 update
Lighting	Lamps and fixtures	–	–	X	X	X	Added guidance for delisted lighting products and for new construction exterior lighting zone selection. Aligned building type names across all commercial measures.
	Lighting controls	–	–	X	X	X	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.
	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	Clarified eligibility criteria.
	Split and packaged air conditioners and heat pumps	–	–	X	X	X	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.
	HVAC chillers	–	–	X	X	X	Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
	Package terminal air conditioners/heat pumps, and room air conditioners	–	–	X	X	X	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.
	Computer room air conditioners	–	–	X	X	–	Added reference to new standard and plan to incorporate in PY2025.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
	Computer room air handler motor efficiency	–	–	X	X	–	No revision.
	HVAC variable frequency drives	–	X	X	–	–	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.
	Condenser air evaporative pre-cooling	–	–	X	–	X	Aligned building type names across all commercial measures.
	High-volume low-speed fans	–	–	X	–	–	No revision.
	Small commercial evaporative cooling	–	X	X	–	–	Aligned building type names across all commercial measures.
	Small commercial smart thermostats	–	–	X	X	X	No revision.
Building envelope	Cool roofs	X	–	X	X	–	No revision.
	Window treatments	X	–	X	X	–	Extended eligibility to windows with existing louvered or Venetian blinds. Added reduced baseline SHGC values for windows with louvered blinds.
	Entrance and exit door air infiltration	–	X	X	–	–	No revision.
Food service	ENERGY STAR® combination ovens	–	X	X	–	–	No revision.
	ENERGY STAR® electric convection ovens	–	X	X	–	–	No revision.
	ENERGY STAR® dishwashers	–	X	X	–	–	Clarified that residential dishwashing equipment can be installed in commercial applications following the methodology in Volume 2 of the TRM.
	ENERGY STAR® electric griddles	–	X	X	–	–	TRM v11.0 origin.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
	ENERGY STAR® electric fryers	–	X	X	–	–	Updated documentation requirements to collect fryer type rather than fryer width.
	ENERGY STAR® electric steam cookers	–	X	X	–	–	No revision.
	ENERGY STAR® hot food holding cabinets	–	X	X	–	–	No revision.
	ENERGY STAR® ice makers	–	X	X	–	–	No revision.
	Demand controlled kitchen ventilation	–	X	X	–	–	Aligned building type names across all commercial measures.
	Pre-rinse spray valves	–	X	X	–	–	Adjusted mixed water hot temperature to match CEE guidance. Aligned building type names across all commercial measures.
	Vacuum-sealing and packaging machines	–	X	–	–	–	No revision.
Refrigeration	Door heater controls	–	X	X	–	–	No revision.
	ECM evaporator fan motors	–	–	X	–	–	Clarified duty cycle assumptions and references.
	Electronic defrost controls	–	–	X	–	–	No revision.
	Evaporator fan controls	–	–	X	–	–	No revision.
	Night covers for open refrigerated display cases	–	X	X	–	–	No revision.
	Solid and glass door reach-ins	–	–	X	–	–	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.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
	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.
Water heating	Heat pump water heaters	–	–	X	–	–	TRM v11.0 origin.
	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	–	–	Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
	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	11.0 update
	Lodging guest room occupancy sensor controls	–	X	–	–	–	No revision.
	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	–	–	TRM v11.0 origin.
	Steam trap repair and replacement	–	X	X	–	–	Aligned building type names across all commercial measures.
	Hydraulic gear lubricants	–	–	X	–	–	No revision.
	Hydraulic oils	–	–	X	–	–	No revision.
	Hand dryers	–	X	X	–	–	No revision.
	Laser projectors	–	–	X	–	–	TRM v11.0 origin.

## 2. NONRESIDENTIAL MEASURES

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### 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

#### 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 delamping<sup>1</sup> 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 table<sup>2</sup>, 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.

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

<sup>2</sup> Maintained by EUMMOT/Frontier Energy: <http://texasefficiency.com/index.php/regulatory-filings/lighting>.

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.

## 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.<sup>3</sup> 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<sup>®</sup> (DLC), ENERGY STAR<sup>®</sup>, or independent lab testing<sup>4</sup> (e.g., LM-79, LM-80, TM-21, ISTMT). Rated life for LED fixtures should be greater than or equal to 50,000

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<sup>3</sup> 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.

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



hours, which can be demonstrated by compliance with DLC v3.0 or later<sup>5</sup> 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 later<sup>6</sup> 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.
- 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: 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:

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<sup>5</sup> Equivalent to the L70 rated life requirement for all categories as specified in DesignLights Consortium™ (DLC) Technical Requirements v3.0. <https://www.designlights.org/wp-content/uploads/2021/01/DLC-Technical-Requirements-Table-V3-0.pdf>.

<sup>6</sup> 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>.

- If the fixture is installed at a reduced setpoint, it should be reported at the maximum input wattage in combination with the institutional tuning control code to claim energy savings associated with a central control lighting output based on tuning sensors. This control type is similar because it is not easily adjustable over time.
- If the fixture is installed with additional controls (e.g., occupancy sensor, daylighting), then it should be reported at the maximum input wattage in combination with the multiple control code.
- If the fixture is installed without adjustment, it should be reported at the maximum input wattage with no control code.
- If the fixture is installed with no additional controls and the DLC certificate specifies a lower wattage setpoint, then it should be reported as the lower input wattage with no control code.
- For all cases, project documentation should include a screenshot of the DLC certificate and an example photo of the field-adjustable setpoint.

**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:<sup>7</sup>

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

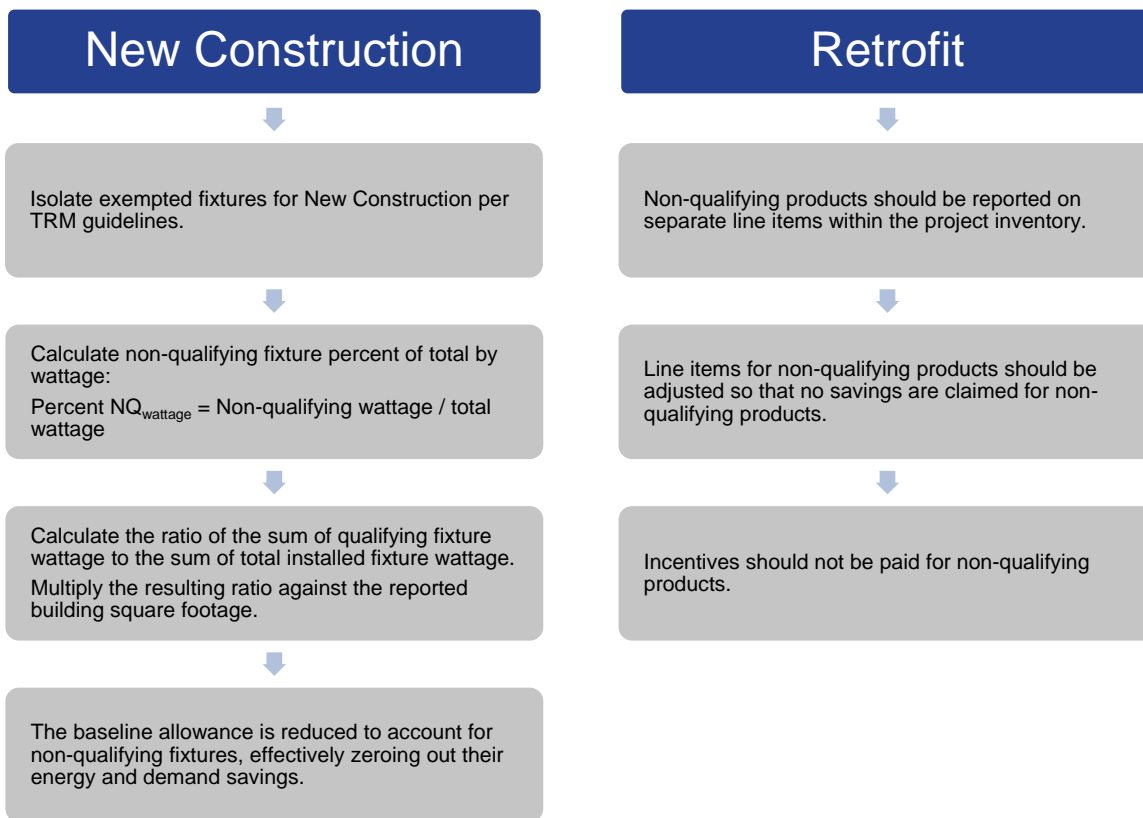
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<sup>7</sup> IECC 2015, Section C405.4.1.

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
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  $NQ_{wattage} = \text{wattage of non-qualifying fixtures} / \text{wattage of total fixtures}$ )

**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 a 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. Eligible baseline fixture types and 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*
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

T12 length	Lamp count	Revised lamp wattage	Revised system wattage
2-foot u-tube	1	32	32
	2	32	60
	3	32	89

<sup>8</sup> 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.<sup>8</sup>
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens/watt efficacy.<sup>9</sup>

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. However, due to the DOE enforcement schedule, savings may be claimed against the first-tier EISA baseline through February 28, 2023, at the utility's discretion.<sup>10</sup>

**Table 3. Lamps & Fixtures—EISA 2007 Baseline Adjustment for GSLs<sup>11 12</sup>**

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	2 <sup>nd</sup> Tier EISA 2007 baseline wattage
250	309	25	Exempt
310	749	40	12
750	1,049	60	20
1,050	1,489	75	28

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

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

<sup>10</sup> See PY2022 TRM 9.0 for methodology and baseline.

<sup>11</sup> Federal standard for General Service Incandescent Lamps (GSILs): [https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=20](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20).

<sup>12</sup> If exempt, refer to incandescent equivalent wattage.

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	2 <sup>nd</sup> Tier EISA 2007 baseline wattage
1,490	2,600	100	45
2,601	3,300	150	66

## 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,<sup>13</sup> 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 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.

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<sup>13</sup> 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.



## Retrofit<sup>14,15</sup>

$$\begin{aligned} \text{Energy Savings [kWh]} \\ = (kW_{pre} \times Hours_{pre} \times EAF_{pre} - kW_{installed} \times Hours_{installed}) \times HVAC_{energy} \end{aligned} \quad \text{Equation 1}$$

$$\text{Peak Demand Savings [kW]} = (kW_{pre} \times CF_{pre} \times PAF_{pre} - kW_{installed} \times CF_{S/W}) \times HVAC_{demand} \quad \text{Equation 2}$$

## New Construction

$$\text{Energy Savings [kWh]} = \left( \frac{LPD \times FloorArea}{1,000} - kW_{installed} \right) \times Hours \times HVAC_{energy} \quad \text{Equation 3}$$

$$\text{Peak Demand Savings [kW]} = \left( \frac{LPD \times FloorArea}{1,000} - kW_{installed} \right) \times CF_{S/W} \times HVAC_{demand} \quad \text{Equation 4}$$

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)<sup>16</sup>

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/ft<sup>2</sup>)

<sup>14</sup> For non-operating fixtures, the baseline demand may be adjusted by using values from the Standard Wattage Table. The number of non-operating fixtures will be limited to 10% of the total fixture count per facility.

<sup>15</sup> The energy and demand savings calculations should also account for lighting controls that are present on existing lighting systems. The EAF and PAF 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. Savings for controls installed on new fixtures are accounted for in the Lighting Controls measure.

<sup>16</sup> 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.

<i>Floor Area</i>	=	<i>Floor area of the treated space where the lights were installed</i>
<i>Hours</i>	=	<i>Hours by building type from Table 9</i>
<i>EAF</i>	=	<i>Energy adjustment factor from Lighting Controls measure (set equal to 1 if no controls are installed on the existing fixture)</i>
<i>CF<sub>S/W</sub></i>	=	<i>Summer/winter seasonal peak coincidence factor by building type (see Table 10 or Table 11)</i>
<i>PAF</i>	=	<i>Power adjustment factor from Lighting Controls measure (set equal to 1 if no controls are installed on the existing fixture)</i>
<i>HVAC<sub>energy</sub></i>	=	<i>Energy interactive HVAC factor by building type</i>
<i>HVAC<sub>demand</sub></i>	=	<i>Demand interactive HVAC factor by building type</i>
<i>ISR</i>	=	<i>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 13)</i>

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.**<sup>17</sup> 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.

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<sup>17</sup> Maintained by EUMMOT/Frontier Energy: <http://texasefficiency.com/index.php/regulatory-filings/lighting>.

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 the code that was in effect at the time of building permit issuance. The current Commercial code for the state of Texas is IECC 2015. These values for interior space types are presented in Table 4.

In Table 6, 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.

In most cases, the Zone 1, 2, or 4 will be selected. Default to Zone 2 if the space type cannot be determined. City zoning drawings can be used to validate a Zone 4 selection. At a minimum, project documentation should include the rationale for selecting Zone 4. Zone 3 should only be selected if it can be clearly demonstrated that none of the others apply. The reported zone should match the code compliance report (COMcheck), if available.

**Table 4. Lamps & Fixtures—New Construction LPDs for Interior Space Types by Building Type<sup>18</sup>**

Facility type	LPD (W/ft <sup>2</sup> )	Facility type	LPD (W/ft <sup>2</sup> )
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

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

Facility type	LPD (W/ft <sup>2</sup> )	Facility type	LPD (W/ft <sup>2</sup> )
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

In addition to the interior building types specified in IECC 2015, the following LPDs have been established for agricultural greenhouses. Greenhouse types are defined as follows:

- High intensity sole-source greenhouse: All plant lighting is provided by ceiling-mounted high intensity artificial electric lighting.
- Supplemented greenhouse: Most plant lighting is provided by natural sunlight with supplemented artificial electric lighting used to extend daylight hours during winter seasons with short periods of sunlight or on inclement weather days when sunlight levels are suboptimal.
- Vertical farming: Plants are sacked along vertical shelving from floor to ceiling to increase grow area.

**Table 5. Lamps & Fixtures—New Construction LPDs for Agricultural Greenhouses<sup>19</sup>**

Facility type <sup>20</sup>	LPD (W/ft <sup>2</sup> )
Agricultural: high intensity sole-source greenhouse	52.16
Agricultural: supplemented greenhouse	10.92
Agricultural: vertical farming <sup>21</sup>	—

The total 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 6.

<sup>19</sup> “Energy Savings Potential of SSL in Agricultural Applications,” US Department of Energy. June 2020. Table E-1. <https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf>.

<sup>20</sup> Weighted average of LPDs specified for LED, HPS/MH, and Fluorescent lighting type categories based on 2019 technology mix from Table E-1.

<sup>21</sup> Vertical farming was excluded due to 100% LED adoption in the 2019 technology mix from Table E-1.

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 6. Lamps & Fixtures—New Construction LPDs for Exterior Space Types<sup>22</sup>**

Space type	LPD (W/ft <sup>2</sup> )			
	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate 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) <sup>23</sup>	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) <sup>24</sup>	0.50	0.50	0.50	0.50
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 <sup>25</sup>	–	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

<sup>22</sup> 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.

<sup>23</sup> 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.

<sup>24</sup> Ibid.

<sup>25</sup> 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.

The following default metal halide baseline wattage assumptions have been approved for exterior athletic fields and courts, which are not included in the above LPD table. These baseline wattages were derived based on a review of reported lumen range for available LED products and their reported equivalent metal halide (MH) wattage.

**Table 7. Lamps & Fixtures—New Construction Baseline Wattages for Athletic Field/Court LEDs**

Equivalent MH wattage	Number of lamps	LED rated lumen range
175	1	< 7,500
250	1	7,500-12,499
400	1	12,500-19,999
400	2	20,000-39,999
1,000	1	40,000-59,999
1,500	1	60,000-74,999
1,000	2	75,000-99,999
1,000	3	100,000-124,999
1,000	4	125,000-149,999
1,000	5	150,000-199,999
1,000	6 plus 1 additional lamp for every 50,000 lumens above 200,000 (rounded down)	> 200,000

### ***Operating Hours (Hours) and Coincidence Factors (CFs)***

Operating hours and peak demand coincidence factors are assigned by building type, as shown in Table 9 through Table 11. The building types used in this table are based on Commercial Buildings Energy Consumption Survey (CBECS)<sup>26</sup> 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.

<sup>26</sup> DOE-EIA Commercial Building Energy Consumption Survey.

**Table 8. Lamps & Fixtures—Building Type Descriptions and Examples**

Building type	Principal building activity	Definition	Detailed business type examples <sup>27</sup>
Agriculture	Dairy buildings	Buildings used to house dairy livestock and collect milk from dairy cows.	1) Dairy buildings
	Grow house	Buildings used to grow herbs, fruits, or vegetables under artificial lighting. Sole-source greenhouses rely on 100% artificial lighting, whereas supplemented greenhouses use both natural sunlight and artificial lighting.	1) 24-hour grow house 2) Non-24-hour sole-source greenhouse 3) Non-24-hour supplemented greenhouse
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 2) Preschool or daycare
	Secondary school		1) High school 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
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

<sup>27</sup> Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building type	Principal building activity	Definition	Detailed business type examples <sup>27</sup>
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 an office building).	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 <sup>27</sup>
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 <sup>27</sup>
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 <sup>27</sup>
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	<ol style="list-style-type: none"> <li>1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center)</li> <li>2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports)</li> <li>3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club)</li> <li>4) Library</li> <li>5) Funeral home</li> <li>6) Student activities center</li> <li>7) Armory</li> <li>8) Exhibition hall</li> <li>9) Broadcasting studio</li> <li>10) Transportation terminal</li> </ol>
Public order and safety	Jail and prison	Government establishments engaged in justice, public order, and safety.	<ol style="list-style-type: none"> <li>1) Correctional institutions</li> <li>2) Prison administration and operation</li> </ol>
	Other		<ol style="list-style-type: none"> <li>1) Police protection</li> <li>2) Legal counsel and prosecution</li> <li>3) Fire protection</li> <li>4) Public order and safety, not elsewhere classified</li> </ol>
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 <sup>27</sup>
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	<ol style="list-style-type: none"> <li>1) Vehicle service or vehicle repair shop</li> <li>2) Vehicle storage/maintenance</li> <li>3) Repair shop</li> <li>4) Dry cleaner or laundromat</li> <li>5) Post office or postal center</li> <li>6) Car wash</li> <li>7) Gas station with no convenience store</li> <li>8) Photo processing shop</li> <li>9) Beauty parlor or barber shop</li> <li>10) Tanning salon</li> <li>11) Copy center or printing shop</li> <li>12) Kennel</li> </ol>
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	<ol style="list-style-type: none"> <li>1) Refrigerated warehouse</li> <li>2) Non-refrigerated warehouse</li> <li>3) Distribution or shipping center</li> </ol>
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

**Table 9. Lamps & Fixtures—Operating Hours by Building Type**

Building type	Operating hours
Agriculture: Long-day lighting <sup>28</sup>	6,209
Agriculture: Non-24-hour sole-source greenhouse <sup>29</sup>	5,479
Agriculture: Non-24-hour supplemented greenhouse <sup>30</sup>	2,000
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 <sup>31</sup>	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

<sup>28</sup> Daily operating hours are 17 hours/day based on assumptions from the Minnesota and Wisconsin TRMs and market research indicating average 16–18 hours of daily operation. Annual operating hours are derived by multiplying 17 hours/day by 365.25 days/year.

<sup>29</sup> Daily operating hours are 15 hours/day based on market research indicating 14-16 hours of daily operation. Annual operating hours are derived by multiplying 15 hours/day by 365.25 days/year.

<sup>30</sup> “Energy Savings Potential of SSL in Agricultural Applications,” US Department of Energy. June 2020. Table E-1. <https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf>.

<sup>31</sup> Assuming a partial summer session in June with no summer session in July.

Building type	Operating hours
Outdoor: Athletic field and court <sup>32</sup>	767
Outdoor: Billboard <sup>33</sup>	3,470
Outdoor: Dusk-to-dawn <sup>34</sup>	4,161
Outdoor: Less than dusk-to-dawn <sup>35</sup>	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
Other	2,638

**Table 10. Lamps & Fixtures—Summer Peak Coincidence Factors by Building Type<sup>36</sup>**

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: Long-day lighting	1.00	1.00	1.00	1.00	1.00
Agriculture: Non-24-hour sole-source greenhouse	1.00	1.00	1.00	1.00	1.00

<sup>32</sup> “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.

<sup>33</sup> Ibid.

<sup>34</sup> 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](https://aa.usno.navy.mil/data/RS_OneYear).

<sup>35</sup> This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

<sup>36</sup> Building operating schedules are adapted from COMNET Appendix C – Schedules (Rev. 3). <https://comnet.org/appendix-c-schedules>. Updated 7/25/2016.

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: Non-24-hour supplemented greenhouse <sup>37</sup>	–	–	–	–	–
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 <sup>38</sup>	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
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

<sup>37</sup> Assuming no peak coincidence because these fixtures are often operated exclusively during off-peak hours (ranging from 10 PM to 6 AM). This time range is not coincident with either the Texas summer or winter peak periods.

<sup>38</sup> 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
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
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
Other	0.65	0.65	0.65	0.65	0.65



**Table 11. Lamps & Fixtures—Winter Peak Coincidence Factors by Building Type<sup>39</sup>**

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 <sup>40</sup>	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn <sup>41</sup>	0.67	0.71	0.61	0.75	1.00
Parking garage	1.00	1.00	1.00	1.00	1.00

### ***Building Type Selection***

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.<sup>42</sup>

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 9 through Table 11. For the majority of the 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.<sup>43</sup> 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.

<sup>39</sup> 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.

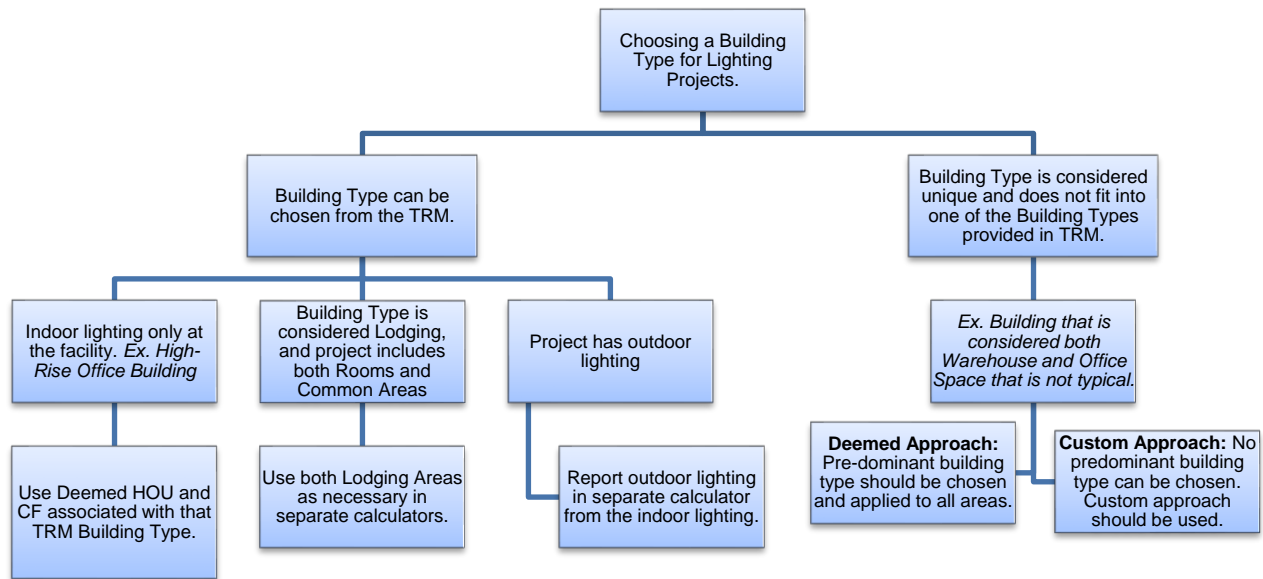
<sup>40</sup> This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule.

<sup>41</sup> This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

<sup>42</sup> *Annual Statewide Portfolio Report for Program Year 2013 – Volume I*. Prepared for the Public Utility Commission of Texas. October 6, 2014.

<sup>43</sup> More information on how these values were created can be found in PUCT Docket #39146.

**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.

**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 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.

### ***Interactive HVAC Factors (HVAC Energy, Demand)***

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 12 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 12. Lamps & Fixtures—Deemed Energy and Demand Interactive HVAC Factors<sup>44</sup>**

Space conditioning type	Energy interactive HVAC factor	Demand interactive HVAC factor
Refrigerated air	1.05	1.10
Evaporative cooling <sup>45</sup>	1.02	1.04
Medium-temperature refrigeration (33 to 41°F)	1.25	1.25
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 2012 CBECS<sup>46</sup> and 2014 MECS<sup>47</sup> as well as lamp density and lamp type distribution survey data from the DOE 2015 US Lighting Market Characterization (LMC)<sup>48</sup>.

<sup>44</sup> PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).

<sup>45</sup> 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.

<sup>46</sup> 2012 Commercial Building Energy Consumption Survey (CBECS).  
<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

<sup>47</sup> 2014 Manufacturing Energy Consumption Survey (MECS).  
<https://www.eia.gov/consumption/manufacturing/>.

<sup>48</sup> 2015 US Lighting Market Characterization, Department of Energy. November 2017.  
[https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015\\_nov17.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf).

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.<sup>49</sup> 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 13. Lamps & Fixtures—Upstream/Midstream Input Assumptions by Lamp Type<sup>50</sup>**

Lamp type	AOH	Coincidence factors <sup>51</sup>					ISR
		Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso	
General service lamp	3,748	0.69	0.69	0.73	0.73	0.71	0.98
Directional/reflector	3,774	0.78	0.79	0.78	0.79	0.82	1.00
LED tube	3,522	0.74	0.75	0.84	0.84	0.76	1.00
High-bay fixture	3,796	0.78	0.79	0.83	0.84	0.80	1.00
Garage	7,884	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor	4,161	0.67	0.71	0.61	0.75	1.00	1.00

Additionally, baseline wattage for ENERGY STAR-qualified products is assumed to be equal to the equivalent wattage from the ENERGY STAR certification. Baseline wattage assumptions for DLC- and third-party-qualified products should be determined based on product technical specifications and/or delivered light output (lumens) and detailed in the program qualified product listing.

## 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.

<sup>49</sup> Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs.

<sup>50</sup> 2012 CBECS and 2014 MECS.

<sup>51</sup> Outdoor coincidence factors are specified for winter peak. All other values reference summer peak.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) values are defined for the following lamp/fixture types.<sup>52</sup> A separate new construction EUL has been established due to account for the whole-building baseline.

- Halogen lamps: 1.5 years
- High-intensity discharge lamps: 15 years
- Integrated-ballast CCFL lamps: 4.5 years
- Integrated-ballast CFL lamps: 2.5 years
- Integral LED lamps: 9 years<sup>53</sup>
- LED fixtures: 15 years
- LED corn cob lamps: 15 years
- LED tubes: 15 years
- Solar LEDs<sup>54</sup>: 10 years
- Modular CFL and CCFL fixtures: 15 years
- T8 and T5 linear fluorescents: 15 years
- New construction interior fixtures/controls<sup>55</sup>: 14 years
- New construction exterior fixtures<sup>56</sup>: 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)

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<sup>52</sup> PUCT Docket 36779.

<sup>53</sup> PUCT Docket 38023.

<sup>54</sup> 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.

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

<sup>56</sup> Ibid.

- **For new construction only:**
  - LPD factor
  - Interior and/or exterior lighting schedules and plans
  - Interior and/or exterior space areas and distances
  - If applicable, verify whether SECO compliance certification forms were filed<sup>57</sup>
- 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 number<sup>58</sup>
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage<sup>59</sup>
- 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 field adjustable light output fixtures only:** isolate these fixtures by setting type and location within reported project inventories and track field adjustment settings
- **For field adjustable light output fixtures only:** post-retrofit lumen readings for inspection sample
- Equipment operating hours

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<sup>57</sup> 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.

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

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

- Lighting measure group (from Measure Life groupings)
- **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
- **For upstream/midstream only:** Qualified product list mapping efficient lighting products to baseline wattage assumptions

## 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 14. Lamps & Fixtures—Revision History

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



TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. Revised to eliminate T12 lamps as a valid baseline. <i>Measure Description section:</i> General clean-up of technology descriptions. <i>Program Tracking Data section:</i> Minor changes and clarifications.
v3.1	11/05/2015	TRM v3.1 update. <i>Revised to eliminate</i> T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. <i>Eligibility Criteria:</i> Adding sources for LED lamp and fixture eligibility.
v3.1	03/23/2016	TRM v3.1 March revision. Updated <i>Linear Fluorescent T12 Special Conditions</i> 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	TRM v4.0 update. Added LPD values and tracking data requirements for exterior space type climate zones used in Codes and Standards.
v5.0	10/2017	TRM v5.0 update. 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	TRM v6.0 update. 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	TRM v7.0 update. 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. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. 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	TRM v9.0 update. 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	TRM v10.0 update. 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	TRM v11.0 update. Added guidance for delisted lighting products and for new construction exterior lighting zone selection. Aligned building type names across all commercial 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 an energy adjustment factor (EAF) for kWh and a power adjustment factor (PAF) for kW.

### Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 15. 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.

**Field adjustable light output:** 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 maximum input wattage in combination with the Institutional Tuning control code to claim energy savings associated with a central control lighting output based on tuning sensors. This control type is similar because it is not easily adjustable over time.
- If the fixture is installed with additional controls (e.g., occupancy sensor, daylighting), then it should be reported the same as above, unless the control system meets the requirements of networked lighting control (NLC).
- If the fixture is installed without adjustment, it should be reported at the maximum input wattage with no control code.
- If the fixture is installed with no additional controls and the DLC certificate specifies a lower wattage setpoint, then it should be reported as the lower input wattage with no control code.
- For all cases, project documentation should include a screenshot of the DLC certificate and an example photo of the field-adjustable setpoint.

**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 energy and power adjustment factors (EAF, PAF) are specified for occupancy sensors in Table 16.

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

## 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.

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<sup>60</sup> Per IECC 2015, C405.2 lighting controls are mandatory.

# 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).

$$Energy\ Savings\ [kWh] = kW_{controlled} \times EAF \times Hours \times HVAC_{energy}$$

**Equation 5**

$$Summer\ Peak\ Demand\ Savings\ [kW] = kW_{controlled} \times PAF \times CF_S \times HVAC_{demand}$$

**Equation 6**

Where:

- $kW_{controlled}$  = Total kW of controlled fixtures (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)
- Hours = Hours by building type from Table 9
- EAF = Lighting control Energy Adjustment Factor (see Table 16)
- PAF = Lighting control Power Adjustment Factor (see Table 16)
- $CF_S$  = Summer peak coincidence factor by building type (see Table 10)
- $HVAC_{energy}$  = Energy Interactive HVAC factor by building type (see Table 12)
- $HVAC_{demand}$  = Demand Interactive HVAC factor by building type (see Table 12)

See Section 2.1.1 of this volume for a full explanation of the non-control variables and their corresponding values. The lighting controls EAFs and PAFs for different building types are presented in Table 16. The EAF and PAF 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 EAF and PAF factors due to the lack of published data for coincidence factors.

**Table 15. Lighting Controls—Control Definitions**

Control type	Description
None	No control
Occupancy	Adjusting light levels according to the presence of occupants <ul style="list-style-type: none"> <li>• Wall- or ceiling-mounted occupancy sensors</li> <li>• Integrated fixture occupancy sensors</li> <li>• Time clocks</li> <li>• Energy management systems</li> </ul>

Control type	Description
Daylighting (indoor)	Adjusting light levels automatically in response to the presence of natural light <ul style="list-style-type: none"> <li>• Photosensors</li> </ul>
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 <ul style="list-style-type: none"> <li>• Dimmers</li> <li>• Wireless ON/OFF switches</li> <li>• Personal computer-based controls</li> <li>• Pre-set scene selection</li> </ul>
Institutional tuning	Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants <ul style="list-style-type: none"> <li>• Dimmable ballasts</li> <li>• ON/OFF or dimmer switches for non-personal tuning</li> <li>• Field adjustable light output</li> </ul>
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 16. Lighting Controls—Energy and Power Adjustment Factors<sup>61</sup>**

Control type	Control codes	CAF	
		Retrofit	NC <sup>62</sup>
None	None	0.00	0.00
Occupancy	OS	0.24	0.00
Continuous daylighting (indoor)	DL	0.28	0.04
Outdoor <sup>63</sup>	Outdoor	0.00	0.00

<sup>61</sup> 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://eta.lbl.gov/publications/meta-analysis-energy-savings-lighting#:~:text=Based%20on%20the%20meta%20analysis,and%2038%25%20for%20multiple%20approaches>.

<sup>62</sup> NC CAFs are derived by deducting the OS CAF from the equivalent retrofit CAF value.

<sup>63</sup> 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.

Control type	Control codes	CAF	
		Retrofit	NC <sup>62</sup>
Personal tuning	PT	0.31	0.07
Institutional tuning	IT	0.36	
Networked lighting control	NLC <sup>64</sup>	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.

## Measure Life and Lifetime Savings

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

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

- Retrofit sensors and controls: 10 years
- New construction interior fixtures/controls<sup>67</sup>: 14 years

<sup>64</sup> “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.

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

<sup>66</sup> 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. <http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures>.

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

## 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 code<sup>68</sup>
- Lighting control mount type: wall, ceiling, integrated fixture, etc.
- Lighting control equipment specification sheets
- 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

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<sup>68</sup> 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.



## References and Efficiency Standards

### Petitions and Rulings

- “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings.” Williams, Alison, Atkinson, Barbara, Barbese, 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 17. Lighting Controls—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v2.1	01/30/2015	TRM v2.1 update. 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.
v3.0	04/10/2015	TRM v3.0 update. 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	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. 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	TRM v6.0 update. Revised multiple/combined control types EAF and PAF.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Added eligibility criteria for new construction applications.

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 update. Added guidance for field adjustable lights. Clarified baseline controls for new construction projects.
v11.0	10/2023	TRM v11.0 update. 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.

## 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.

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

Equation 7

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

Equation 8

Where:

$kW_{\text{fixture}}$  = Total kW of controlled fixture (approved baseline fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity)<sup>69</sup>

AOH = Hours by outdoor application (see Table 18)

$CF_{S/W}$  = Seasonal peak coincidence factor by outdoor application and climate zone (see Table 19)

**Table 18. Exterior Photocell Repair—Annual Operating Hours by Outdoor Application**

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

<sup>69</sup> Look up approved fixture wattage from the Standard Fixture Wattage Table.

<http://texasefficiency.com/index.php/regulatory-filings/lighting>.

<sup>70</sup> “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.

<sup>71</sup> Ibid.

<sup>72</sup> 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](https://aa.usno.navy.mil/data/RS_OneYear).

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

**Table 19. Exterior Photocell Repair—Winter Peak Coincidence Factors by Outdoor Application<sup>74,75</sup>**

Building type	Summer peak CF	Winter peak CF				
	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 <sup>76</sup>	0.00	0.26	0.27	0.24	0.29	0.38
Outdoor: Billboard <sup>77</sup>	0.00	0.59	0.62	0.53	0.65	0.87
Outdoor: Dusk-to-dawn <sup>78</sup>	0.00	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn <sup>79</sup>	0.00	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.<sup>80</sup> 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.

<sup>74</sup> 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.

<sup>75</sup> Summer coincidence factor is set to zero for all exterior lighting applications.

<sup>76</sup> “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.

<sup>77</sup> Ibid.

<sup>78</sup> 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](https://aa.usno.navy.mil/data/RS_OneYear).

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

<sup>80</sup> 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 20. Exterior Photocell Repair—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. 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 standard<sup>81</sup>, 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.

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<sup>81</sup> 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](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12).

**Table 21. LED Traffic Signals—Federal Standard Maximum Wattages<sup>82</sup> and Nominal Wattages<sup>83</sup>**

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.

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

**Equation 9**

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

**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 22

$CF_S$  = Summer peak coincidence factor from Table 22

<sup>82</sup> 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.

<sup>83</sup> 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 22. LED Traffic Signals—Savings Calculation Input Assumptions<sup>84</sup>**

Fixture type	Incandescent wattage	LED wattage	AOH	CF <sub>s</sub> <sup>85</sup>
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 23. 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 24. LED Traffic Signals—EULs by Fixture Type<sup>86</sup>**

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.

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<sup>84</sup> 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/>.

<sup>85</sup> 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.

<sup>86</sup> 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 25. LED Traffic Signals—Revision History**

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. General reference checks and text edits.
v11.0	10/2023	TRM v11.0 update. 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:** See Table 34 through Table 40

**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.

### Air Conditioner Inspection and Tune-up Checklist<sup>87</sup>

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

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<sup>87</sup> Based on ENERGY STAR® HVAC Maintenance Checklist.  
[www.energystar.gov/index.cfm?c=heat\\_cool.pr\\_maintenance](http://www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance).

- Clean indoor blower fan components
- 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 refrigerant level and adjust to manufacturer 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.<sup>88</sup> 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

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:

$$EER_{pre} = \text{Efficiency of the cooling equipment before tune-up [Btuh/W]}$$

<sup>88</sup> 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>.

$EL$	=	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 26)
$HSPF_{pre}$	=	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 26)

**Table 26. AC/HP Tune-Ups—Default EER and HSPF per Size Category<sup>89</sup>**

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  $\pm 3$  degrees of target sub-cooling for units with thermal expansion valves (TXV) and  $\pm 5$  degrees of target super heat for units with fixed orifices or capillary tubes.

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 HSPF<sup>90</sup>, and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER<sup>91</sup> 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  $HSPF = 3.412 \times COP$ .

<sup>89</sup> 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  $\geq 65,000$  Btu/hr).  $HSPF = COP \times 3.412$ .

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

<sup>91</sup> 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." U.S. Department of Energy. Revised October 2010. <http://www.nrel.gov/docs/fy11osti/49246.pdf>.

## **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.<sup>92</sup>

Heating energy savings are only applicable to heat pumps.

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

**Equation 13**

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

**Equation 14**

$$\text{Heating Energy Savings [kWh}_H] = \text{Cap}_H \times \left( \frac{1}{\text{HSPF}_{pre}} - \frac{1}{\text{HSPF}_{post}} \right) \times \text{EFLH}_H \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

**Equation 15**

Where:

$\text{Cap}_C$  = Rated cooling/heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)

$\text{EFLH}_{C/H}$  = Cooling/heating equivalent full-load hours for appropriate climate zone [hours]; see Table 36 through Table 40 in Section 2.2.2

### **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.

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

**Equation 16**

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

**Equation 17**

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

Where:

$CF_{S/W}$  = Summer/winter seasonal peak coincidence factor; see Table 36 through Table 40 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.<sup>93</sup>

## 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

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<sup>93</sup> 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.



- Cooling capacity of the serviced unit (tons)
- Heating capacity of the serviced unit, if applicable (tons)
- Recommended
  - Serial number
  - Refrigerant type
  - Target superheat or subcooling
  - Post-tune-up superheat or subcooling
  - Amount of refrigerant added or removed
  - Static pressures before and after a tune-up
  - Return and supply dry bulb and wet bulb temperatures
  - 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).

## **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 27. AC/HP Tune-Ups—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v4.0	10/10/2016	TRM v4.0 origin.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Clarified eligibility criteria.

## 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:** See Table 34 through Table 40

**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 36 through Table 40. Building type descriptions and examples are provided in Table 34 and Table 35.

- 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.<sup>94,95</sup>

## 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 28 through Table 32 according to the capacity, system type, and age (based on year manufactured) of the replaced system.<sup>96</sup> When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in

Table 28 through Table 32 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.<sup>97</sup> 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.

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

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

<sup>96</sup> 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.

<sup>97</sup> 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.

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

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 28 through Table 32 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 < 5.4 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.

Refer to TRM 9.0 for exempted HPs < 5.4 tons referencing the previous federal standard. Units with a SEER2 rating are expected to comply with the guidelines outlined in this measure.

For 5.4+ ton 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 11.3+ tons, 0.2 EER may be added for no heating.

**Table 28. 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)
≤ 2005	7.8	7.8	7.5	10.1	9.5	9.3	9.0
2006–2009	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 29. DX HVAC—ER Baseline Part-Load Efficiency for ACs<sup>98</sup>**

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)
≤ 2005	9.5	9.5	9.2	10.3	9.7	9.4	9.1
2006–2009	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 30. 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)
≤ 2005	7.8	7.5	10.1	9.3	9.0	9.0
2006–2009	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 31. DX HVAC—ER Baseline Part-Load Cooling Efficiency for HPs<sup>99</sup>**

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)
≤ 2005	9.5	9.2	10.3	9.5	9.1	9.1
2006–2009	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

<sup>98</sup> 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.

<sup>99</sup> 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 32. 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)
≤ 2005	5.7	5.6	3.2	3.1	3.1
2006–2009	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 33. 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 less than 65,000 Btu/hour (Btuh) (5.42 tons) and for units rated between 65,000-759,999 Btuh. 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 IECC 2015.<sup>100</sup>

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.

**Table 33. DX HVAC—NC/ROB Baseline Efficiency Levels<sup>101</sup>**

System type	Capacity (tons)	Baseline efficiencies	Source <sup>102</sup>
Air conditioner	Split < 3.75	11.7 EER2 14.3 SEER2	DOE Standards
	Split ≥ 3.75	11.2 EER2 13.8 SEER2	
	Packaged < 5.4 tons	10.9 EER2 <sup>103</sup> 13.4 SEER2	

<sup>100</sup> 2015 International Energy Conservation Code (IECC). <https://codes.iccsafe.org/content/IECC2015>.

<sup>101</sup> IECC 2015 Table C403.2.3(1) and C403.2.3(2).

<sup>102</sup> These 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.

<sup>103</sup> Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER.

System type	Capacity (tons)	Baseline efficiencies	Source <sup>102</sup>
	All < 5.4 tons rated at $\geq 15.2$ SEER2	9.8 EER2 <sup>104</sup>	
	5.4 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	
	$\geq 63.3$	9.5 EER 11.0 IEER	IECC 2015
Heat pump (cooling) <sup>105</sup>	Split < 5.4	11.7 EER2 14.3 SEER2	DOE Standards
	Packaged < 5.4	10.9 EER2 <sup>106</sup> 13.4 SEER2	
	All < 5.4 tons rated at $\geq 15.2$ SEER2	9.8 EER2 <sup>107</sup>	
	5.4 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

<sup>104</sup> 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.

<sup>105</sup> 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”.

<sup>106</sup> 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.

<sup>107</sup> 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 <sup>102</sup>
Heat pump (heating) <sup>108</sup>	Split < 5.4	7.5 HSPF2	DOE Standards
	Packaged < 5.4	6.7 HSPF2	
	5.4 to < 11.25	3.3 COP	DOE Standards
	<u>11.3 to &lt; 20</u>	3.3 COP	
	≥ 20	3.2 COP	IECC 2015

## High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 33. Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired 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 STAR<sup>®109</sup> and the Consortium for Energy Efficiency (CEE)<sup>110</sup> 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:<sup>111</sup>

- For ER projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling 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 within ± 20 percent. 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.

<sup>108</sup> Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

<sup>109</sup> ENERGY STAR Heating & Cooling, [https://www.energystar.gov/products/heating\\_cooling](https://www.energystar.gov/products/heating_cooling).

<sup>110</sup> CEE Program Resources, <http://www.cee1.org/content/cee-program-resources>.

<sup>111</sup> From PUCT Docket #41070.



- 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**

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

**Equation 18**

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

**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 will 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 33) [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 33) [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  $\geq 5.4$  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 36 through Table 40)
- $EFLH_{C/H}$  = Cooling/heating equivalent full-load hours [hours] (see Table 36 through Table 40)

### **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 34 and Table 35. These building types are derived from the EIA CBECS study.<sup>112</sup>

The CF and EFLH values for packaged and split AC and HP units are presented in Table 36 through Table 40.

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

**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.

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<sup>112</sup> 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/>.

**Table 34. DX HVAC—Building Type Descriptions and Examples**

Building type	Principal building activity	Definition	Detailed business type examples <sup>113</sup>
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.	1) College or university 2) Career or vocational training 3) Adult education
	Primary school	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) Elementary or middle school 2) Preschool or daycare
	Secondary school		1) High school 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
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.

<sup>113</sup> Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building type	Principal building activity	Definition	Detailed business type examples <sup>113</sup>
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 <sup>113</sup>
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	<ol style="list-style-type: none"> <li>1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center)</li> <li>2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports)</li> <li>3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club)</li> <li>4) Library</li> <li>5) Funeral home</li> <li>6) Student activities center</li> <li>7) Armory</li> <li>8) Exhibition hall</li> <li>9) Broadcasting studio</li> <li>10) Transportation terminal</li> </ol>
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.	<ol style="list-style-type: none"> <li>1) Vehicle service or vehicle repair shop</li> <li>2) Vehicle storage/maintenance</li> <li>3) Repair shop</li> <li>4) Dry cleaner or laundromat</li> <li>5) Post office or postal center</li> <li>6) Car wash</li> <li>7) Gas station with no convenience store</li> <li>8) Photo processing shop</li> <li>9) Beauty parlor or barber shop</li> <li>10) Tanning salon</li> <li>11) Copy center or printing shop</li> <li>12) Kennel</li> </ol>

Building type	Principal building activity	Definition	Detailed business type examples <sup>113</sup>
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 35. DX HVAC—Building Type Floor Area and Number of Floors<sup>114</sup>**

Building type	Principal building activity	Average floor area (ft <sup>2</sup> )	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

<sup>114</sup> 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 <sup>2</sup> )	Average number of floors
Public assembly	Public assembly	Not specified	Not specified
Religious worship	Religious worship	Not specified	Not specified
Service	Service: Excluding food	Not specified	Not specified
Warehouse	Warehouse	52,045	1

**Table 36. DX HVAC—CF and EFLH Values for Climate Zone 1: Amarillo**

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump <sup>115</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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

<sup>115</sup> 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 <sup>115</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 37. DX HVAC—CF and EFLH Values for Climate Zone 2: Dallas**

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump <sup>116</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
Data center	Data center	1.08	3,401	1.08	3,401	–	–
Education	College/university	1.02	1,595	1.02	1,595	–	–
	Primary school	0.88	1,208	0.88	1,208	0.66	397
	Secondary school	1.02	1,084	1.02	1,084	0.59	489
Food sales	Convenience store	1.08	1,835	1.08	1,835	–	–
	Supermarket	0.58	615	0.58	615	–	–
Food service	Full-service restaurant	1.09	1,823	1.09	1,823	0.50	688
	24-hour full-service restaurant	1.09	2,061	1.09	2,061	0.49	873
	Quick-service restaurant	1.08	1,588	1.08	1,588	0.61	631
	24-hour quick-service restaurant	1.08	1,765	1.08	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 multifamily	Midrise apartment	1.04	1,709	1.04	1,709	–	–

<sup>116</sup> 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 <sup>116</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
Lodging	Large hotel	0.70	2,079	0.70	2,079	0.82	464
	Nursing home	1.04	1,736	1.04	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	1.01	1,539	1.01	1,539	0.57	632
	Strip and enclosed mall	0.91	1,100	0.91	1,100	0.55	376
Office	Large office	1.03	2,379	1.03	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	1.09	1,412	1.09	1,412	–	–
Warehouse	Warehouse	0.84	597	0.84	597	–	–
Other	Other	0.55	567	0.55	567	0.28	153

**Table 38. DX HVAC—CF and EFLH Values for Climate Zone 3: Houston**

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump <sup>117</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
Data center	Data center	1.05	4,022	1.05	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	1.03	2,142	1.03	2,142	–	–
	Supermarket	0.60	744	0.60	744	–	–

<sup>117</sup> 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 <sup>117</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
Food service	Full-service restaurant	1.05	2,135	1.05	2,135	0.44	429
	24-hour full-service restaurant	1.06	2,426	1.06	2,426	0.44	559
	Quick-service restaurant	1.03	1,853	1.03	1,853	0.51	372
	24-hour quick-service restaurant	1.05	2,059	1.05	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	1.05	1,653	1.05	1,653	–	–
Warehouse	Warehouse	0.84	633	0.84	633	–	–
Other	Other	0.60	576	0.60	576	0.19	69

**Table 39. 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 <sup>118</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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	–	–
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

<sup>118</sup> 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.

**Table 40. 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 <sup>119</sup>			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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
	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

<sup>119</sup> 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.

## 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 41. Assumed values have been weighted based on building-type survey data from 2012 CBECS<sup>120</sup> and 2014 MECS<sup>121</sup>.

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 36 through Table 40. For program designs where the building type is unknown, you may use the savings coefficients from Table 41. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

**Table 41. DX HVAC—Upstream/Midstream Input Assumptions<sup>122</sup>**

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLH <sub>c</sub>	1,062	1,543	1,752	1,947	1,338
EFLH <sub>H</sub>	504	245	130	79	243
CF <sub>s</sub>	0.68	0.92	0.91	0.84	0.84
CF <sub>w</sub>	0.37	0.39	0.27	0.14	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.<sup>123</sup>

<sup>120</sup> 2012 Commercial Building Energy Consumption Survey (CBECS).

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

<sup>121</sup> 2014 Manufacturing Energy Consumption Survey (MECS).

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

<sup>122</sup> 2012 CBECS and 2014 MECS.

<sup>123</sup> 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 42. 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 42. DX HVAC—RUL of Early Retirement Systems<sup>124,125</sup>**

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 <sup>126</sup>	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

<sup>124</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>125</sup> 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 greyed out in the table and displayed for informational purposes only.

<sup>126</sup> RULs are capped at the 75<sup>th</sup> 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 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 and/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
- 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 43. DX HVAC—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. 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	TRM v2.1 update. Minor text updates and clarification of ER requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of 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	TRM v3.1 update. Update 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	TRM v4.0 update. 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	TRM v5.0 update. 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	TRM v6.0 update. 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	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. 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	TRM v9.0 update. 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	TRM v10.0 update. Added additional guidance for selection of building types for complex projects. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. 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.

### 2.2.3 HVAC Chillers Measure Overview

**TRM Measure ID:** NR-HV-CH

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 57 through Table 61.

**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:<sup>127</sup>

- 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 57 through Table 61. Building type descriptions and examples are provided in Table 34 and Table 35.
- 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.

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<sup>127</sup> 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

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.<sup>128, 129</sup>

## 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 44 through Table 55 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.<sup>130</sup> When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 44 through Table 55 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,<sup>131</sup> 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  $\leq 2001$  rather than 1990-2001.

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<sup>128</sup> Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

<sup>129</sup> Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

<sup>130</sup> 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.

<sup>131</sup> IECC 2015 not enforced in Texas until program year 2018.

## ER Baseline: Air-Cooled Chillers

**Table 44. Chillers—Air-Cooled Path A ER Baseline Full-Load Efficiency<sup>132</sup>**

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	<i>9.212</i>	<i>9.212</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
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 45. Chillers—Air-Cooled Path B ER Baseline Full-Load Efficiency<sup>133</sup>**

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	<i>9.212</i>	<i>9.212</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
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 46. Chillers—Air-Cooled Path A ER Baseline Part-Load Efficiency (IPLV)<sup>134</sup>**

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	<i>9.554</i>	<i>9.554</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
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

<sup>132</sup> 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.

<sup>133</sup> Ibid.

<sup>134</sup> Ibid.

**Table 47. Chillers—Air-Cooled Path B ER Baseline Part-Load Efficiency (IPLV)<sup>135</sup>**

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

**ER Baseline: Centrifugal Water-Cooled Chillers**

**Table 48. Chillers—Water-Cooled Centrifugal Path A ER Baseline Full-Load Efficiency<sup>136</sup>**

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 49. Chillers—Water-Cooled Centrifugal Path B ER Baseline Full-Load Efficiency<sup>137</sup>**

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

<sup>135</sup> Ibid.

<sup>136</sup> Ibid.

<sup>137</sup> Ibid.

**Table 50. Chillers—Water-Cooled Centrifugal Path A ER Baseline Part-Load Efficiency (IPLV)<sup>138</sup>**

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

**Table 51. Chillers—Water-Cooled Centrifugal Path B ER Baseline Part-Load Efficiency (IPLV)<sup>139</sup>**

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 52. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Full-Load Efficiency<sup>140</sup>**

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

<sup>138</sup> Ibid.

<sup>139</sup> Ibid.

<sup>140</sup> Ibid.



**Table 53. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Full-Load Efficiency<sup>141</sup>**

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

**Table 54. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Part-Load Efficiency (IPLV)<sup>142</sup>**

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 55. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Part-Load Efficiency (IPLV)<sup>143</sup>**

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 56, 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-

<sup>141</sup> Ibid.

<sup>142</sup> Ibid.

<sup>143</sup> Ibid.

load efficiency conditions in the energy and demand savings algorithms.<sup>144</sup> 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.

**Table 56. Chillers—NC/ROB Baseline Efficiencies<sup>145</sup>**

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 56 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:<sup>146</sup>

- For early retirement projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling 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

<sup>144</sup> 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).

<sup>145</sup> IECC 2015 Table C403.2.3(7).

<sup>146</sup> From PUCT Docket #41070.

pre- and post-capacities for the total combination of systems are within  $\pm 20$  percent. 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, 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***

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

**Equation 24**

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

**Equation 25**

Where:

$\text{Cap}_{C,pre}$	=	<i>For ER, rated equipment cooling capacity of the existing equipment at AHRI<sub>standard</sub> conditions; for ROB &amp; NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [tons]</i>
$\text{Cap}_{C,post}$	=	<i>Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions [tons]</i>
$\eta_{baseline}$	=	<i>Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/ton] – default values, based on system type, are given in Table 44 through Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]</i>
$\eta_{installed}$	=	<i>Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]</i>

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

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

**Equation 26**

$CF_s$	=	Summer peak coincidence factor (see Table 57 through Table 61)
$EFLH_c$	=	Cooling equivalent full-load hours [hours] (see Table 57 through Table 61)

### **Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment<sup>147</sup>**

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

<sup>147</sup> 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 57 through Table 61 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 34 and Table 35. These building types are derived from the EIA CBECS study.<sup>148</sup>

Deemed peak CF and EFLH values are presented by building type and climate zone for chillers in Table 57 through Table 61. 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 Other building type is used, 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 57. Chillers—CF and EFLH for Climate Zone 1: Amarillo**

Building type	Principal building activity	Chiller <sup>149</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
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
	Secondary school	0.70	802	0.58	1,772
Healthcare	Inpatient	0.70	2,006	0.65	2,711
Large multifamily	Midrise apartment	0.41	421	0.50	1,098

<sup>148</sup> 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/>.

<sup>149</sup> 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 <sup>149</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
Lodging	Large hotel	0.58	1,283	0.59	1,553
	Nursing home	0.41	428	0.50	1,115
Mercantile	Stand-alone retail	0.52	489	0.54	719
	24-hour retail	0.67	681	0.62	974
Office	Large 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 58. Chillers—CF and EFLH for Climate Zone 2: Dallas**

Building type	Principal building activity	Chiller <sup>150</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
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
Healthcare	Inpatient	0.90	2,784	0.81	3,683
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
Mercantile	Stand-alone retail	0.79	936	0.72	1,328
	24-hour retail	0.89	1,307	0.79	1,975
Office	Large 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

**Table 59. Chillers—CF and EFLH for Climate Zone 3: Houston**

Building type	Principal building activity	Chiller <sup>151</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
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

<sup>150</sup> Ibid.

<sup>151</sup> Ibid.

Building type	Principal building activity	Chiller <sup>151</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
Healthcare	Inpatient	0.85	3,116	0.79	4,171
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
Mercantile	Stand-alone retail	0.83	1,224	0.78	1,712
	24-hour retail	0.80	1,513	0.74	2,427
Office	Large 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 60. Chillers—CF and EFLH for Climate Zone 4: Corpus Christi**

Building type	Principal building activity	Chiller <sup>152</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
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
Healthcare	Inpatient	0.79	3,455	0.82	4,637
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
Mercantile	Stand-alone retail	0.75	1,394	0.76	1,953
	24-hour retail	0.70	1,725	0.73	2,768
Office	Large office	0.82	2,027	0.72	2,570
Public assembly	Public assembly	0.45	1,260	0.61	2,481
Religious worship	Religious worship	0.75	839	0.76	1,176
Other	Other	0.45	839	0.55	1,176

<sup>152</sup> Ibid.

**Table 61. Chillers—CF and EFLH for Climate Zone 5: El Paso**

Building type	Principal building activity	Chiller <sup>153</sup>			
		Air-cooled		Water-cooled	
		CF	EFLH <sub>c</sub>	CF	EFLH <sub>c</sub>
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
Healthcare	Inpatient	0.71	2,355	0.59	2,992
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
Mercantile	Stand-alone retail	0.64	722	0.55	948
	24-hour retail	0.61	884	0.60	1,371
Office	Large 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.

## Upstream/Midstream Lighting

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 CBECS<sup>154</sup> and 2014 MECS<sup>155</sup>.

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 57 through Table 61. For program designs where building type is unknown, you may use the savings coefficients from Table 62 and Table 63. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

<sup>153</sup> Ibid.

<sup>154</sup> 2012 Commercial Building Energy Consumption Survey (CBECS).  
<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

<sup>155</sup> 2014 Manufacturing Energy Consumption Survey (MECS).  
<https://www.eia.gov/consumption/manufacturing/>.



**Table 62. Chillers—Air-Cooled Upstream/Midstream Input Assumptions<sup>156</sup>**

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLHc	967	1,408	1,575	1,789	1,211
CFs	0.62	0.80	0.78	0.72	0.71

**Table 63. Chillers—Water-Cooled Upstream/Midstream Input Assumptions<sup>157</sup>**

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLHc	1,349	1,941	2,232	2,511	1,578
CFs	0.58	0.68	0.70	0.70	0.59

## Measure Life and Lifetime Savings

### *Estimated Useful Life (EUL)*

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years<sup>158</sup>
- Centrifugal chillers: 25 years.<sup>159</sup>

### *Remaining Useful Life (RUL)*

The RUL of replaced systems is provided according to system age in Table 64. 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.

<sup>156</sup> 2012 CBECS and 2014 MECS.

<sup>157</sup> Ibid.

<sup>158</sup> 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.

<sup>159</sup> PUCT Docket No. 40885, review of multiple studies looking at the lifetime of centrifugal chillers as detailed in petition workpapers.

**Table 64. Chillers—RUL of Early Retirement Systems<sup>160,161</sup>**

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
8	11.8	16.9	24 <sup>162</sup>	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 <sup>163</sup>	–	0.0
16	5.5	9.3			

<sup>160</sup> PUCT Docket No. 40885, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>161</sup> 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.

<sup>162</sup> RULs are capped at the 75<sup>th</sup> 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.

<sup>163</sup> Ibid.

## 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)
- 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 65. Chillers—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. 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	TRM v2.1 update. Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of savings method to allow for part-load efficiency calculations.
v3.1	11/05/2015	TRM v3.1 update. 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	TRM v4.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones.
v5.0	10/2017	TRM v5.0 update. 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	TRM v6.0 update. 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	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. 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	TRM v9.0 update. 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	TRM v10.0 update. Added guidance for redundant chiller configurations. Incremented RUL table for code compliance.
v11.0	10/2022	TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.

## 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 Table 70 through Table 74

**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 in<sup>2</sup>. 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 in<sup>2</sup>.

**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.<sup>164,165</sup>

## 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.<sup>166</sup> When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 66, 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.

When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years.<sup>167</sup> A default RUL may be used exclusively if applied consistently for all

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<sup>164</sup> Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

<sup>165</sup> Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

<sup>166</sup> 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.

<sup>167</sup> 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

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 66. PTAC/PTHPs—ER Baseline Efficiency Levels for Standard Size Units<sup>168</sup>**

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 67 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.

**Table 67. PTAC/PTHPs—NC/ROB Baseline Efficiency Levels<sup>169,170</sup>**

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTAC	Standard Size	<7,000	11.9	–
		7,000-15,000	$14.0 - (0.300 \times \text{Cap}/1,000)$	–
		>15,000	9.5	–

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.

<sup>168</sup> 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.

<sup>169</sup> IECC 2015 Table C403.2.3(3).

<sup>170</sup> 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.



Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
	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 68 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 68. SPVAC/SPVHPs—NC/ROB Baseline Efficiency Levels<sup>171</sup>**

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

Table 69 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.<sup>172</sup>

<sup>171</sup> Table 11 to 10 CFR 431.97.

<sup>172</sup> Current DOE minimum efficiency standard for residential room air conditioners.

<https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057>.

**Table 69. Room ACs—NC/ROB Baseline Efficiency Levels<sup>173</sup>**

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 67 and Table 69.

The high-efficiency retrofits must also meet the following criteria:<sup>174</sup>

- For early retirement projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling 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 within ± 20 percent. 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

<sup>173</sup> Direct final rule for new Room Air Conditioner Standards was published on April 21<sup>st</sup>, 2011 (76 FR 22454), effective August 19<sup>th</sup>, 2011, and are required starting June 1<sup>st</sup>, 2014. These are found in 10 CFR Part 430.

<sup>174</sup> Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend Early Retirement to cover PTAC/PTHP.

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**

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

**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**

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

**Equation 35**

Where:

$\text{Cap}_{C/H,pre}$	=	<i>For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions; for ROB &amp; NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [BTUH]; 1 ton = 12,000 Btuh</i>
$\text{Cap}_{C/H,post}$	=	<i>Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh</i>
$\eta_{baseline,C}$	=	<i>Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 66 through Table 69)</i>

$\eta_{baseline,H}$	=	Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 66 and Table 67) <sup>175</sup>
$\eta_{installed,C}$	=	Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]—(Must exceed minimum federal standards found in Table 67 and Table 69) <sup>176</sup>
$\eta_{installed,H}$	=	Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 67)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 36 through Table 40)
$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours [hours] (see Table 70 through Table 74)

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 70 through Table 74 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.

<sup>175</sup> Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.

<sup>176</sup> Ibid.

**Table 70. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 1: Amarillo**

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 71. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 2: Dallas**

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 72. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 3: Houston**

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 73. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 4: Corpus Christi**

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 74. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 5: El Paso**

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>s</sub>	EFLH <sub>c</sub>	CF <sub>w</sub>	EFLH <sub>H</sub>
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 Lighting

For upstream/midstream program delivery, use the EFLH and CF assumptions from Table 75. Assumed values have been weighted based on building type survey data from 2012 CBECS<sup>177</sup> and 2014 MECS<sup>178</sup>.

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 70 through Table 74. For program designs where building type is unknown, you may use the savings coefficients from Table 75. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

**Table 75. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—Upstream/Midstream Input Assumptions<sup>179</sup>**

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLH <sub>c</sub>	1,019	1,661	1,774	1,916	1,562
EFLH <sub>H</sub>	247	193	40	46	176
CF <sub>s</sub>	0.55	0.78	0.68	0.60	0.73
CF <sub>w</sub>	0.43	0.52	0.23	0.14	0.12

<sup>177</sup> 2012 Commercial Building Energy Consumption Survey (CBECS).

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

<sup>178</sup> 2014 Manufacturing Energy Consumption Survey (MECS).

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

<sup>179</sup> 2012 CBECS and 2014 MECS.



## Measure Life and Lifetime Savings

### ***Estimated Useful Life (EUL)***

The EUL of PTAC/PTHP units is 15 years, as specified in DEER 2014.<sup>180</sup>

The EUL of SPVAC/SPVHP units is 15 years, as determined by the DOE in its September 2015 final rule.<sup>181</sup>

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.<sup>182</sup>

### ***Remaining Useful Life (RUL) for PTAC/PTHP Systems***

The RUL of ER replaced systems is provided according to system age in Table 76.

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 76. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement Standard Size PTACs<sup>183,184</sup>**

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

<sup>180</sup> <http://www.deeresources.com/>

<sup>181</sup> 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>

<sup>182</sup> Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. <https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013>.

<sup>183</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>184</sup> 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	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 <sup>185</sup>	0.0

**Table 77. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement Standard Size PTHPs<sup>186,187</sup>**

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 <sup>188</sup>	0.0

<sup>185</sup> RULs are capped at the 75<sup>th</sup> 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.

<sup>186</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>187</sup> Current federal standard effective date is 10/8/2012. 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.

<sup>188</sup> RULs are capped at the 75<sup>th</sup> 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.

## 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
- **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 78. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated EUL 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	TRM v2.1 update. Corrections to energy and demand coefficients for heat pumps in Climate Zone 3 (Houston).
v3.0	04/10/2015	TRM v3.0 update. 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.
v3.1	11/05/2015	TRM v3.1 update. Added updated building type definitions and descriptions, minor updates to text for clarification and consistency.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. 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	TRM v6.0 update. Revised early retirement criteria for systems with an overall capacity change.

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 update. Revised early retirement criteria for systems with an overall capacity change. Added clarification for PTHPs replacing PTACs with electric resistance heating. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. 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	TRM v9.0 update. 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	TRM v10.0 update. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. 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.

## 2.2.5 Computer Room Air Conditioners Measure Overview

**TRM Measure ID:** NR-HV-CR

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 80 and Table 81

**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 seasonal COP (SCOP). 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.<sup>189,190</sup>

## 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 projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

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

Baseline efficiency levels for CRACs are provided in Table 79. These baseline efficiency levels reflect the minimum efficiency requirements from IECC 2015, which uses the Sensible Coefficient of Performance (SCOP) as the standard efficiency metric.

Note: A new federal standard became effective August 1, 2023, with full compliance required by May 28, 2024. An update to the efficiency levels has been delayed to PY2025 to allow for sell-through.

**Table 79. CRACs—NC/ROB Baseline Efficiency Levels<sup>191</sup>**

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)	Source
Air conditioners, air-cooled	< 65,000	2.20 / 2.09	IECC 2015
	≥ 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	

<sup>189</sup> Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

<sup>190</sup> Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

<sup>191</sup> IECC 2015 Table C403.2.3(9)

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)	Source
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	
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	

## High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 33. 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***

Early retirement projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

## 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:

$Cap_{C,pre}$  = Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$Cap_{C,post}$  = Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

Note: 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]

$\eta_{installed,C}$  = Rated cooling efficiency of the newly installed equipment (SCOP)—(Must exceed ROB/NC baseline efficiency standards in Table 33) [SCOP]

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

$CF_s$  = Summer peak coincidence factor (see Table 81)

$EFLH_C$  = Cooling equivalent full-load hours [hours] (see Table 81)

## Early Retirement Savings

Early retirement projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

## Deemed Energy and Demand Savings Tables

Deemed coincident coincidence factor (CF) 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.<sup>192</sup>

The CF and EFLH values for CRAC units are presented in Table 81. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

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<sup>192</sup> 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 80. CRACs—Building Type Descriptions and Examples**

Building type	Principal building activity	Definition	Detailed business type examples <sup>193</sup>
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

**Table 81. CRACs—CF and EFLH Values**

Climate zone	Building type and principal building activity	CF <sub>s</sub>	EFLH <sub>c</sub>
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.<sup>194</sup>

### ***Remaining Useful Life (RUL)***

This section will not apply unless the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

<sup>193</sup> Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

<sup>194</sup> 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.

## **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 or county
- Baseline number of units
- Baseline equipment type
- Baseline equipment rated cooling capacity
- Installed number of units
- Installed equipment type
- Installed equipment rated cooling capacity
- Installed cooling efficiency ratings
- Installed manufacturer and model
- Installed 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	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed text referring to building types other than data centers.
v9.0	10/2021	TRM v9.0 update. Updated baseline table citation. Added capacity conversion from kW to Btu/hr.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Added reference to new standard and plan to incorporate in PY2025.

## 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<sup>195</sup>.

### 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).

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<sup>195</sup> 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.<sup>196</sup>

### Energy Savings Algorithms

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

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
- $\eta$  = 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 RPM<sup>197</sup>**

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

0.746 = Constant to convert from hp to kW

$kW/hp_{post}$  = Efficient kW per motor hp<sup>198</sup> = 0.27

<sup>196</sup> Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.

<sup>197</sup> For unlisted motor horsepower values, round down to the next lowest horsepower value.

<sup>198</sup> Oncor site data. Average kW/hp values are weighted by measure count.

$$hp_{post} = \text{Total efficient motor horsepower}$$

$$hours = \text{Annual operating hours} = 8,760$$

### **Demand Savings Algorithms**

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

**Equation 40**

Where:

$$CF_{S/W} = \text{Summer/winter seasonal peak coincidence factor} = 0.11^{199}$$

### **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.<sup>200</sup>

The EUL for HVAC VFD measure is 15 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.

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

<sup>199</sup> 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.

<sup>200</sup> 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>.

## **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**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	TRM v11.0 update. 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:** See Table 90 through Table 97

**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 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

Supply fans may not have variable pitch blades. Supply fans 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 process loads is 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.

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 will maintain a constant static pressure by adjusting fan speed and delivering the same amount of air as the baseline condition.

## 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 TMY3<sup>201</sup> 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 (see Table 85)</i>

The minimum flow rate is set to 60 percent cfm based on common design practice.<sup>202</sup> 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.<sup>203</sup>

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<sup>201</sup> 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>.

<sup>202</sup> 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%.

<sup>203</sup> ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

**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	Flow rate (%cfm)	60	100	1.18	16.92
	Dry bulb T (°F)	65	98.8		
Climate Zone 2	Flow rate (%cfm)	60	100	1.10	-11.43
	Dry bulb T (°F)	65	101.4		
Climate Zone 3	Flow rate (%cfm)	60	100	1.23	19.75
	Dry bulb T (°F)	65	97.6		
Climate Zone 4	Flow rate (%cfm)	60	100	1.25	-21.50
	Dry bulb T (°F)	65	96.9		
Climate Zone 5	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 data<sup>204</sup>
- $m$  = the slope of the relationship between WBT and cfm (see *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	Flow rate (%cfm)	40	100	3.98	-184.25
	Wet bulb T (°F)	56.3	71.4		
Climate Zone 2	Flow rate (%cfm)	40	100	2.99	-135.13
	Wet bulb T (°F)	58.5	78.6		
Climate Zone 3	Flow rate (%cfm)	40	100	2.95	-136.58
	Wet bulb T (°F)	59.9	80.2		

<sup>204</sup> 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>.

Climate zone	Condition	Minimum	Maximum	Slope (m)	Intercept (b)
Climate Zone 4	Flow rate (%cfm)	40	100	2.92	-137.43
	Wet bulb T (°F)	60.8	81.3		
Climate Zone 5	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.<sup>205</sup> 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.<sup>206</sup>

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.<sup>207</sup> 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.<sup>208</sup>

<sup>205</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.240, cooling tower minimum speed default.

<sup>206</sup> ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Evaporation WB

<sup>207</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

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

**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	Flow rate (%GPM)	10	100	2.66	163.08
	Dry bulb T (°F)	65	98.8		
Climate Zone 2	Flow rate (%GPM)	10	100	2.47	-150.71
	Dry bulb T (°F)	65	101.4		
Climate Zone 3	Flow rate (%GPM)	10	100	2.77	169.45
	Dry bulb T (°F)	65	97.6		
Climate Zone 4	Flow rate (%GPM)	10	100	2.82	-173.39
	Dry bulb T (°F)	65	96.9		
Climate Zone 5	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.<sup>209</sup> 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.<sup>210</sup>

<sup>209</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

<sup>210</sup> 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 ( <i>m</i> )	Intercept ( <i>b</i> )
Climate Zone 1	Flow rate (%GPM)	10	100	-1.66	117.93
	Dry bulb T (°F)	65	10.8		
Climate Zone 2	Flow rate (%GPM)	10	100	-2.16	150.63
	Dry bulb T (°F)	65	23.4		
Climate Zone 3	Flow rate (%GPM)	10	100	-2.68	184.11
	Dry bulb T (°F)	65	31.4		
Climate Zone 4	Flow rate (%GPM)	10	100	2.96	202.43
	Dry bulb T (°F)	65	34.6		
Climate Zone 5	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:<sup>211</sup>

$$\%power_{i,OutletDamper} = 0.00745 \times \%CFM_i^2 + 0.10983 \times \%CFM_i + 20.41905$$

**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 1 for each hour where %power is less than 1 for the other baseline control types. When %power exceeds 1 for the other baseline control types, %power for no fan control is set equal to the maximum value from the other baseline control types.

<sup>211</sup> [https://focusonenergy.com/sites/default/files/Focus%20on%20Energy\\_TRM\\_January2015.pdf](https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf), page 225. Please note, the CFM<sup>2</sup> 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 pumps<sup>212</sup>:

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

**Equation 49**

### VFD Technology

For AHU supply fan<sup>213</sup>:

$$\%power_{VFD} = 0.00004 \times \%CFM_i^3 + 0.00766 \times \%CFM_i^2 - 0.19567 \times \%CFM_i + 5.9$$

**Equation 50**

For cooling tower<sup>214</sup>:

$$\text{if } t_{wb_i} > t_{wb\_min}, \text{ then } \%power_{VFD} = 0.9484823 \times \%CFM_i^3 + 0.60556507 \times \%CFM_i^2 - 0.88567609 \times \%CFM_i + 0.33162901, \text{ otherwise } 0$$

**Equation 51**

For chilled water, hot water, and condenser pumps<sup>215</sup>:

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

**Equation 52**

Note: for all applications, baseline %power should use a minimum of zero.

**Step 3** - Calculate kW<sub>full</sub> 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:

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

**Equation 53**

<sup>212</sup> 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.

<sup>213</sup> [https://focusonenergy.com/sites/default/files/Focus%20on%20Energy\\_TRM\\_January2015.pdf](https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf), page 225.

<sup>214</sup> 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.

<sup>215</sup> 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).

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

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)<sup>216</sup>
- $kW_{full}$  = 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
- $\eta$  = 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 RPM<sup>217</sup>**

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
40	0.941
50	0.945
60	0.95

<sup>216</sup> Fan curves by control type are provided in the BPA ASD Calculator, <https://www.bpa.gov/-/media/Aep/energy-efficiency/industrial/Industrial-files/ASDCalculators>.

<sup>217</sup> For unlisted motor horsepower values, round down to the next lowest horsepower value.



Motor horsepower	Full load efficiency
75	0.95
100	0.954

**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. 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

$$(kW_i)_{\text{Saved}} = [(kW_i)_{\text{Baseline}} - (kW_i)_{\text{VFD}}] \times \text{schedule}_i$$

**Equation 55**

Where:

$\text{schedule}_i$  = 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<sup>218,219</sup>**

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
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
Education	8am–11pm	closed	4,884
Convenience store, service, strip mall	9am–10pm	9am–8pm (Saturday) 10am–7pm (Sunday)	5,298
Stand-alone retail, supermarket	8am–10pm	8am–11pm (Saturday) 10am–7pm (Sunday)	5,674

<sup>218</sup> 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](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.

<sup>219</sup> Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Restaurants	6am–2am	6am–2am	7,592
Warehouse	7am–7pm	closed	4,258
Assembly, worship	9am–11pm	9am–11pm	5,840
Other <sup>220</sup>	7am–7pm	closed	4,258

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:

$PDPF_i$  = 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. 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:

$Cooling_{EER}$  = 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:

$$Energy\ Savings\ [kWh] = \sum_{i=1}^{8,760} (kW_i \times schedule_i)$$

Equation 58

Where:

8,760 = Total of hours per year

<sup>220</sup> 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.

**Step 2** - Subtract the Annual kWh<sub>new</sub> from the Annual kWh<sub>baseline</sub> to get the Energy Savings:

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

Equation 59

## Deemed Energy and Demand Savings Tables<sup>221</sup>

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,160	1,101	1,071	1,047	1,122
Office—large, medium	724	682	659	641	695
Office—small	576	543	522	507	552
Education	633	596	577	561	606
Convenience store, service, strip Mall	677	637	614	599	649
Stand-alone retail, supermarket	728	685	661	644	698
Restaurants	995	941	913	892	959
Warehouse	548	516	496	481	526
Assembly, worship	751	707	684	668	720
Other	548	516	496	481	526
<b>Summer kW savings (kW per motor HP)</b>					
All building types	0.041	0.023	0.020	0.063	0.042

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,825	1,672	1,598	1,535	1,723
Office—large, medium	1,126	1,024	968	923	1,052
Office—small	894	813	766	727	834

<sup>221</sup> Data centers are covered in Section 2.2.6 Computer Room Air Handler Motor Efficiency.

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
Education	984	895	848	808	917
Convenience store, service, strip mall	1,046	950	897	859	976
Stand-alone retail, supermarket	1,128	1,025	967	925	1,052
Restaurants	1,556	1,420	1,352	1,298	1,462
Warehouse	850	773	727	690	794
Assembly, worship	1,164	1,057	1,003	961	1,086
Other	850	773	727	690	794
<b>Summer kW Savings (kW per Motor HP)</b>					
All building types	0.045	0.026	0.024	0.069	0.047

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388	345	325	307	359
Office—large, medium	237	209	194	182	217
Office—small	188	166	154	143	171
Education	207	183	170	159	189
Convenience store, service, strip mall	219	194	179	169	200
Stand-alone retail, supermarket	237	209	193	182	216
Restaurants	329	292	273	258	303
Warehouse	179	158	146	135	163
Assembly, worship	245	216	201	189	223
Other	179	158	146	135	163
<b>Summer kW savings (kW per motor HP)</b>					
All building types	0.009	0.009	0.005	0.011	0.013

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	3,302	3,034	2,905	2,794	3,125
Office—large, medium	2,038	1,856	1,757	1,677	1,907
Office—small	1,617	1,473	1,389	1,320	1,511
Education	1,780	1,622	1,540	1,468	1,663
Convenience store, service, strip mall	1,893	1,721	1,626	1,557	1,768
Stand-alone retail, supermarket	2,040	1,856	1,754	1,679	1,907
Restaurants	2,817	2,577	2,457	2,360	2,651
Warehouse	1,538	1,401	1,317	1,251	1,438
Assembly, worship	2,106	1,916	1,819	1,745	1,969
Other	1,538	1,401	1,317	1,251	1,438
<b>Summer kW savings (kW per motor HP)</b>					
All building types	0.033	0.004	0.027	0.088	0.025

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,124	1,528	1,883	2,070	1,389
Office—large, medium	704	972	1,196	1,314	901
Office—small	558	788	955	1,039	712
Education	610	869	1,054	1,143	784
Convenience store, service, strip mall	663	925	1,142	1,248	858
Stand-alone retail, supermarket	712	986	1,216	1,332	915
Restaurants	966	1,323	1,632	1,792	1,215
Warehouse	534	749	908	986	676

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
Assembly, worship	733	1,020	1,264	1,380	946
Other	534	749	908	986	676
<b>Summer kW savings (kW per motor HP)</b>					
All building types	0.097	0.041	0.170	0.175	0.216

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	778	1,154	1,339	1,482	1,050
Office—large, medium	564	775	882	968	735
Office—small	456	624	703	768	592
Education	491	683	768	843	647
Convenience store, service, strip mall	554	747	848	918	706
Stand-alone retail, supermarket	587	795	905	982	754
Restaurants	723	1,030	1,183	1,297	960
Warehouse	435	594	670	730	563
Assembly, worship	601	818	933	1,011	773
Other	435	594	670	730	563
<b>Summer kW savings (kW per motor HP)</b>					
All building types	0.0487	0.0183	0.0293	0.0920	0.0439

**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
<b>Energy savings (kWh per motor HP)</b>					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,298	912	721	610	1,038
Office—large, medium	774	536	418	338	606

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	609	423	328	266	473
Education	677	468	368	301	526
Convenience store, service, strip mall	706	482	375	306	558
Stand-alone retail, supermarket	764	526	410	335	606
Restaurants	1,086	756	598	500	863
Warehouse	579	402	309	251	449
Assembly, worship	791	544	426	351	630
Other	579	402	309	251	449
<b>Winter kW savings (kW per motor HP)</b>					
All building types	0.118	0.045	0.045	0.133	0.225

## 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.<sup>222</sup>

## 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)
- Climate zone or county
- Motor horsepower
- **For AHU supply fans only:** Baseline part-load control type (e.g., outlet damper, inlet damper, inlet guide vane, constant volume/no control).

<sup>222</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## 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	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. 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	TRM v4.0 update. Added reference for percent power and corrected signs for variables in Equation 50.
v5.0	10/2017	TRM v5.0 update. Updated deemed energy/demand tables for revised peak demand definition.
v6.0	10/2018	TRM v6.0 update. 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	TRM v7.0 update. Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Added motor efficiency default assumptions.
v9.0	10/2021	TRM v9.0 update. Expanded available building types and updated occupancy schedules.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2021	TRM v11.0 update. 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.



## 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:** See Table 100 through Table 104

**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 Conditions<sup>223</sup>**

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**

$$Peak\ Demand\ Savings\ [kW] = (Cap_C \times \eta_C) \times DRF$$

**Equation 61**

<sup>223</sup> 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

$\eta_c$  = 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

Deemed peak demand reduction factor (DRF) and equivalent full-load hour reduction ( $EFLH_{reduction}$ ) 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 34. These building types are derived from the EIA CBECS study.<sup>224</sup>

The DRF and  $EFLH_{reduction}$  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 DRF and  $EFLH_{reduction}$  values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a

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<sup>224</sup> 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.*

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.

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 <sub>red</sub>	CF	EFLH <sub>red</sub>
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

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH <sub>red</sub>	CF	EFLH <sub>red</sub>
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 <sub>red</sub>	CF	EFLH <sub>red</sub>
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 <sub>red</sub>	CF	EFLH <sub>red</sub>
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
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 <sub>red</sub>	CF	EFLH <sub>red</sub>
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

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH <sub>red</sub>	CF	EFLH <sub>red</sub>
Food sales	Convenience store	0.14	188	-	-
	Supermarket	0.08	74	-	-
Food service	Full-service restaurant	0.13	157	-	-
	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 <sub>red</sub>	CF	EFLH <sub>red</sub>
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	-	-

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	EFLH <sub>red</sub>	CF	EFLH <sub>red</sub>
Healthcare	Inpatient	0.26	273	0.20	247
	Outpatient	0.23	259	-	-
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.<sup>225</sup>

<sup>225</sup> 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](https://wcec.ucdavis.edu/wp-content/uploads/2016/06/et13sce1020_evaporative_pre-cooler_final.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.

- Decision/action type: Retrofit or new construction
- 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	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Specified that formulas use tons and kW/ton values and added conversion factors from other units.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

## 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:** 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

While many applications exist for HVLS fans, the guidance in this measure is specific to agricultural operations. Savings estimates may be developed for other applications in future iterations of the TRM.

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.<sup>226</sup> 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.

## 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**

$$\text{Energy Savings}[kWh] = \left( \frac{W_{base} - W_{HVLS}}{1,000} \right) \times \text{Hours}$$

Equation 63

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<sup>226</sup> 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](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>.

$$\text{Peak Demand Savings [kW]} = \left( \frac{W_{\text{base}} - W_{\text{HVLS}}}{1,000} \right) \times CF_S$$

**Equation 64**

Where:

$W_{\text{base}}$	=	Power input required to move replaced fans at rated speed
$W_{\text{HVLS}}$	=	Power input required to move installed HVLS fans at rated speed
Hours	=	Hours of operation in the project application, as described below
$CF_S$	=	Summer peak coincidence factor = 1.0, as fans are always operating in summer peak conditions
1,000	=	Constant to convert from W to kW

### **Retrofit (Early Retirement)**

For early retirement projects, the base wattage ( $W_{\text{base}}$ ) is estimated according to the number of fans replaced and their rated efficiency:

$$W_{\text{base,ER}} = \frac{CFM_{\text{base}} * N_{\text{base}}}{\eta_{\text{base}}}$$

**Equation 65**

Where:

$CFM_{\text{base}}$	=	Airflow rate produced by replaced fans
$\eta_{\text{base}}$	=	Efficacy of replaced fans (CFM/watt)

Note: For retrofit projects where the baseline equipment ratings cannot be determined, the use of the replace-on-burnout/new construction calculation procedure is permitted.

### **Replace-on-Burnout/New Construction**

For replace-on-burnout or new construction projects, base case power requirements are estimated for conventional fans producing an equivalent/comparable airflow (CFM) as that of the HVLS fan(s) being installed. The efficiency of the baseline conventional fans shall be 22 CFM/watt.<sup>227</sup>

<sup>227</sup> 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, 230V circulating fans 48" diameter and larger. Available at <http://www.bess.illinois.edu/currentc.asp>.

$$W_{base,ROB/NC} = \frac{CFM_{HVLS}}{22 CFM/W}$$

Equation 66

## Hours of Operation

Table 106 provides the hours to be used in calculating energy savings for HVLS fan installation by climate zone.

**Table 106. HVLS Fans—Hours of Circulating Fan Operation by Barn Type<sup>228</sup>**

Climate zone	Hours
Climate Zone 1: Amarillo	2,215
Climate Zone 2: Dallas	3,969
Climate Zone 3: Houston	4,750
Climate Zone 4: Corpus Christi	5,375
Climate Zone 5: El Paso	3,034

## 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 #3<sup>229</sup> suggests motors should last approximately 35,000 hours. The average annual hours of operation in dairy farms for the Texas TRM zones is about 3,870 hours. Accordingly, the EUL for HVLS fans in Texas is estimated to be 9 years.

<sup>228</sup> 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 10/29/2012. An amended petition dated 11/13/2012 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).

<sup>229</sup> DOE Motor Systems Tip Sheet #3 available at [https://www.energy.gov/sites/prod/files/2014/04/f15/extend\\_motor\\_operlife\\_motor\\_systemts3.pdf](https://www.energy.gov/sites/prod/files/2014/04/f15/extend_motor_operlife_motor_systemts3.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.

### **All Projects:**

- Barn type (animal)
- Climate zone or county
- Decision/action type: ROB, NC, or ER
- HVLS fan(s): diameter, rated HP, rated CFM, count
- **For early retirement only:** replaced fans: count, diameter, rated HP, rated CFM, rated CFM/watt

## **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 107. HVLS Fans—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 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:** See Table 34 through Table 40

**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 33. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.



**Table 108. Evaporative Cooling—NC/ROB Baseline Efficiency Levels for DX AC<sup>230</sup>**

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source <sup>231</sup>
Packaged air conditioner	< 5.4	All	11.8 EER <sup>232</sup> 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 67**

$$\text{Energy Savings [kWh]} = Cap_C \times \frac{1}{\eta_{baseline,C}} \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times CRF$$

**Equation 68**

Where:

- $Cap_C$  = Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh<sup>233</sup>; 1 ton = 12,000 Btuh
- $\eta_{baseline,C}$  = Cooling efficiency of standard equipment (ROB/NC) [Btuh/W] (see Table 33)
- Note: Use EER for kW savings calculations and SEER for kWh savings calculations.
- $CF_S$  = Summer peak coincidence factor (see Table 40)
- $EFLH_C$  = Cooling equivalent full-load hours [hours] (see Table 40)
- $CRF$  = Consumption reduction factor<sup>234</sup> = 75%

<sup>230</sup> IECC 2015 Table C403.2.3(1) and C403.2.3(2).

<sup>231</sup> 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>.

<sup>232</sup> IECC 2015 Table C403.2.3(1) and C403.2.3(2).

<sup>233</sup> New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.

<sup>234</sup> 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 109. Evaporative Cooling—CF and EFLH Values for Climate Zone 5: El Paso**

Building type	Principal building activity	DX AC	
		CF <sub>s</sub>	EFLH <sub>c</sub>
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 <sub>s</sub>	EFLH <sub>c</sub>
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.<sup>235</sup>

## 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

<sup>235</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

- **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 110. Evaporative Cooling—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

## 2.2.11 Small Commercial Smart Thermostats Measure Overview

**TRM Measure ID:** NR-HV-ST

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 34 through Table 40

**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.<sup>236</sup>

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<sup>236</sup> 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)<sup>237</sup> 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.

$$\text{Total Energy Savings [kWh]} = kWh_c + kWh_H \quad \text{Equation 69}$$

$$\text{Cooling Energy Savings [kWh}_c\text{]} = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times EFLH_c \times CRF \times BAF \quad \text{Equation 70}$$

$$\text{Heating Energy Savings [kWh}_H\text{]} = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times EFLH_c \times HRF \times BAF \quad \text{Equation 71}$$

$$\text{Summer Peak Demand Savings [kW]} = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times CF_S \times CRF \times BAF \quad \text{Equation 72}$$

$$\text{Winter Peak Demand Savings [kW]} = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times CF_W \times HRF \times BAF \quad \text{Equation 73}$$

Where:

$CAP_{C/H}$	=	Controlled-HVAC rated cooling/heating capacity (Btuh) <sup>238</sup>
$\eta_{C/H}$	=	HVAC rated cooling/heating efficiency (see Table 33 for retrofit applications; use rated system efficiencies from AHRI or equivalent certification for new construction)

<sup>237</sup> ENERGY STAR QPL: <https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results>.

<sup>238</sup> Eligible cooling and heating capacity is capped at 10 tons (or 120,000 btu/hr).

Note: 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.<sup>239</sup>

$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours (see Table 36 through Table 40)
$CF_{S/W}$	=	Summer/winter coincidence factor (see Table 36 through Table 40)
$CRF$	=	Cooling reduction factor = 10% <sup>240</sup>
$HRF$	=	Heating reduction factor = 8% <sup>241</sup>
$BAF$	=	Baseline adjustment factor (1.0 for manual baseline, 0.6 for programmable and new construction baselines, and 0.8 for unknown baseline) <sup>242,243</sup>

## 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 36 through Table 40.

## 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.

<sup>239</sup> COP converted to HSPF using  $HSPF = COP \div 1,055 \text{ J/Btu} \times ,600 \text{ J/W-h} = COP \times 3.412$ .

<sup>240</sup> 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.

<sup>241</sup> Ibid.

<sup>242</sup> 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.

<sup>243</sup> 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.<sup>244</sup>

## 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, new construction)
- Baseline thermostat type (manual, programmable, unknown)
- Manufacturer
- Model number
- Quantity of newly installed thermostats
- Building type
- 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.

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<sup>244</sup> DEER READI. <http://www.deeresources.com/index.php/ready>.



## Document Revision History

**Table 111. Smart Thermostats—Revision History**

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. 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.<sup>245</sup> Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification.<sup>246</sup> 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 less<sup>247</sup>

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<sup>245</sup> ENERGY STAR Roof Products Sunset Decision Memo.  
<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf>.

<sup>246</sup> ENERGY STAR Program Requirements for Roof Products v2.1.  
[https://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/roofs\\_prog\\_req.pdf](https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf).

<sup>247</sup> 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)<sup>248,249</sup> and be listed on the CRRC Rated Roof Products Directory.<sup>250</sup> This is consistent with the former ENERGY STAR test criteria’s allowances for products already participating in the CRRC Product Rating program<sup>251</sup> 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.<sup>252</sup>

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 112. 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

<sup>248</sup> 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>.

<sup>249</sup> CRRC Roof Rating program. <https://coolroofs.org/programs/roof-rating-program>.

<sup>250</sup> CRRC Rated Roof Products Directory. <https://coolroofs.org/directory/roof>.

<sup>251</sup> CRRC Rated Products Directory: <https://coolroofs.org/directory>.

<sup>252</sup> Lawrence Berkeley National Lab Cool Roofing Material Database. <https://heatisland.lbl.gov/resources/cool-roofing-materials-database>.

## 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 113.

**Table 113. Cool Roofs—ENERGY STAR Specification<sup>253</sup>**

Roof slope	Characteristic	Performance specification
Low slope ≤ 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 115 through Table 119. 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.

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 74**

<sup>253</sup> ENERGY STAR Roof Products Specification.

[https://www.energystar.gov/products/building\\_products/roof\\_products/key\\_product\\_criteria](https://www.energystar.gov/products/building_products/roof_products/key_product_criteria).

$$\text{Summer Peak Demand Savings [kW]} = \text{Roof Area} \times CF_S \times 10^{-5}$$

**Equation 75**

$$\text{Winter Peak Demand Savings [kW]} = \text{Roof Area} \times CF_W \times 10^{-6}$$

**Equation 76**

Where:

- Roof Area* = Total area of ENERGY STAR roof (sq. ft.)
- ESF* = Energy savings factor from Table 115 through Table 119 by building type, pre-/post-insulation levels, and heating/cooling system
- CF<sub>S</sub>* = Peak summer coincidence factor from Table 115 through Table 119 by building type, pre-/post-insulation levels, and heating/cooling system
- CF<sub>W</sub>* = Peak winter coincidence factor from Table 115 through Table 119 by building type, pre/post insulation levels, and heating/cooling system

If the insulation levels are unknown, use the mapping in Table 114 to estimate the R-value based on the construction year.

**Table 114. Cool Roofs—Estimated R-Value Based on Construction Year**

Construction Year	Estimated R-value <sup>254</sup>
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

**Table 115. Cool Roofs—Savings Coefficients for Climate Zone 1: Amarillo**

Building type	Pre-R-value	Post R-value	ESF	CF <sub>S</sub>	CF <sub>W</sub>
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

<sup>254</sup> Estimates R-values are based on applicable code requirements in the construction year.

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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 116. Cool Roofs—Savings Coefficients for Climate Zone 2: Dallas**

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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
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
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 117. Cool Roofs—Savings Coefficients for Climate Zone 3: Houston**

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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 <sub>s</sub>	CF <sub>w</sub>
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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 118. Cool Roofs—Savings Coefficients for Climate Zone 4: Corpus Christi**

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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
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
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 119. Cool Roofs—Savings Coefficients for Climate Zone 5: El Paso**

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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	CFs	CFw
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF <sub>s</sub>	CF <sub>w</sub>
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.<sup>255</sup>

## 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
- New roof insulation R-value, if adding insulation
- New roofing initial solar reflectance
- New roofing three-year solar reflectance
- New roofing rated life

<sup>255</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

- 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 120. Cool Roofs—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Clarified that reflectance is three years basis. Rounded off values, too many insignificant digits.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. 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	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. 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	TRM v7.0 update. Minor error updates to Savings Factor Table for greater than and less than symbols. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Added building type to tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Changed eligibility criteria from strictly ENERGY STAR to CRRC certification.
v11.0	10/2023	TRM v11.0 update. No revision.

## 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 building types

**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 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 121). 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 more permanent shading devices.<sup>256</sup> They also do not prevent heat from entering the envelope in the space between the blinds and window. Therefore, windows with existing interior louvered or Venetian blinds are not excluded from using this measure.

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<sup>256</sup> “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 122.

## 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

$$\text{Demand Savings}_o \text{ [kW]} = \frac{A_{film,o} \times SHGF_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

**Equation 77**

$$\text{Peak Demand Savings [kW]} = \text{DemandSaving}_{o,max}$$

**Equation 78**

$$\text{Energy Savings}_o \text{ [kWh]} = \frac{A_{film,o} \times SHG_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

**Equation 79**

$$\text{Total Energy Savings [kWh]} = \sum \text{Energy Savings}_o$$

**Equation 80**

Where:

$\text{Demand Savings}_o$	=	Peak demand savings per window orientation
$\text{Energy Savings}_o$	=	Energy savings per window orientation
$A_{film,o}$	=	Area of window film applied to orientation [ft <sup>2</sup> ]
$SHGF_o$	=	Peak solar heat gain factor for orientation of interest [Btu/hr-ft <sup>2</sup> -year] (see Table 121)



$SHG_o$  = Solar heat gain for orientation of interest [Btu/ft<sup>2</sup>-year]  
(see Table 121)

$SHGC_{pre}$  = Solar heat gain coefficient for existing glass with no  
interior-shading device (see Table 122)

$SHGC_{post}$  = Solar heat gain coefficient for new film/interior-shading  
device, from manufacturer specs

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.<sup>257</sup>

COP = Cooling equipment coefficient of performance (COP)  
based on Table 123 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 121. Windows Treatments—Solar Heat Gain Factors<sup>258</sup>**

Orientation <sup>259</sup>	Solar heat gain (SHG) [Btu/ft <sup>2</sup> -year]	Peak hour solar heat gain (SHGF) [Btu/hr-ft <sup>2</sup> -year]				
		Climate Zone 1: Amarillo <sup>260</sup>	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

<sup>257</sup> 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

<sup>258</sup> 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 21<sup>st</sup> 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.

<sup>259</sup> N = North, S = South, E = East, and W = West.

<sup>260</sup> 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 122. Windows Treatments—Recommended Clear Glass SHGC<sub>pre</sub> by Window Thickness<sup>261</sup>**

Existing window configuration	Louvered Blinds	SHGC <sub>pre</sub>
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 <sup>262</sup>	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 123. Windows Treatments—Recommended COP by HVAC System Type<sup>263</sup>**

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.

<sup>261</sup> 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>.

<sup>262</sup> 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>.

<sup>263</sup> Based on review applicable codes, including IECC 2000, 2009, and 2015.

## 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.<sup>264</sup>

## 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 124. Windows Treatments—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Eliminated east-facing windows from consideration for energy savings.

<sup>264</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. 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	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Updated peak demand values for climate zones and PDPF values.
v9.0	10/2021	TRM v9.0 update. Corrected footnote for SC to SHGC conversion. Updated performance factors to 2017 ASHRAE Fundamentals. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Extended eligibility to windows with existing louvered or Venetian blinds. Added reduced baseline SHGC values for windows with louvered blinds.

### 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 building types

**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 weather stripping 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 1/8–3/4 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 weather stripping 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).<sup>265</sup> Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,<sup>266</sup> 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,  $\Delta p_s$ . The aggregate curve fit for Figure 5.1 is shown below where  $x$  is based on the dry bulb temperature from the TMY3 data, and the design temperature based on the appropriate seasonal condition.

$$\Delta p_s / C_d = 0.0000334003x - 0.00014468$$

**Equation 81**

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,  $\Delta p_w$ . 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 82**

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,  $\Delta p_{Total}$ :

$$\Delta p_{Total} = \Delta p_s + \Delta p_w$$

**Equation 83**

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<sup>265</sup> ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980.  
[http://portal.hud.gov/hudportal/documents/huddoc?id=doc\\_10603.pdf](http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf).

<sup>266</sup> 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](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf).

Solving for  $\Delta p_{Total}$  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 84**

$$Q/P_{1/4"} = 81.913x^{0.5063}$$

**Equation 85**

$$Q/P_{1/2"} = 164.26x^{0.5086}$$

**Equation 86**

$$Q/P_{3/4"} = 246.58x^{0.5086}$$

**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 126)
- $T_{avg\ outside\ ambient}$  = Average outside ambient temperature, specified by month [°F] (see Table 125)

**Table 125. Air Infiltration—Average Monthly Ambient Temperatures (°F)<sup>267</sup>**

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 126. Air Infiltration—Daytime and Nighttime Design Temperatures**

Temperature description	T <sub>design</sub> (°F)
Daytime cooling design temperature	74
Daytime heating design temperature	72
Nighttime cooling design temperature <sup>268</sup>	78
Nighttime heating design temperature <sup>269</sup>	68

## Savings Algorithms and Input Variables

To calculate HVAC load associated with air infiltration, the following sensible heat equation is used:

### Electric Cooling Energy Savings

$$\begin{aligned}
 & \text{Cooling Energy Savings [kWh]}_{\text{Day}} \\
 &= \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times \text{Hours}_{day}}{12,000 \text{ Btuh/ton}}
 \end{aligned}$$

**Equation 89**

<sup>267</sup> TMY3 climate data.

<sup>268</sup> Assuming four-degree setback.

<sup>269</sup> Ibid.



$$\begin{aligned} & \text{Cooling Energy Savings [kWh]}_{\text{Night}} \\ &= \frac{CFM_{\text{pre,night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{night}}}{12,000 \text{ Btuh/ton}} \end{aligned}$$

**Equation 90**

$$\begin{aligned} & \text{Cooling Energy Savings [kWh]} \\ &= \text{Cooling Energy Savings [kWh]}_{\text{Day}} + \text{Cooling Energy Savings [kWh]}_{\text{Night}} \end{aligned}$$

**Equation 91**

### **Electric Heating Energy Savings**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]}_{\text{Day}} \\ &= \frac{CFM_{\text{pre,day}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{day}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 92**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]}_{\text{Night}} \\ &= \frac{CFM_{\text{pre,night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{night}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 93**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]} \\ &= \text{Cooling Energy Savings [kWh]}_{\text{Day}} + \text{Cooling Energy Savings [kWh]}_{\text{Night}} \end{aligned}$$

**Equation 94**

### **Electric Cooling Demand Savings (weighted by climate zone peak hour probability)**

$$\text{Summer Peak Demand Savings [kW]}_{\text{Day}} = \frac{CFM_{\text{pre,day}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}}}{12,000 \text{ Btuh/ton}}$$

**Equation 95**

### **Electric Heating Demand Savings (weighted by climate zone peak hour probability)**

$$\begin{aligned} & \text{Winter Peak Demand Savings [kW]}_{\text{Day/Night}} \\ &= \frac{CFM_{\text{pre,day/night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 96**

Where:

- $CFM_{pre}$  = Calculated pre-retrofit air infiltration (cubic feet per minute)
- $CFM_{reduction}$  =  $59\%^{270} \times TDF$
- $TDF$  = Technical degradation factor =  $85\%^{271}$
- 1.08 = Sensible heat equation conversion<sup>272</sup>
- $\Delta T$  = 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 linear foot of installed weather stripping or door sweep are specified below based on climate zone and existing door gap width. The length measurement should be initially measured to the nearest ¼ inch and converted to linear feet rounded to hundredths (0.02) including any segments that are not sealed due to corners, hinges, handles, or other obstructions. The width of the door gap should be rounded to nearest gap width in inches in Table 127 through Table 132. 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.

**Table 127. Air Infiltration—Cooling Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	1.90	3.83	7.60	11.42
Climate Zone 2: Dallas	3.90	7.88	15.65	23.49
Climate Zone 3: Houston	3.01	6.09	12.09	18.14
Climate Zone 4: Corpus Christi	5.00	10.08	20.03	30.06
Climate Zone 5: El Paso	2.81	5.69	11.28	16.93

<sup>270</sup> CLEARResult, “Commercial Door Air Infiltration Memo”. March 18, 2015. Average reduction in Arkansas based on test results from the CLEARResult Brush Weather Stripping Testing Method and Results (59% infiltration reduction).

<sup>271</sup> 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.

<sup>272</sup> 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

**Table 128. Air Infiltration—ER Heating Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	101.26	204.24	405.72	609.05
Climate Zone 2: Dallas	48.90	98.82	196.15	294.44
Climate Zone 3: Houston	27.18	55.06	109.19	163.91
Climate Zone 4: Corpus Christi	22.78	46.02	91.35	137.13
Climate Zone 5: El Paso	45.59	92.23	182.99	274.69

**Table 129. Air Infiltration—HP Heating Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	30.69	61.89	122.94	184.56
Climate Zone 2: Dallas	14.82	29.95	59.44	89.22
Climate Zone 3: Houston	8.24	16.69	33.09	49.67
Climate Zone 4: Corpus Christi	6.90	13.94	27.68	41.56
Climate Zone 5: El Paso	13.81	27.95	55.45	83.24

**Table 130. Air Infiltration—Summer Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0053	0.0105	0.0210	0.0315
Climate Zone 2: Dallas	0.0044	0.0090	0.0179	0.0269
Climate Zone 3: Houston	0.0043	0.0087	0.0173	0.0259
Climate Zone 4: Corpus Christi	0.0041	0.0082	0.0164	0.0246
Climate Zone 5: El Paso	0.0041	0.0083	0.0165	0.0247

**Table 131. Air Infiltration—ER Winter Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0268	0.0541	0.1074	0.1612
Climate Zone 2: Dallas	0.0412	0.0828	0.1648	0.2474
Climate Zone 3: Houston	0.0211	0.0425	0.0844	0.1267
Climate Zone 4: Corpus Christi	0.0190	0.0383	0.0762	0.1144
Climate Zone 5: El Paso	0.0099	0.0202	0.0400	0.0602

**Table 132. Air Infiltration—HP Winter Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep**

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0138	0.0277	0.0550	0.0825
Climate Zone 2: Dallas	0.0178	0.0357	0.0710	0.1066
Climate Zone 3: Houston	0.0102	0.0207	0.0410	0.0615
Climate Zone 4: Corpus Christi	0.0087	0.0175	0.0348	0.0523
Climate Zone 5: El Paso	0.0049	0.0099	0.0197	0.0296

## 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.<sup>273</sup> 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
- Existing gap width (1/8", 1/4", 1/2", or 3/4")
- Installed measure (weather stripping or door sweep)
- Linear feet (to nearest 0.02 feet = 1/4") of installed weather stripping or door sweep

## 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.

<sup>273</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 133. Air Infiltration—Revision History**

TRM version	Date	Description of change
v6.0	10/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. Minor text revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Degradation factor added to deemed savings values. Guidance clarified for measuring gap sizes.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 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:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR 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  $\geq 3$  and  $\leq 40$ .<sup>274, 275</sup>

- 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.

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<sup>274</sup> 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](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf).

<sup>275</sup> ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results>.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.<sup>276</sup>

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  $\geq 5$  and  $\leq 20$  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 134.

**Table 134. Combination Ovens—ENERGY STAR Specification<sup>277</sup>**

Operation	Idle rate (kW) <sup>278</sup>	Cooking energy efficiency (%)
<b>Full-size and half-size ovens with 5–40 pan capacity</b>		
Steam mode	$\leq 0.133P + 0.64$	$\geq 55$
Convection mode	$\leq 0.083P + 0.35$	$\geq 78$
<b>Full-size and half-size ovens with 3–4 pan capacity</b>		
Steam mode	$\leq 0.60P$	$\geq 51$
Convection mode	$\leq 0.05P + 0.55$	$\geq 70$

<sup>276</sup> CEE Commercial Kitchens Initiative’s overview of the Food Service Industry.

[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).

<sup>277</sup> ENERGY STAR Commercial Ovens Key Product Criteria.

[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_ovens/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria).

<sup>278</sup> P = Pan capacity.

Furthermore, pan capacity<sup>279</sup> must be  $\geq 3$  and  $\leq 40$  (for both half- and full-size combination ovens). Pan capacity must be  $\geq 3$  and  $\leq 5$  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:

$$\text{Energy Savings } [\Delta kWh] = kWh_{base} - kWh_{ES} \quad \text{Equation 97}$$

$$kWh_{base} = kWh_{ph,base} + kWh_{conv,base} + kWh_{st,base} \quad \text{Equation 98}$$

$$kWh_{ES} = kWh_{ph,ES} + kWh_{conv,ES} + kWh_{st,ES} \quad \text{Equation 99}$$

$kWh_{ph}$ ,  $kWh_{conv}$  and  $kWh_{st}$  are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 100, except they require their respective input assumptions relative to preheat, cooking and idle operation in convection and steam modes as seen in Table 135.

$$kWh = \left( E_{ph} + \left( \frac{W_{food} \times E_{food} \times 50\%}{\eta_{cook}} \right) + E_{idle} \times \left( \left( t_{on} - \frac{W_{food}}{PC} \right) \times 50\% \right) \right) \times \frac{t_{days}}{1,000} \quad \text{Equation 100}$$

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh - \left( \frac{\Delta E_{ph} \times t_{days}}{1,000} \right)}{t_{on} \times t_{days}} \times CF \quad \text{Equation 101}$$

Where:

$kWh_{base}$	=	Baseline annual energy consumption [kWh]
$kWh_{ES}$	=	ENERGY STAR annual energy consumption [kWh]
$E_{ph}$	=	Preheat energy [Wh/BTU]
$\Delta E_{ph}$	=	Difference in baseline and ENERGY STAR preheat energy

<sup>279</sup> 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 day [lb/day]
$\eta_{cook}$	=	Cooking energy efficiency [%]
PC	=	Production capacity per pan [lb/hr]
$t_{on}$	=	Equipment operating hours per day [hr/day]
$t_{days}$	=	Facility operating days per year [days/year]
1,000	=	Constant to convert from W to kW
CF	=	Peak coincidence factor

**Table 135. Combination Ovens—Savings Calculation Input Assumptions<sup>280</sup>**

Parameter		Convection mode		Steam mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
$E_{ph}$	P < 15	3,000		1,500	
	P ≥ 15	3,750		2,000	
$W_{food}$	P < 15	200		200	
	P ≥ 15	250		250	
$E_{food}$		73.2		30.8	
$\eta_{cook}$	3 ≥ P < 5	70%	70%	49%	51%
	P ≥ 5	72%	78%	49%	55%
$E_{idle}$	3 ≥ P < 5	1,320	(0.05P + 0.55) x 1,000	5,260	0.60P x 1,000
	5 ≥ P < 15	1,320	(0.083P + 0.35) x 1,000	5,260	(0.133P + 0.64) x 1,000
	P ≥ 15	2,280		8,710	
PC <sup>281</sup>	P < 15	79	119	126	177
	P ≥ 15	166	201	295	349

<sup>280</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>281</sup> 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.

Parameter	Convection mode		Steam mode	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
t <sub>on</sub>				12
t <sub>days</sub>				365
CF <sup>282</sup>				0.90

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 133 are based on the input assumptions from Table 135.

**Table 136. Combination Ovens—Energy and Peak Demand Savings<sup>283</sup>**

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

<sup>282</sup> 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.

<sup>283</sup> ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment Calculator. [http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial\\_kitchen\\_equipment\\_calculator.xlsx](http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx).

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID Cook-ElecCombOven.<sup>284</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 137. Combination Ovens—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.

<sup>284</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. Updated previous method based upon the Food Service Technology Center (FSTC) assumptions to an approach using the newly developed ENERGY STAR Commercial Ovens Program Requirements Version 2.1, which added combination ovens under this version. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR measure.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator updates. Corrected ENERGY STAR idle rate formulas. Updated tracking system requirements and EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.4.2 ENERGY STAR® Electric Convection Ovens Measure Overview

**TRM Measure ID:** NR-FS-CV

**Market Sector:** Commercial

**Measure Category:** Food service equipment

**Applicable Building Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification, with half-size and full-size electric ovens as defined below:<sup>285, 286</sup>

- 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.

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<sup>285</sup> 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](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf).

<sup>286</sup> ENERGY STAR Qualified Product Listing. <https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results>.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.<sup>287</sup>

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

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

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

## 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 138.

**Table 138. Convection Ovens—ENERGY STAR Specification<sup>288</sup>**

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

<sup>287</sup> CEE Commercial Kitchens Initiative’s overview of the food service industry.

[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf)

<sup>288</sup> ENERGY STAR Commercial Ovens Key Product Criteria.

[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_ovens/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria).

## Energy and Demand Savings Methodology

### Savings Calculations and Input Variables

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

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

**Equation 102**

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

**Equation 103**

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

**Equation 104**

$kWh_{ph}$ ,  $kWh_{cook}$ , and  $kWh_{idle}$  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 as seen in Table 139.

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

**Equation 105**

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

**Equation 106**

Where:

$kWh_{base}$	=	Baseline annual energy consumption [kWh]
$kWh_{ES}$	=	ENERGY STAR annual energy consumption [kWh]
$E_{ph}$	=	Preheat energy [Wh/BTU]
$\Delta E_{ph}$	=	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]
$\eta_{cook}$	=	Cooking energy efficiency [%]

$PC$	=	<i>Production capacity [lb/hr]</i>
$t_{on}$	=	<i>Operating hours per day [hr/day]</i>
$t_{days}$	=	<i>Facility operating days per year [days/year]</i>
1,000	=	<i>Constant to convert from W to kW</i>
$CF$	=	<i>Coincidence factor</i>

**Table 139. Convection Ovens—Savings Calculation Input Assumptions<sup>289</sup>**

Parameter	Full size ≥ 5 pans		Full size < 5 pans		Half size		
	Baseline	ENERGY STAR	Baseline	ENERGY STAR	Baseline	ENERGY STAR	
$E_{ph}$	1,563	1,389	1,563	1,389	890	700	
$W_{food}$						100	
$E_{food}$						73.2	
$\eta_{cook}$	65%	76%	65%	76%	68%	70.67%	
$E_{idle}$	2,000	1,400	2,000	1,000	1,030	1,000	
$PC$	90	90	90	90	45	50	
$t_{on}$						12	
$t_{days}$						365	
$CF^{290}$						0.90	

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 137 are based on the input assumptions from Table 139.

**Table 140. Convection Ovens—Energy and Peak Demand Savings**

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

## Claimed Peak Demand Savings

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

<sup>289</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>290</sup> 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.



## 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.<sup>291</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 141. Convection Ovens—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR Commercial Ovens Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR Measure.

<sup>291</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Corrected convection oven definitions. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated changes from March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.4.3 ENERGY STAR® Dishwashers Measure Overview

**TRM Measure ID:** NR-FS-DW

**Market Sector:** Commercial

**Measure Category:** Food service equipment

**Applicable Building Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification and fall under one of the following categories.<sup>292, 293</sup> These categories are described in Table 142:

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

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<sup>292</sup> ENERGY STAR Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria v3.0. [https://www.energystar.gov/products/commercial\\_dishwashers/partners](https://www.energystar.gov/products/commercial_dishwashers/partners).

<sup>293</sup> ENERGY STAR Qualified Product Listing. <https://www.energystar.gov/productfinder/product/certified-commercial-dishwashers/results>.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.<sup>294</sup>

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 142. 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.

<sup>294</sup> CEE Commercial Kitchens Initiative's overview of the Food Service Industry: [https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf)

## Baseline Condition

Baseline equipment is either a low-temperature<sup>295</sup> or high-temperature<sup>296</sup> machine as defined by Table 142, 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 143.

**Table 143. Dishwashers—ENERGY STAR Specification<sup>297</sup>**

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 <sup>298</sup>

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Deemed savings values are calculated using the following algorithms:

<sup>295</sup> Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

<sup>296</sup> High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

<sup>297</sup> ENERGY STAR Commercial Dishwashers Key Product Criteria.  
[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_dishwashers/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria).

<sup>298</sup> Water consumption for pot, pan, and utensil is specified in gallons-per-square-foot rather than gallons-per-rack.

*Energy Savings* [ $\Delta kWh$ ]

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

**Equation 107**

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

**Equation 108**

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

**Equation 109**

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

**Equation 110**

Where:

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

**Table 144. Dishwashers—Savings Calculation Input Assumptions<sup>299</sup>**

Inputs	UC	SSTD	STC	MTC	PP&U
$\rho_{\text{water}}$	61.4 ÷ 7.48 = 8.2				
$C_p$	1.0				
$\Delta T_{\text{DHW}}$	Gas water heaters: 0°F Electric water heaters: 70 °F				
$\Delta T_{\text{boost}}$	Gas booster heaters: 0 °F Electric booster heaters: 40 °F				
$\eta_{\text{DHW}}$	98%				
$t_{\text{on}}$	18				
$t_{\text{days}}$	365				
$CF^{300}$	0.90				
Low-temperature units					
$N_{\text{racks}}$	75	280	400	600	–
$V_{\text{rack,base}}$	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	–
$t_{\text{wash}}$	2.0	1.5	0.3	0.3	–
High-temperature units					
$N_{\text{racks}}$	75	280	400	600	280
$V_{\text{rack,base}}$	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
$t_{\text{wash}}$	2.0	1.0	0.3	0.2	3.0

<sup>299</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>300</sup> Itron, Inc., “2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report.” Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 145 are based on the input assumptions from Table 144.

**Table 145. Dishwashers—Energy and Peak Demand Savings**

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 146. Dishwashers—Equipment Lifetime by Machine Type**

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



## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 147. Dishwashers—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Update savings based on the newest version of ENERGY STAR deemed input variables.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Water Use per Rack in Table 2-90.
v3.0	04/30/2015	TRM v3.0 update. Aligned calculation approach with ENERGY STAR Commercial Dishwashers Program Requirements Version 2.0. Simplified methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. Added high-efficiency requirements for pots, pans, and utensils.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated ENERGY STAR specification and incorporated March 2021 calculator update. Updated variable definitions.
v10.0	10/2022	TRM v10.0 update. Corrected mismatch between formula definitions and variables. Replaced URL for ENERGY STAR listing.
v11.0	10/2023	TRM v11.0 update. Clarified that residential dishwashing equipment can be installed in commercial applications following the methodology in Volume 2 of TRM.

## 2.4.4 ENERGY STAR® Electric Griddles Measure Overview

**TRM Measure ID:** NR-FS-GR

**Market Sector:** Commercial

**Measure Category:** Food service equipment

**Applicable Business Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR commercial 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.<sup>301</sup> The efficiency requirements for this appliance are evaluated on a per-square-foot basis.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial food service operations, healthcare, hospitality, and supermarkets.<sup>302</sup>

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

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<sup>301</sup> ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-griddles/results>.

<sup>302</sup> "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](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).

## 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.

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v1.2 specification, effective January 1, 2011.<sup>303</sup> Qualified products must meet the minimum idle energy rate requirement from Table 148.

**Table 148. Commercial Griddles—ENERGY STAR Specification<sup>304</sup>**

Operation	Criteria
Cooking energy efficiency at heavy-load conditions	Reported
Normalized idle energy rate	≤ 320 watts/ft <sup>2</sup> .

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 111

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

Equation 112

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

Equation 113

<sup>303</sup> 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>.

<sup>304</sup> ENERGY STAR Commercial Griddles Key Product Criteria. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_griddles/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_product_criteria).

kWh<sub>ph</sub>, kWh<sub>cook</sub>, and kWh<sub>idle</sub> 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 149.

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

**Equation 114**

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

**Equation 115**

Where:

$kWh_{base}$	=	Baseline annual energy consumption [kWh]
$kWh_{ES}$	=	ENERGY STAR annual energy consumption [kWh]
$E_{ph}$	=	Preheat energy [Wh/day]
$\Delta E_{ph}$	=	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]
$\eta_{cook}$	=	Cooking energy efficiency [%]
$PC$	=	Production capacity per pan [lb/hr]
$t_{on}$	=	Equipment operating hours per day [hr/day]
$t_{days}$	=	Facility operating days per year [days/year]
1,000	=	Constant to convert from W to kW
$CF$	=	Peak coincidence factor

**Table 149. Griddles—Savings Calculation Input Assumptions<sup>305</sup>**

Parameter	Single-sided		Double-sided	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
$E_{ph}$ (Wh/ft <sup>2</sup> )	667	333	667	333
$W_{food}$ (lb/day/ ft <sup>2</sup> )				17
$E_{food}$ (Wh/lb)	139			139
$\eta_{cook}$ (%)	65%	70%	65%	72%
$E_{idle}$ (W/ft <sup>2</sup> )	400	320	400	320
PC (lbs/hr/ft <sup>2</sup> )	5.83	6.67	11.67	13.92
$t_{on}$				12
$t_{days}$				365
CF <sup>306</sup>				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 135.

**Table 150. Griddles—Energy and Peak Demand Savings<sup>307</sup>**

Griddle size (ft <sup>2</sup> )	Single-sided		Double-sided	
	kWh	kW	kWh	kW
4	1,759	0.26	2,120	0.34
6	2,639	0.39	3,179	0.50
8	3,519	0.52	4,239	0.67
10	4,398	0.65	5,299	0.84
12	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.

<sup>305</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>306</sup> 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.

<sup>307</sup> ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment Calculator. [http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial\\_kitchen\\_equipment\\_calculator.xlsx](http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx).

## 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.<sup>308</sup>

## 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

## 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 151. ENERGY STAR Griddles—Revision History**

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

<sup>308</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

## 2.4.5 ENERGY STAR® Electric Fryers Measure Overview

**TRM Measure ID:** NR-FS-EF

**Market Sector:** Commercial

**Measure Category:** Cooking equipment

**Applicable Building Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

Eligible units must 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:<sup>309, 310</sup>

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.<sup>311</sup>

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<sup>309</sup> 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>.

<sup>310</sup> ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-fryers/results>.

<sup>311</sup> CEE Commercial Kitchens Initiative's overview of the Food Service Industry:  
[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).



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

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

## Baseline Condition

The baseline condition is an electric standard-size fryer 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 152.

**Table 152. Fryers—ENERGY STAR Specification<sup>312</sup>**

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 116**

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

**Equation 117**

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

**Equation 118**

<sup>312</sup> ENERGY STAR Commercial Fryers Key Product Criteria.

[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_fryers/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria).

$kWh_{ph}$ ,  $kWh_{cook}$ , and  $kWh_{idle}$  are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 119, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 153.

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

**Equation 119**

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

**Equation 120**

Where:

$kWh_{base}$	=	Baseline annual energy consumption [kWh]
$kWh_{ES}$	=	ENERGY STAR annual energy consumption [kWh]
$E_{ph}$	=	Preheat energy [Wh/day]
$\Delta E_{ph}$	=	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]
$\eta_{cook}$	=	Cooking energy efficiency [%]
$PC$	=	Production capacity [lb/hr]
$t_{on}$	=	Equipment operating hours per day [hr/day]
$t_{ph}$	=	Preheat time [min/day]
$t_{days}$	=	Facility operating days per year [days/year]
60	=	Constant to convert from min to hr
1,000	=	Constant to convert from W to kW
$CF$	=	Peak coincidence factor

**Table 153. Fryers—Savings Calculation Input Assumptions<sup>313</sup>**

Parameter	Standard-sized vat		Large vat	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
$E_{ph}$	2,400	1,900	2,400	1,900
$W_{food}$				150
$E_{food}$				167
$\eta_{cook}$	75%	83%	70%	80%
$E_{idle}$	1,200	800	1,350	1,100
PC	65	70	100	110
$t_{on}$				12
$t_{ph}$				15
$t_{days}$				365
$CF^{314}$				0.90

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 154 are based on the assumptions from Table 153.

**Table 154. Fryers—Energy and Peak Demand Savings**

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

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecFryer.<sup>315</sup>

<sup>313</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>314</sup> 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.

<sup>315</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

- Manufacturer and model number
- Fryer 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

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 36779—Provides EUL for Electric Fryers.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 155. Fryers—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR Electric Fryers Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Savings and efficiencies revised for ENERGY STAR 3.0 specifications. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Minor variable definition updates.
v11.0	10/2023	TRM v11.0 update. Updated documentation requirements to collect fryer type rather than fryer width.

## 2.4.6 ENERGY STAR® Electric Steam Cookers Measure Overview

**TRM Measure ID:** NR-FS-SC

**Market Sector:** Commercial

**Measure Category:** Cooking equipment

**Applicable Building Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR electric steam cookers. Steam cookers are available in 3-, 4-, 5-, or  $\geq$  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.<sup>316, 317</sup> Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.<sup>318</sup>

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

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<sup>316</sup> 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](https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf).

<sup>317</sup> ENERGY STAR Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results>.

<sup>318</sup> CEE Commercial Kitchens Initiative's overview of the Food Service Industry:  
[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).

## Baseline Condition

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

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v1.2 specification, effective August 1, 2003. Qualified products must meet the requirements from Table 156.

**Table 156. Steam Cookers—ENERGY STAR Specification<sup>319</sup>**

Pan capacity	Cooking energy efficiency (%) <sup>320</sup>	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

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

**Equation 121**

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

**Equation 122**

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

**Equation 123**

$kWh_{ph}$ ,  $kWh_{cook}$ , and  $kWh_{idle}$  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 as seen in Table 157.

<sup>319</sup> ENERGY STAR Commercial Steam Cookers Key Product Criteria.

[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_steam\\_cookers/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria).

<sup>320</sup> Cooking Energy Efficiency is based on “heavy load (potato) cooking capacity,” i.e., 12 by 20 by 2½ inch (300 by 500 by 65 mm) perforated hotel pans each filled with 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of fresh, whole, US No. 1, size B, red potatoes.

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

**Equation 124**

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

**Equation 125**

Where:

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



**Table 157. Steam Cookers—Savings Calculation Input Assumptions<sup>321</sup>**

Parameter	Baseline value	ENERGY STAR value
$E_{ph}$	1,776	1,671.7
$W_{food}$		100
$E_{food}$		30.8
$\eta_{cook}$	Boiler-based: 26% Steam generator: 30%	50%
$E_{idle}$	Boiler-based: 1,000 Steam generator: 1,200	3-pan: 400 4-pan: 530 5-pan: 670 6-pan: 800
PC	23.3	16.7
P		3, 4, 5, or 6
$t_{on}$		9.25
$t_{days}$		311
CF <sup>322</sup>		0.90

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 158 are based on the input assumptions from Table 157.

**Table 158. Steam Cookers—Energy and Peak Demand Savings**

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

<sup>321</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>322</sup> Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study: Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecStmCooker.<sup>323</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

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

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 159. Steam Cookers—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated EUL based on ENERGY STAR and DEER 2014.

<sup>323</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR Steam Cooker Program Requirements Version 1.2. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Corrected formula errors. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Corrected formula error and minor variable definition updates.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.4.7 ENERGY STAR® Hot Food Holding Cabinets Measure Overview

**TRM Measure ID:** NR-FS-HC

**Market Sector:** Commercial

**Measure Category:** Food service equipment

**Applicable Building Types:** See eligibility criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

HFHCs must be compliant with the current ENERGY STAR specification.<sup>324, 325</sup> Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.<sup>326</sup>

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<sup>324</sup> 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](https://www.energystar.gov/sites/default/files/specs/private/Commercial_HFHC_Program_Requirements_2.0.pdf).

<sup>325</sup> ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-hot-food-holding-cabinets/results>.

<sup>326</sup> CEE Commercial Kitchens Initiative's overview of the Food Service Industry:  
[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).

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

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

## Baseline Condition

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

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v2.0 specification, effective October 1, 2011. Table 160 summarizes idle energy rate requirement based on cabinet interior volume.

**Table 160. HFHCs—ENERGY STAR Specification<sup>327,328</sup>**

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

## Energy and Demand Savings Methodology

### Savings Calculations and Input Variables

Deemed values are calculated using the following algorithms:

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

**Equation 126**

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

**Equation 127**

<sup>327</sup> ENERGY STAR Commercial Fryers Key Product Criteria.

[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_hot\\_food\\_holding\\_cabinets/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria).

<sup>328</sup> V = Interior Volume which equals Interior Height x Interior Width x Interior Depth.

Where:

$V$	=	Product interior volume [ft <sup>3</sup> ]
$E_{Idle,base}$	=	Baseline idle energy rate [W]
$E_{Idle,ES}$	=	ENERGY STAR idle energy rate after installation [W]
$t_{on}$	=	Equipment operating hours per day [hrs/day]
$t_{days}$	=	Facility operating days per year [days/year]
1,000	=	Constant to convert from W to kW
$CF$	=	Peak coincidence factor

**Table 161. HFHCs—Savings Calculation Input Assumptions<sup>329</sup>**

Input variable	Product interior volume range		
	$0 < V < 13$	$13 \leq V < 28$	$28 \leq V$
$V^{330}$	8	22	53
$E_{Idle,base}$	$30 \times V$		
$E_{Idle,ES}$	$21.5 \times V$	$2 \times V + 254$	$3.8 \times V + 203.5$
$t_{on}$	9		
$t_{days}$	365		
$CF^{331}$	0.90		

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 162 are based on the input assumptions from Table 161.

**Table 162. HFHCs—Energy and Peak Demand Savings**

Product interior volume (ft <sup>3</sup> )	kWh Savings	kW Savings
$0 < V < 13$	223	0.061
$13 \leq V < 28$	1,189	0.326
$28 \leq V$	3,893	1.067

<sup>329</sup> ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. [https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment](https://www.energystar.gov/products/commercial_food_service_equipment).

<sup>330</sup> Averages of product interior volume determined based on review of ENERGY STAR qualified product listing. Accessed 7/30/2020.

<sup>331</sup> Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-HoldCab.<sup>332</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

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

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 163. HFHCs—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR Hot Food Holding Cabinet Program Requirements Version 2.0. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

<sup>332</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Minor formatting.
v11.0	10/2023	TRM v11.0 update. No revision.



## 2.4.8 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.<sup>333, 334</sup>

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.<sup>335</sup>

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

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<sup>333</sup> 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>.

<sup>334</sup> ENERGY STAR Qualified Product Listing: <https://www.energystar.gov/productfinder/product/certified-commercial-ice-machines/results>.

<sup>335</sup> CEE Commercial Kitchens Initiative's overview of the Food Service Industry:  
[https://forum.cee1.org/system/files/library/4203/CEE\\_CommKit\\_InitiativeDescription\\_Aug2021.pdf](https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf).

## Baseline Condition

The baseline condition is an ice maker meeting the federal standards published in 10 CFR 431 listed in Table 164. 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 164. Ice Makers—Federal Standard<sup>336</sup>**

Equipment type	Harvest rate (lbs ice per 24 hrs)	Max energy use rate (kWh/100 lb ice) H=harvest rate
<b>Batch</b>		
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
<b>Continuous</b>		
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

<sup>336</sup> 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](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 165.

**Table 165. Ice Makers—ENERGY STAR Specification<sup>337</sup>**

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

## Energy and Demand Savings Methodology

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

<sup>337</sup> ENERGY STAR Commercial Ice Maker Key Product Criteria .  
[https://www.energystar.gov/products/commercial\\_food\\_service\\_equipment/commercial\\_ice\\_makers/key\\_product\\_criteria](https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria).

## Savings Algorithms and Input Variables

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

Equation 128

$$\text{Peak Demand Savings } [\Delta kW] = \Delta kWh \times CF$$

Equation 129

Where:

$E_{base}$	=	Baseline rated energy consumption (kWh) per 100 pounds of ice (see Table 164)
$E_{ES}$	=	ENERGY STAR rated energy consumption (kWh) per 100 pounds of ice (see Table 165)
$H$	=	Harvest rate in pounds of ice produced per 24 hours
$DC$	=	Machine duty cycle, 75% <sup>338</sup>
$t_{days}$	=	Number of days per year, default is 365 based on continuous use for both batch and continuous type ice makers.
$CF$	=	Seasonal peak coincidence factor (see Table 166)

Table 166. Ice Makers—Seasonal Peak CFs

Probability weighted peak CF <sup>339</sup>		
Climate zone	Summer	Winter
Climate Zone 1: Amarillo	0.00012	0.00011
Climate Zone 2: Dallas		
Climate Zone 3: Houston		
Climate Zone 4: Corpus Christi		
Climate Zone 5: El Paso		0.00012

## Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure.

<sup>338</sup> The assumed duty cycle value of 80% is taken from a PGE Emerging Technologies study, ET Project #ET12PGE3151 Food Service Technology—Efficient Ice Machines and Load Shifting, average duty cycle of preexisting machines in tables ES1 and ES2.

<sup>339</sup> Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Commercial Refrigeration. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. <http://loadshape.epri.com/enduse>.

## **Deemed Summer and Winter Demand Savings Tables**

There are no deemed demand savings tables for this measure.

## **Claimed Peak Demand Savings**

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

## **Measure Life and Lifetime Savings**

The estimated useful life (EUL) for automatic ice makers is 8.5 years.<sup>340</sup>

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

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

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<sup>340</sup> 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 167. Ice Makers—Revision History**

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator update.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.4.9 Demand-Controlled Kitchen Ventilation Measure Overview

**TRM Measure ID:** NR-FS-KV

**Market Sector:** Commercial

**Measure Category:** Food service

**Applicable Building Types:** Restaurants and buildings with commercial kitchens

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed value

**Savings Methodology:** Algorithms

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

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

## **Energy and Demand Savings Methodology**

Energy savings are calculated based on monitoring data gathered during field studies conducted by the Food Service Technology Center (FSTC) and published in the ASHRAE Journal.<sup>341</sup> Assumptions for average savings, operating hours and days, and makeup air factors are calculated as the averages for corresponding building types from FSTC monitoring data.

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

Interactive heating and cooling savings are taken by multiplying the percent airflow savings from the FSTC study by the estimated heating and cooling loads output by the FSTC Outdoor Air Load Calculator (OALC).<sup>342</sup> This output is adjusted by population to account for the percentage of sites with electric resistance or heat pump heating.<sup>343</sup> Additionally, because output from the OALC is per 1,000 CFM, a CFM per HP ratio<sup>344</sup> 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 130**

$$\text{Peak Demand Savings } [\Delta kW] = \Delta kWh \times CF$$

**Equation 131**

Where:

$HP_{\text{exhaust}}$	=	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 169)
$\text{AvgSav}_{kWh/HP}$	=	Average hourly energy savings per horsepower by building type (see Table 168)

<sup>341</sup> Fisher, D., Swierczyna, R., and Karas, A. (February 2013) Future of DCV for Commercial Kitchens. *ASHRAE Journal*, 48-53.

<sup>342</sup> Food Service Technology Center Outdoor Air Load Calculator. No longer available online.

<sup>343</sup> Percentage of buildings with electric resistance and heat pump heat are taken from the Energy Information Administration 2012 Commercial Buildings Energy Survey (CBECS), tables b.28 Primary space-heating energy sources and b.38 Heating equipment, using data for buildings with cooking. <https://www.eia.gov/consumption/commercial/data/2012>.

<sup>344</sup> The CFM per HP ratio was calculated using data from Southern California Edison, ET 07.10 Report on Demand Control Ventilation for Commercial Kitchen Hoods, June 2009.



- DOH* = Average daily operating hours, facility specific (if unknown, use defaults from Table 168)
- AOD* = Annual operating days, facility specific (if unknown use defaults from Table 168)
- MAU* = Make-up air unit factor applied to account for presence of dedicated MAU; value = 1 if there is a dedicated MAU; see Table 168 for values when there is no dedicated MAU
- CF* = Seasonal peak coincidence factor; see Table 170

**Table 168. DCKV—Savings Calculation Input Assumptions**

Building type	AvgSav <sub>V<sub>kWh</sub>/HP</sub>	DOH	AOD	MAU with no dedicated MAU
Food service: Full-service restaurant <sup>345</sup>	0.667	15	365	0.65
Food service: Quick-service restaurant <sup>346</sup>				
Food service: 24-hour restaurant <sup>347</sup>	0.631	24	365	0.65
Education: K-12 or college/university with summer session <sup>348</sup>	0.566	11	325	0.51
Education: K-12 without summer session	0.566	11	252	0.51

**Table 169. 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	608
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	851
	Education: K-12 or college/university with summer session	455
	Education: K-12 without summer session	206

<sup>345</sup> Pennsylvania TRM, “3.5.3 High-Efficiency Fan Motors for Walk-In Refrigerated Cases”. Page 369, Table 3-93. June 2016.

<sup>346</sup> Ibid.

<sup>347</sup> All values are the average of Hotel Restaurant data from Future of DCV for Commercial Kitchens.

<sup>348</sup> 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 168.

Climate zone	Building type	Interactive savings (kWh/hp)
Climate Zone 2: Dallas	Food service: Full-service restaurant	1,123
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	1,758
	Education: K-12 or college/university with summer session	838
	Education: K-12 without summer session	409
Climate Zone 3: Houston	Food service: Full-service restaurant	1,191
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	1,844
	Education: K-12 or college/university with summer session	959
	Education: K-12 without summer session	571
Climate Zone 4: Corpus Christi	Food service: Full-service restaurant	1,393
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	2,262
	Education: K-12 or college/university with summer session	1,119
	Education: K-12 without summer session	689
Climate Zone 5: El Paso	Food service: Full-service restaurant	1,023
	Food service: Quick-service restaurant	
	Food service: 24-hour restaurant	1,510
	Education: K-12 or college/university with summer session	775
	Education: K-12 without summer session	450

**Table 170. DCKV—Seasonal Peak CFs<sup>349</sup>**

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

<sup>349</sup> 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 171. 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	4,253	2,990
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	6,376	4,418
	Education: K-12 or college/university with summer session	2,480	1,498
	Education: K-12 without summer session	1,779	1,016
Climate Zone 2: Dallas	Food service: Full-service restaurant	4,768	3,504
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	7,282	5,324
	Education: K-12 or college/university with summer session	2,864	1,881
	Education: K-12 without summer session	1,981	1,218
Climate Zone 3: Houston	Food service: Full-service restaurant	4,836	3,572
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	7,368	5,410
	Education: K-12 or college/university with summer session	2,985	2,002
	Education: K-12 without summer session	2,144	1,381
Climate Zone 4: Corpus Christi	Food service: Full-service restaurant	5,038	3,775
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	7,787	5,829
	Education: K-12 or college/university with summer session	3,144	2,162
	Education: K-12 without summer session	2,261	1,499
Climate Zone 5: El Paso	Food service: Full-service restaurant	4,668	3,404
	Food service: Quick-service restaurant		
	Food service: 24-hour restaurant	7,034	5,077
	Education: K-12 or college/university with summer session	2,801	1,818
	Education: K-12 without summer session	2,023	1,260

**Table 172. 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	0.57	0.40	0.62	0.44
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	0.85	0.59	0.93	0.65
	Education: K-12 or college/university with summer session	0.33	0.20	0.36	0.22
	Education: K-12 without summer session	0.24	0.14	0.26	0.15
Climate Zone 2: Dallas	Food service: Full-service restaurant	0.65	0.48	0.69	0.51
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	0.99	0.72	1.05	0.77
	Education: K-12 or college/university with summer session	0.39	0.26	0.41	0.27
	Education: K-12 without summer session	0.27	0.17	0.29	0.18
Climate Zone 3: Houston	Food service: Full-service restaurant	0.65	0.48	0.69	0.51
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	0.99	0.72	1.05	0.77
	Education: K-12 or college/university with summer session	0.40	0.27	0.43	0.29
	Education: K-12 without summer session	0.29	0.18	0.31	0.20

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	0.66	0.50	0.73	0.55
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.02	0.76	1.13	0.85
	Education: K-12 or college/university with summer session	0.41	0.28	0.46	0.31
	Education: K-12 without summer session	0.30	0.20	0.33	0.22
Climate Zone 5: El Paso	Food service: Full-service restaurant	0.68	0.49	0.68	0.50
	Food service: Quick-service restaurant				
	Food service: 24-hour restaurant	1.02	0.74	1.03	0.74
	Education: K-12 or college/university with summer session	0.41	0.26	0.41	0.27
	Education: K-12 without summer session	0.29	0.18	0.30	0.18

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-VSD-fan.<sup>350</sup>

<sup>350</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

- Climate zone or county
- Kitchen ventilation system exhaust fan horsepower
- Building type
- Kitchen ventilation makeup air unit fan horsepower, if present
- Presence of dedicated makeup air unit
- Testing and balancing report, if available

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 173. DCKV—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Formula updates and corrected table error.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

## 2.4.10 Pre-Rinse Spray Valves Measure Overview

**TRM Measure ID:** NR-FS-SV

**Market Sector:** Commercial

**Measure Category:** Food service equipment

**Applicable Building Types:** See Table 175

**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 174 (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 174.<sup>351</sup>

**Table 174. PRSVs—Flow Rate Limits**

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

<sup>351</sup> 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 21<sup>st</sup>, 2005 that it would no longer pursue an ENERGY STAR specification for pre-rinse spray valves.<sup>352</sup> 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 174 for the pre-rinse spray valve's respective product class. The sprayer should be capable of the same cleaning ability as the old sprayer.<sup>353</sup>

## 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 132**

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

**Equation 133**

Where:

$U$	=	Water usage duration (see Table 175)
$F_B$	=	Baseline sprayer flow rate (GPM) (see Table 174)
$F_P$	=	PRSV flow rate (GPM), use actual
$AOD$	=	Facility annual operating days (see Table 175)

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<sup>352</sup> "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](https://www.energystar.gov/ia/partners/prod_development/downloads/PRSV_Decision_Memo_Final.pdf?1e37-d3b8).

<sup>353</sup> FEMP Performance Requirements for Federal Purchases of Pre-rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-rinse Spray Valves.



$T_H$	=	Average mixed hot water (after spray valve) temperature for prewashing [°F] = 120°F <sup>354</sup>
$T_C$	=	Average supply (cold) water temperature [°F] = 71.4°F <sup>355</sup>
$\rho$	=	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 <sup>356</sup>
3,412	=	Constant to convert from Btu to kWh
$CF$	=	Seasonal peak coincidence factor (see Table 176)
100,000	=	Constant to convert values for easier readability

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

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

<sup>354</sup> “CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves,” Consortium of Energy Efficiency (CEE). Page 3.

<https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf>.

<sup>355</sup> Average calculated input water temperature for five Texas climate zone cities, based on typical meteorological year (TMY) dataset for TMY3: Available at

<http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

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

<sup>357</sup> “CEE Commercial Kitchens Initiative Program Guidance on pre-rinse valves”, page 3. Midpoint of typical hours of operation in footnoted building types.

<https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf>.

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

**Table 176. PRSV—Seasonal Peak CFs<sup>359</sup>**

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

## Deemed Energy and Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

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

<sup>359</sup> 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.

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

<sup>361</sup> Ibid.

<sup>362</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Attachment A:  
[https://interchange.puc.texas.gov/Documents/40669\\_3\\_735684.PDF](https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF).
- PUCT Docket 36779—Provides EUL for pre-rinse sprayers

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 177. PRSVs—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated the baseline and post-Retrofit minimum flow rate values, based on federal standards. Removed reference to a list of qualifying pre-rinse spray valves.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks, updates to input assumptions, and update peak demand savings. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Formula and variable definition updates.
v11.0	10/2023	TRM v11.0 update. Adjusted mixed water hot temperature to match CEE guidance. Aligned building type names across all commercial measures.

## 2.4.11 Vacuum-Sealing and Packaging Machines Measure Overview

**TRM Measure ID:** NR-MS-VS

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** Supermarket, Grocery, Food Store

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** M&V

### Measure Description

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

### Eligibility Criteria

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

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

### Baseline Condition

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

### High-Efficiency Condition

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

## Savings Algorithms and Input Variables

Southern California Edison (SCE) and the Food Service Technology Center (FSTC) conducted a field study to evaluate and compare energy savings and demand reduction potential between baseline and on-demand package sealers in supermarkets.<sup>363</sup> 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.<sup>364</sup> This approach is more consistent with the 15-minute interval data typically used in calculated demand and energy charges by utilities. Demand savings are calculated by dividing energy savings by 8,760 and multiplying against the coincidence factor.

## Deemed Energy and Demand Savings Tables

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

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

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for vacuum-sealing and packaging machines is 10 years, based on the University of California Useful Life Indices.<sup>365</sup>

<sup>363</sup> “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](https://www.etcc-ca.com/sites/default/files/reports/ET10SCE1450%20Vacuum%20Sealing%20Packaging%20Machine%20Report_Final.pdf).

<sup>364</sup> See Volume 1, Section 4.

<sup>365</sup> “Useful Life Indices for Equipment Depreciation”, University of California Office of the President. <https://eulid.ucop.edu/>.

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 179. Vacuum-Sealing & Packaging Machines—Revision History**

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

## 2.5 NONRESIDENTIAL: REFRIGERATION

### 2.5.1 Door Heater Controls Measure Overview

**TRM Measure ID:** NR-RF-HC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This document presents the deemed savings methodology for the installation of door heater controls for glass-door refrigerated cases with anti-sweat heaters (ASH). A door heater controller senses dew point (DP) temperature in the store and 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 ( $kWh_{refrig}$ ). These savings are calculated using the following procedures:

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

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

**Equation 134<sup>366</sup>**

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.<sup>367</sup> 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 135**

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

For medium temperature (coolers):

$$kW_{ASH} = 0.109 \text{ per door or } 0.0436 \text{ per horizontal linear foot of door}^{369}$$

**Equation 136**

<sup>366</sup> 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](https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc).

<sup>367</sup> 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.

<sup>368</sup> Pennsylvania TRM, "3.5.6 Controls: Anti-Sweat Heater Controls". page 381, Table 3-101. June 2016.

<http://www.puc.pa.gov/pdocs/1350348.docx>. Additional reference from Pennsylvania TRM: State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual. Table 4-75., March 22, 2010.  
[https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10\\_evaluationreport.pdf](https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf).

<sup>369</sup> Ibid.



For low temperature (freezers):

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

**Equation 137**

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

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

**Equation 138**

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

**Equation 139**

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system,<sup>371</sup> 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 140**

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data. The compressor analysis is limited to the cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

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

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<sup>370</sup> Ibid.

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

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

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

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

**Equation 141<sup>373</sup>**

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

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

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

**Equation 142<sup>374</sup>**

Where:

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

<sup>373</sup> 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](https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc).

<sup>374</sup> Ibid.

<i>d</i>	=	0.00218892905109218
<i>e</i>	=	-2.48866737934442
<i>f</i>	=	-0.248051519588758
<i>g</i>	=	-7.57495453950879 × 10 <sup>-6</sup>
<i>h</i>	=	2.03606248623924
<i>i</i>	=	-0.0214774331896676
<i>j</i>	=	0.000938305518020252
<i>PLR</i>	=	1/1.15 = 0.87
<i>SCT<sub>LT</sub></i>	=	<i>T<sub>db</sub></i> + 10
<i>T<sub>DB</sub></i>	=	Dry-bulb temperature

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

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

**Equation 143**

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

**Equation 144**

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

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

**Equation 145**

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

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

**Equation 146**

Peak demand savings are calculated as the weighted average of the probability of winter or summer peak load's top twenty hours' coincidence with system peak and the hourly calculated *kWh<sub>total</sub>* 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;<sup>375</sup> Table 180 provides these deemed values. Savings are specified per horizontal linear feet of door.

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

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

### Claimed Peak Demand Savings

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

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ASH.<sup>376</sup>

### 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

<sup>375</sup> <http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>

<sup>376</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## References and Efficiency Standards

### Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Attachment A:  
[https://interchange.puc.texas.gov/Documents/40669\\_7\\_736774.PDF](https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF).  
[https://interchange.puc.texas.gov/Documents/40669\\_7\\_736775.PDF](https://interchange.puc.texas.gov/Documents/40669_7_736775.PDF).
- PUCT Docket 36779—Provides EUL for Anti-Sweat Heater Controls

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 181. Door Heater Controls—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. In the energy savings equation used to determine the EER, rounded off the regression coefficients to 4 or 5 significant figures.
v2.1	01/30/2015	TRM v2.1 update. Correction to state that savings are on a per-linear foot of display case.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Update Deemed kW <sub>ASH</sub> for Medium temperature cases and add kW <sub>ASH</sub> for Low-temperature cases. Added more significant digits to the input variables a-j for Equation 141 and Equation 142.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated peak demand methodology to follow Volume 1 methods. Changed Zone 4 reference location from McAllen to Corpus Christi. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.2 ECM Evaporator Fan Motors Measure Overview

**TRM Measure ID:** NR-RF-FM

**Market Sector:** Commercial

**Measure Category:** Refrigeration

**Applicable Building Types:** Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools<sup>377</sup>

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

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

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<sup>377</sup> 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

$$\text{Peak Demand Savings } [\Delta kW] = N \times \Delta kW_{\text{peak per unit}} \quad \text{Equation 147}$$

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}})/1,000 \times LF \times DC_{\text{EvapCooler}} \times \left(1 + \frac{1}{COP_{\text{cooler}}}\right) \quad \text{Equation 148}$$

$$\text{Energy Savings } [\Delta kWh] = N \times \Delta kWh_{\text{per unit}} \quad \text{Equation 149}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} \times \text{Hours} \times (1 - \%OFF) \quad \text{Equation 150}$$

#### Freezer

$$\text{Demand Savings } [\Delta kW] = N \times \Delta kW_{\text{peak per unit}} \quad \text{Equation 151}$$

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}})/1,000 \times LF \times DC_{\text{EvapFreeze}} \times \left(1 + \frac{1}{COP_{\text{freezer}}}\right) \quad \text{Equation 152}$$

$$\text{Energy Savings } [\Delta kWh] = N \times \Delta kWh_{\text{per unit}} \quad \text{Equation 153}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} \times \text{Hours} \times (1 - \%OFF) \quad \text{Equation 154}$$

Where:

$N$	=	Number of motors replaced
$W_{\text{base}}$	=	Input wattage of existing/baseline evaporator fan motor (see Table 182)
$W_{\text{ee}}$	=	Input wattage of new energy efficient evaporator fan motor (see Table 182)

$LF$	=	Load factor of evaporator fan motor = 0.9 (default) <sup>378</sup>
$DC_{EvapCool}$	=	Duty cycle of evaporator fan motor for cooler = 100% (default) <sup>379</sup>
$DC_{EvapFreeze}$	=	Duty cycle of evaporator fan motor for freezer = 97.8% (default) <sup>380,381</sup>
$COP_{cooler}$	=	$12/EER_{MT}$ , 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. <sup>382,383</sup>
%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%. <sup>384</sup>
1,000	=	Constant to convert from W to kW

<sup>378</sup> 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>.

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

<sup>380</sup> 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>.

<sup>381</sup> “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.

<sup>382</sup> 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>.

<sup>383</sup> “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.

<sup>384</sup> 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.<sup>385</sup>

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

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

**Equation 155<sup>386</sup>**

Where:

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

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

<sup>386</sup> 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](https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc).

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

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

Equation 156<sup>387</sup>

Where:

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

Table 182. ECM Evaporator Fan Motors—Motor Sizes, Efficiencies, and Input Watts<sup>388,389</sup>

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

<sup>387</sup> Ibid.

<sup>388</sup> 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/pdocs/1350348.docx>.

The last two rows are estimated using logarithmic linear regression of smaller motor efficiencies.

<sup>389</sup> Motor efficiencies: “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Department of Energy. December 2013. Motor efficiencies for the baseline motors are from Table 2.1, which provides peak efficiency ranges for a variety of motors. ECM motor efficiencies is from discussion in Section 2.4.3. <https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf>.

Nominal motor size	Motor output (W)	Shaded pole eff	Shaded pole input (W)	PSC eff	PSC input (W)	ECM eff	ECM input (W)
1/15 HP (49W)	49.0	30%	163	60%	82	70%	70
1/4 HP	186.5	30%	622	60%	311	70%	266
1/3 HP	248.7	30%	829	60%	415	70%	355

**Table 183. ECM Evaporator Fan Motors—Cooler & Freezer Compressor COP**

Climate zone	Summer design dry-bulb temperature <sup>390</sup>	EER <sub>MT</sub>	COP <sub>cooler</sub>	EER <sub>LT</sub>	COP <sub>freezer</sub>
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 GrocWklIn-WEvapFanMtr.<sup>391</sup>

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

<sup>391</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 184. ECM Evaporator Fan Motors—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Updated the methodology with cooler and freezer values.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added <i>schools</i> as an eligible building type.
v11.0	10/2023	TRM v11.0 update. Clarified duty cycle assumptions and references.

## 2.5.3 Electronic Defrost Controls Measure Overview

**TRM Measure ID:** NR-RF-DC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

**Applicable Building Types:** Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools<sup>392</sup>

**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.

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<sup>392</sup> 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:

$$\text{Energy Savings } [\Delta kWh] = \Delta kWh_{\text{defrost}} + \Delta kWh_{\text{heat}} \quad \text{Equation 157}$$

$$\Delta kWh_{\text{defrost}} = kW_{\text{defrost}} \times DRF \times \text{Hours} \quad \text{Equation 158}$$

Medium temperature:

$$\Delta kWh_{\text{heat}} = \Delta kWh_{\text{defrost}} \times 0.28 \times COP_{MT} \quad \text{Equation 159}$$

Low temperature:

$$\Delta kWh_{\text{heat}} = \Delta kWh_{\text{defrost}} \times 0.28 \times COP_{LT} \quad \text{Equation 160}$$

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{\text{Hours}} \quad \text{Equation 161}$$

Where:

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

$\Delta kWh_{\text{heat}}$  = Energy savings due to the reduced heat from reduced number of defrosts

$kW_{\text{defrost}}$  = Load of electric defrost, default = 0.9 kW<sup>393</sup>

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<sup>393</sup> Efficiency Vermont TRM, 3/16/2015, p. 170. The total defrost element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900 W per fan. [https://www.puc.nh.gov/EESE%20Board/EERS\\_WG/vt\\_trm.pdf](https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf).

<i>Hours</i>	=	<i>Number of hours defrost occurs over a year without defrost controls, 487<sup>394</sup></i>
<i>DRF</i>	=	<i>Defrost reduction factor—percent reduction in defrosts required per year, see Table 185</i>
<i>0.28</i>	=	<i>Conversion of kW to tons; 3,412 Btuh/kW divided by 12,000 Btuh/ton</i>
<i>COP<sub>MT</sub></i>	=	<i>12/EER<sub>MT</sub>, the coefficient of performance of compressor in the cooler</i>
<i>COP<sub>LT</sub></i>	=	<i>12/EER<sub>LT</sub>, 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<sub>MT</sub>) is calculated as the design dry-bulb temperature plus 15 degrees. For low-temperature refrigerated cases, the SCT<sub>LT</sub> 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.<sup>395</sup>

For medium-temperature compressors, the following equation is used to determine EER<sub>MT</sub> [Btu/hr/watts] for each hour of the year.

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

**Equation 162<sup>396</sup>**

Where:

<i>a</i>	=	<i>3.75346018700468</i>
<i>b</i>	=	<i>-0.049642253137389</i>
<i>c</i>	=	<i>29.4589834935596</i>

<sup>394</sup> 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>.

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

<sup>396</sup> 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](https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc).



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

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

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

**Equation 163<sup>397</sup>**

Where:

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

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<sup>397</sup> Ibid.

**Table 185. Defrost Controls—Savings Calculation Input Assumptions**

Climate zone	DRF <sup>398</sup>	COP <sub>MT</sub> <sup>399</sup>	COP <sub>LT</sub> <sup>400</sup>
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.<sup>401</sup>

## 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

<sup>398</sup> 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>

<sup>399</sup> Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPCNRRN009 (rev.o.2007).

<sup>400</sup> Ibid.

<sup>401</sup> GDS Associates, Inc. (June 2007). *Measure Life Report*. Prepared for The New England State Program Working Group (SPWG). [https://library.cee1.org/sites/default/files/library/8842/CEE\\_Eval\\_MeasureLifeStudyLights&HVACGDS\\_1Jun2007.pdf](https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf)

Additionally, the Pennsylvania TRM Volume 3 Page 162 cites the Vermont TRM, March 16, 2015. Pg. 171: "This is a conservative estimate is based on a discussion with Heatcraft based on the components expected life. [https://www.puc.nh.gov/EESE%20Board/EERS\\_WG/vt\\_trm.pdf](https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf)"

- Load of electric defrost
- Refrigeration temperature (low temperature or medium temperature)

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 186. Defrost Controls—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper.
v10.0	10/2022	TRM v10.0 update. Added <i>schools</i> as an eligible building type.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.4 Evaporator Fan Controls Measure Overview

**TRM Measure ID:** NR-RF-FC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

**Applicable Building Types:** Any commercial retail facility such as supermarkets, grocery stores, hotels, restaurants, convenience stores, and schools<sup>402</sup>

**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.

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<sup>402</sup> 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 164**

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

**Equation 165**

Where:

$kW_{\text{evap}}$	=	Connected load kW of each evaporator fan, see Table 187
$kW_{\text{circ}}$	=	Connected load kW of the circulating fan, see Table 187
$n_{\text{fans}}$	=	Number of evaporator fans
$DC_{\text{comp}}$	=	Duty cycle of the compressor, see Table 187
$DC_{\text{evap}}$	=	Duty cycle of the evaporator fan, see Table 187
$BF$	=	Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running, see Table 187
8,760	=	Annual hours per year

**Table 187. Evaporator Fan Controls—Savings Calculation Input Assumptions<sup>403</sup>**

Variable	Deemed values
kW <sub>evap</sub>	0.123 kW
kW <sub>circ</sub>	0.035 kW
DC <sub>comp</sub>	50%
DC <sub>evap</sub>	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.<sup>404</sup>

<sup>403</sup> 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<sub>evap</sub>: 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<sub>circ</sub>: Page 78, footnote 367 states this value is the “wattage of fan used by Freeaire and Cooltrol”
- DC<sub>comp</sub>: 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<sub>evap</sub>: 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.”

<sup>404</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

## **Relevant Standards and Reference Sources**

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

## **Document Revision History**

**Table 188. Evaporator Fan Controls—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added schools as an eligible building type.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.5 Night Covers for Open Refrigerated Display Cases Measure Overview

**TRM Measure ID:** NR-RF-NC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

Eligible high-efficiency equipment is considered any suitable low-emissivity material sold as a night cover. The night cover must be applied for a period of at least six hours<sup>405</sup> per day (i.e., average continuous overnight use).

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<sup>405</sup> 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 166**

Where:

<i>L</i>	=	<i>Horizontal linear feet of the low- or medium-temperature refrigerated display case</i>
<i>kWh<sub>baseline</sub></i>	=	<i>Average annual unit energy consumption in terms of kWh/horizontal linear foot/year</i>
<i>9%</i>	=	<i>The reduction in compressor's electricity usage due to the night cover's decreasing of convection, conduction, and radiation heat transfer<sup>406</sup></i>

### **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.<sup>407</sup> Vertical and horizontal *open* equipment types were selected for inclusion given the nature of this measure.

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<sup>406</sup> 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”

<sup>407</sup> In 2013, the U.S. DOE conducted an extensive life-cycle cost (LCC) analysis of the commercial refrigeration equipment classes listed in the current federal standard [10 CFR 431.66](#) to determine average annual unit energy consumption per equipment class. In this analysis, 10,000 separate simulations yielded probability distributions for various parameters associated with each equipment class, among them: the efficiency level in kWh/yr. These efficiency levels were then subject to roll-up calculations to determine market shares of each efficiency level, which were then utilized to compute the average consumption for said efficiency level listed in Table 189.

Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. LCC Summary Statistics: Section 8B2; Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4. [https://www1.eere.energy.gov/buildings/appliance\\_standards/pdfs/cre2\\_nopr\\_tsd\\_2013\\_08\\_28.pdf](https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf).

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

Temperature <sup>408</sup>	Condensing unit configuration	Equipment family	Average annual energy consumption/lin. ft. (kWh <sub>baseline</sub> )	kWh Savings	kW Savings <sup>409</sup>
Medium (≥32 ± 2°F)	Remote condensing	Vertical open	1,453	130.77	0
		Horizontal open	439	39.51	0
	Self-contained	Vertical open	2,800	252.00	0
		Horizontal open	1,350	121.50	0
Low (<32 ± 2°F)	Remote condensing	Vertical open	3,292	296.28	0
		Horizontal open	1,007	90.63	0
	Self-contained	Horizontal open	2,748	247.32	0

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-DispCvrs.<sup>410</sup>

## 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)

<sup>408</sup> Temperature ranges per commercial refrigeration equipment type are detailed in the current federal standard 10 CFR 431.66.

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

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

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

- Operating temperature (low or medium as defined in Table 189)
- Horizontal linear feet length of refrigerated case

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40669 provides energy and demand savings and measure specifications: [https://interchange.puc.texas.gov/Documents/40669\\_7\\_736774.PDF](https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF).

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 190. Night Covers—Revision History**

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Removed all references to peak demand savings as this measure is implemented outside of the peak demand period. Also, rounded off savings to a reasonable number of significant digits.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Added more significant digits to the input variables a-j.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated reference city for climate zone 4. Added “linear feet” for tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.6 Solid and Glass Door Reach-Ins Measure Overview

**TRM Measure ID:** NR-RF-RI

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This document presents the deemed savings methodology for the installation of ENERGY STAR or CEE certified vertical or horizontal closed solid and glass (transparent) door reach-in refrigerators and freezers.

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

### Eligibility Criteria

Solid- or glass-door reach-in vertical and horizontal refrigerators and freezers must meet ENERGY STAR minimum efficiency requirements (See Table 192).

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

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

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

## Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 191.

**Table 191. Door Reach-Ins—Baseline Energy Consumption<sup>411,412</sup>**

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 192.

**Table 192. Door Reach-Ins—Efficient Energy Consumption Requirements<sup>413</sup>**

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	$0.05V + 0.28$	$0.057V + 0.55$

<sup>411</sup> 10 CFR 431.66. [https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431\\_166&rgn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8).

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

<sup>413</sup> ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 5.0, US Environmental Protection Agency. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20%28Rev.%20November%20-202022%29%20Commercial%20Refrigerators%20and%20Freezers%20Specification.pdf>.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

The energy and demand savings of solid and glass door reach-in refrigerators and freezers are calculated using values in Table 191 and Table 192, based on the volume of the units.

The savings calculations are specified as:

$$\text{Energy Savings } [\Delta kWh] = (kWh_{base} - kWh_{ee}) \times 365 \quad \text{Equation 167}$$

$$\text{Summer Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{8,760} \times CF_s \quad \text{Equation 168}$$

Where:

$kWh_{base}$  = Baseline maximum daily energy consumption in kWh, based on volume ( $V$ ) of unit (see Table 191)

$kWh_{ee}$  = Efficient maximum daily energy consumption in kWh, based on volume ( $V$ ) of unit (see Table 192)

$V$  = Chilled or frozen compartment volume [ $ft^3$ ] (as defined in the Association of Home Appliance Manufacturers Standard HRF-1-1979)

365 = Days per year

8,760 = Hours per year

$CF_s$  = Summer peak coincidence factor<sup>414</sup> = 1.0

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<sup>414</sup> The summer peak coincidence factor is assumed equal to 1.0, since the annual kWh savings is divided by the total annual hours (8,760), effectively resulting in the average kW reduction during the peak period.

## Deemed Energy and Demand Savings Tables

Table 193. Door Reach-Ins—Energy and Peak Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume <sup>415,416</sup>	kWh savings	kW savings
Refrigerator	Vertical closed solid door	0 < V < 15	9.0	693	0.079
		15 ≤ V < 30	20.6	956	0.109
		30 ≤ V < 50	41.7	1,341	0.153
		V ≥ 50	67.5	1,972	0.225
	Vertical closed glass door	0 < V < 15	47.9	1,129	0.129
		15 ≤ V < 30	21.0	1,347	0.154
		30 ≤ V < 50	42.1	1,771	0.202
		V ≥ 50	70.7	2,012	.0230
	Horizontal closed solid	0 < V < 15	11.4	850	0.097
		15 ≤ V < 30	18.6	982	0.112
		30 ≤ V < 50	30.0	1,190	0.136
		V ≥ 50	50.0	1,555	0.178
	Horizontal closed glass	0 < V < 15	3.0	1,194	0.136
		15 ≤ V < 30	20.2	1,633	0.186
		30 ≤ V < 50	30.0	1,883	0.215
		V ≥ 50	50.0	2,394	0.273

<sup>415</sup> 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>.

<sup>416</sup> For product types with no ENERGY STAR certified units, the low end of the volume range was used as a placeholder in the event that additional products are certified before the TRM can be updated, with one exception. Horizontal closed glass door units assume the product volume specified for the equivalent refrigerator category to avoid using a volume of zero.

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume <sup>415,416</sup>	kWh savings	kW savings
Freezer	Vertical closed solid door	0 < V < 15	9.4	827	0.094
		15 ≤ V < 30	20.0	1,727	0.197
		30 ≤ V < 50	42.3	3,388	0.0387
		V ≥ 50	68.8	5,573	0.636
	Vertical closed glass door	0 < V < 15	6.8	1,921	0.219
		15 ≤ V < 30	20.7	4,549	0.519
		30 ≤ V < 50	41.9	8,557	0.977
		V ≥ 50	72.5	14,343	1.637
	Horizontal closed solid	0 < V < 15	14.2	2,081	0.238
		15 ≤ V < 30	19.1	2,694	0.308
		30 ≤ V < 50	30.0	4,059	0.463
		V ≥ 50	50.0	6,563	0.749
	Horizontal closed glass	0 < V < 15	3.0	2,055	0.235
		15 ≤ V < 30	15.0	5,090	0.581
		30 ≤ V < 50	30.0	8,884	1.014
		V ≥ 50	50.0	13,943	1.592

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.<sup>417</sup>

## 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)

<sup>417</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.



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

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 194. Door Reach-Ins—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Updated methodology for ENERGY STAR Version 4.0.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Citation added for average product volumes.
v11.0	10/2023	TRM v11.0 update. Updated ENERGY STAR efficiency requirements. Clarified that residential refrigerator and freezer equipment can be installed in commercial applications following the methodology in Volume 2 of the TRM. Updated documentation requirements.

## 2.5.7 Strip Curtains for Walk-In Refrigerated Storage Measure Overview

**TRM Measure ID:** NR-RF-SC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** M&V analysis

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

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

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

The algorithms and assumptions detailed in this section are based on the Regional Technical Forum's methodology<sup>418</sup>, 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 169**

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

**Equation 170**

Where:

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

<sup>418</sup> Regional Technical Forum Strip Curtains UES Measure Workbook (Commercial Grocery Strip Curtain v2.1.xlsx). September 10<sup>th</sup>, 2019. <https://rtf.nw council.org/measure/strip-curtains>.

$$\begin{aligned}
C_{13} &= 6.5459673E+00 \\
{}^{\circ}R_{Adj} &= \text{Adjacent absolute temperature, } t_{DB,Adj} + 459.67 \text{ (see Table 195)} \\
{}^{\circ}R_{Refrig} &= \text{Refrigeration box absolute temperature, } t_{DB,Refrig} + 459.67 \\
&\text{(see Table 195)}
\end{aligned}$$

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

$$W_{Adj} = 0.62198 \times \frac{Rh_{Adj} \times P_{ws,Adj}}{14.696 - (Rh_{Adj} \times P_{ws,Adj})} \quad \text{Equation 171}$$

$$W_{Refrig} = 0.62198 \times \frac{Rh_{Refrig} \times P_{ws,Refrig}}{14.696 - (Rh_{Refrig} \times P_{ws,Refrig})} \quad \text{Equation 172}$$

Where:

$$\begin{aligned}
W_{Adj} &= \text{Humidity ratio of the adjacent space} \\
W_{Refrig} &= \text{Humidity ratio of the refrigerated space} \\
Rh_{Adj} &= \text{Relative humidity of the adjacent space (see Table 195)} \\
Rh_{Refrig} &= \text{Relative humidity of the refrigerated space (see Table 195)}
\end{aligned}$$

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

$$h_{Adj} = 0.24 \times t_{DB,Adj} + \left( W_{Adj} \times \left( 1061 + (0.444 \times t_{DB,Adj}) \right) \right) \quad \text{Equation 173}$$

$$h_{Refrig} = 0.24 \times t_{DB,Refrig} + \left( W_{Refrig} \times \left( 1061 + (0.444 \times t_{DB,Refrig}) \right) \right) \quad \text{Equation 174}$$

Where:

$$\begin{aligned}
h_{Adj} &= \text{Air enthalpy of the adjacent space} \\
h_{Refrig} &= \text{Air enthalpy of the refrigerated space} \\
t_{DB,Adj} &= \text{Dry-bulb temperature of the adjacent space (see Table 195)} \\
t_{DB,Refrig} &= \text{Dry-bulb temperature of the refrigerated space (see Table 195)}
\end{aligned}$$

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:

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

**Equation 175**

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

**Equation 176**

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

**Equation 177**

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

**Equation 178**

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

**Equation 179**

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

**Equation 180**

Where:

$v_{Adj}$	=	Specific volume of the adjacent space
$v_{Refrig}$	=	Specific volume of the refrigerated space
$\rho_{Adj}$	=	Air temperature density of the adjacent space
$\rho_{Refrig}$	=	Air temperature density of the refrigerated space
$DF$	=	Density factor
$q$	=	Refrigeration load for fully established flow
$h$	=	Doorway height (see Table 195)
$w$	=	Doorway width (see Table 195)

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

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

**Equation 181**

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

**Equation 182**

Where:

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

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

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

**Equation 183**

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

**Equation 184**

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

**Equation 185**

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

**Equation 186**

Where:

$kW_{baseline}$	=	<i>Baseline demand consumption of the compressor</i>
$kW_{retrofit}$	=	<i>Demand consumption of the compressor, post-retrofit</i>
$kWh_{baseline}$	=	<i>Baseline energy consumption of the compressor</i>
$kWh_{retrofit}$	=	<i>Energy consumption of the compressor, post-retrofit</i>

<i>EER</i>	=	<i>EER per facility type (see Table 195), which are averaged or weighted across suction-group types (see Table 196)</i>
<i>FLH</i>	=	<i>Assumed full-load hours per facility type (see Table 195)</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:

$$\Delta kW = kW_{baseline} - kW_{retrofit} \quad \text{Equation 187}$$

$$\Delta kWh = kWh_{baseline} - kWh_{retrofit} \quad \text{Equation 188}$$

$$\text{Peak Demand Savings } [kW_{savings}] = \frac{\Delta kW}{h \times w} \quad \text{Equation 189}$$

$$\text{Energy Savings } [kWh_{savings}] = \frac{\Delta kWh}{h \times w} \quad \text{Equation 190}$$

Where:

$\Delta kW$	=	<i>Whole-door demand savings</i>
$\Delta kWh$	=	<i>Whole-door energy savings</i>

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 195. EER variables are calculated as either the simple or weighted average of representative EERs for refrigeration suction groups that correspond to medium temperature (cooler) or low temperature (freezer) multiplex or standalone units; these are detailed in Table 196.

**Table 195. Strip Curtains—Savings Calculation Input Assumptions<sup>419</sup>**

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	$R_h$	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 <sup>420</sup>	$EER$	9.8	4.0	9.8	4.0	11	4.1	9.8	–

<sup>419</sup> 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>.

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



**Table 196. Strip Curtains—Default EER by System Configuration<sup>421</sup>**

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

**Table 197. Strip Curtains—Energy Consumption and Demand for Coolers and Freezers**

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

<sup>421</sup> Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10<sup>th</sup>, 2019. <https://rtf.nwccouncil.org/measure/strip-curtains>.

## Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are shown below in Table 198.

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

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

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

### Claimed Peak Demand Savings

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

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWikIn-StripCrtn.<sup>422</sup>

### 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

<sup>422</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 199. Strip Curtains—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Added documentation for calculation methodology. Updated tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.8 Zero-Energy Doors for Refrigerated Cases Measure Overview

**TRM Measure ID:** NR-RF-ZE

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This document presents the deemed savings methodology for the installation of zero-energy doors for refrigerated cases. These new zero-energy door designs eliminate the need for anti-sweat heaters to prevent the formation of condensation on the glass surface by incorporating heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate glass panes, and/or non-metallic frames.

### Eligibility Criteria

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

### Baseline Condition

The baseline efficiency case is a standard vertical reach-in refrigerated case with anti-sweat heaters on the glass surface of the doors.<sup>423</sup>

### 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.

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<sup>423</sup> An open refrigerated case is not a baseline for these existing deemed savings. Contact the evaluation team for preliminary approval of the savings methodology for the application of a zero-energy door to an open refrigerated case.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

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

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

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

For medium temperature:

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

For low temperature:

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

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

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

**Equation 191**

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

**Equation 192**

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system,<sup>426</sup> 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 193**

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<sup>424</sup> 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](https://www.puc.pa.gov/Electric/pdf/Act129/Act129_TRM-2016_Redlined-Final.pdf).

<sup>425</sup> Ibid. Here, “low temperature” is equivalent to the categorization “freezers”.

<sup>426</sup> *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.<sup>427</sup>

For medium temperature compressors, the following equation is used to determine the EER<sub>MT</sub> [Btu/hr/watts]. These values are shown in Table 200.

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

**Equation 194<sup>428</sup>**

Where:

<i>a</i>	=	3.75346018700468
<i>b</i>	=	-0.049642253137389
<i>c</i>	=	29.4589834935596
<i>d</i>	=	0.000342066982768282
<i>e</i>	=	-11.7705583766926
<i>f</i>	=	-0.212941092717051
<i>g</i>	=	-1.46606221890819 x 10 <sup>-6</sup>
<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</i>	=	<i>T</i> <sub>DB</sub> + 15
<i>T</i> <sub>DB</sub>	=	Dry-bulb temperature

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

<sup>428</sup> 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](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<sub>LT</sub> [Btu/hr/watts]:

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

Equation 195<sup>429</sup>

Where:

<i>a</i>	=	9.86650982829017
<i>b</i>	=	-0.230356886617629
<i>c</i>	=	22.905553824974
<i>d</i>	=	0.00218892905109218
<i>e</i>	=	-2.4886737934442
<i>f</i>	=	-0.248051519588758
<i>g</i>	=	-7.57495453950879 × 10 <sup>-6</sup>
<i>h</i>	=	2.03606248623924
<i>i</i>	=	-0.0214774331896676
<i>j</i>	=	0.000938305518020252
<i>SCT</i>	=	<i>T</i> <sub>DB</sub> + 10

**Table 200. Zero-Energy Doors—Savings Calculations Input Assumptions**

Climate zone	<i>T</i> <sub>DB</sub> <sup>430</sup>	<i>SCT</i> <sub>MT</sub>	<i>SCT</i> <sub>LT</sub>	<i>EER</i> <sub>MT</sub>	<i>EER</i> <sub>LT</sub>
Climate Zone 1: Amarillo	98.6	113.6	108.6	6.18	4.74
Climate Zone 2: Dallas	101.4	116.4	111.4	5.91	4.56
Climate Zone 3: Houston	97.5	112.5	107.5	6.29	4.86
Climate Zone 4: Corpus Christi	96.8	111.8	106.8	6.36	4.91
Climate Zone 5: El Paso	101.1	116.1	111.1	5.94	4.58

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

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

Equation 196

<sup>429</sup> Ibid.

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

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

**Equation 197**

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

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

**Equation 198**

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

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

**Equation 199**

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

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

**Equation 200**

**Table 201. Zero-Energy Doors—Energy and Peak Demand Savings**

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

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ZeroHtDrs.<sup>431</sup>

<sup>431</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.



## **Program Tracking Data and Evaluation Requirements**

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

- Refrigeration temperature range

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

## **Relevant Standards and Reference Sources**

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

## **Document Revision History**

**Table 202. Zero-Energy Doors—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Updated savings methodology to be consistent with the door heater controls measure.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Clarified energy and demand savings are in kilowatt/door rather than kilowatt/feet. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Added clarification for baseline condition.
v11.0	10/2023	TRM v11.0 update. No revision.

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

**TRM Measure ID:** NR-RF-DG

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

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

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets with at least six inches of damage for reach-in units and at least two feet of damage for walk-in units.<sup>432</sup> An average baseline gasket efficacy<sup>433</sup> of 90 percent is assumed for this measure.

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

<sup>433</sup> 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.<sup>434,435</sup> The results from the PG&E evaluation were used as the foundation for establishing the energy savings for the refrigeration gasket measures. The energy savings achievable for new gaskets replacing baseline gaskets were found during this study to be dependent almost entirely on the leakage through the baseline gaskets. Therefore, the energy savings attributable to door gaskets were derived for various scenarios regarding baseline gasket efficacies and are shown in Table 203 below.

**Table 203. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. of Installed Door Gasket)<sup>436</sup>**

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

As the PG&E analysis was performed in California with different climate zones as compared to those in Texas, an analysis was conducted to develop an adjustment factor to associate the savings in the table above to Texas anticipated results. The PG&E study could not be used to determine these effects, as insufficient climate zones were researched. Therefore, the SCE study was utilized as savings in this study were determined for each of the 16 climate zones in California and were similar<sup>437</sup> to those assessed within the PG&E results at 90 percent efficacy. A comparison was completed between the SCE energy savings and the typical meteorological year 3 (TMY3) data<sup>438</sup> 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.

<sup>434</sup> 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.

<sup>435</sup> 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](http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf).

<sup>436</sup> Ibid., Table 5-3.

<sup>437</sup> 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.

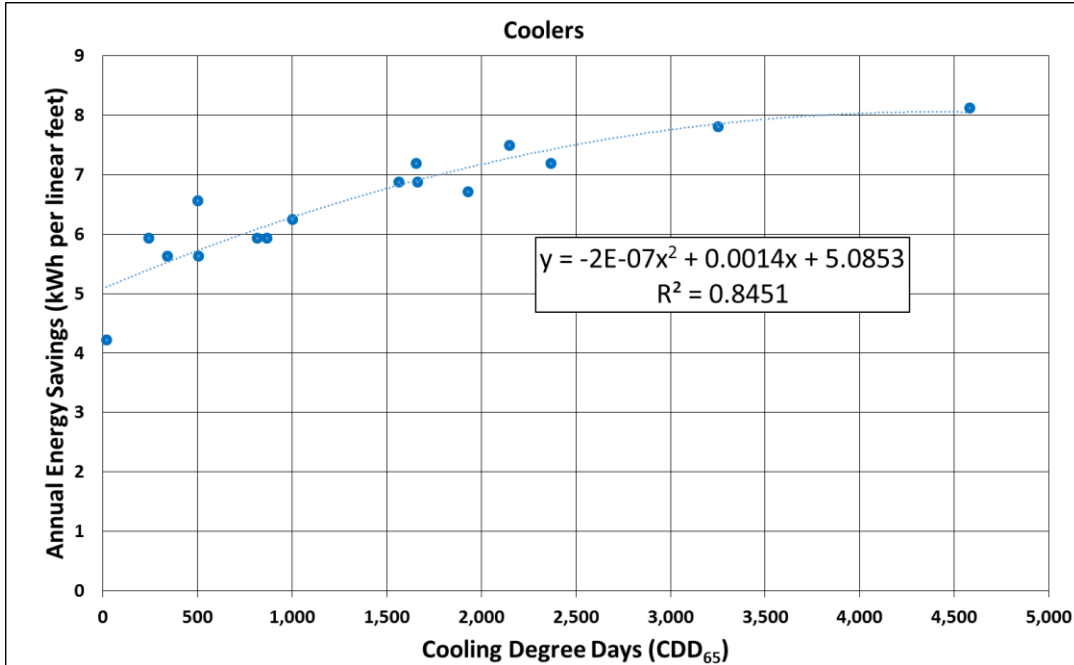
[http://www.calmac.org/publications/comfac\\_evaluation\\_v1\\_final\\_report\\_02-18-2010.pdf](http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf).

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.

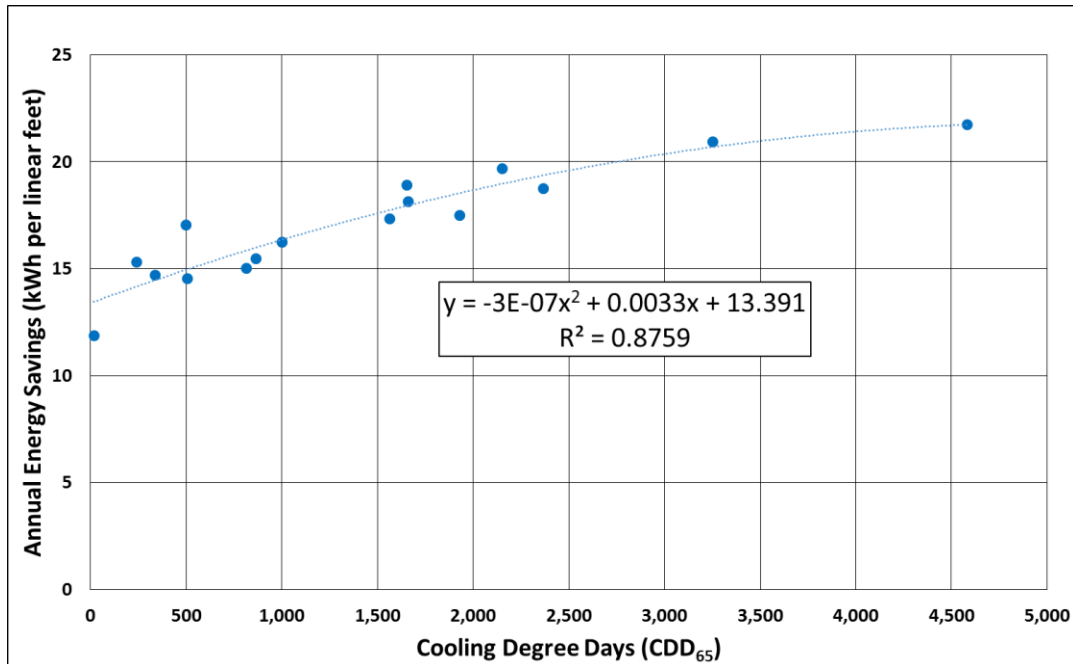
<sup>438</sup> <http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>

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

**Figure 3. Door Gaskets—Comparison of Projected Annual Energy Savings to CDDs for All 16 CA Climate Zones for Reach-In Display Cases (Coolers)**



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



These correlations were used to adjust the energy savings and TMY3 CDDs in California to TMY3 CDDs in Texas to determine an average energy savings of 7.4 and 20.0 kWh/linear feet for coolers and freezers in Texas. Comparing the average energy savings between California and Texas, the CDD adjustment results in a 113 percent adjustment factor for coolers and a 117 percent adjustment factor for freezers. For simplicity, an average adjustment factor of 115 percent (the midpoint of 113% and 117% TX vs. CA energy savings values) was applied to the PG&E results at 90 percent efficacy (as shown in Table 203 above), resulting in Texas-based annual energy savings values for coolers of 3.5 kWh/linear feet and freezers of 26.5 kWh/linear feet. These results are summarized in Table 204 below.

**Table 204. Door Gaskets—Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Lin. Ft. of Installed Door Gasket)**

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

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

## Savings Algorithms and Input Variables

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

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

**Equation 201**

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

**Equation 202**

Where:

$\Delta kWh/ft$  = Annual energy savings per linear foot of gasket (see Table 205)

$L$  = Total gasket length (ft.)

## Deemed Energy and Demand Savings Tables

**Table 205. Door Gaskets—Energy and Peak Demand Savings per Lin. Ft. of Door Gasket**

Refrigerator type	$\Delta kW/ft$	$\Delta kWh/ft$
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.<sup>439</sup>

## 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.

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

## Document Revision History

**Table 206. Door Gaskets—Revision History**

TRM version	Date	Description of change
v6.0	10/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.5.10 High-Speed Doors for Cold Storage Measure Overview

**TRM Measure ID:** NR-RF-HS

**Market Sector:** Commercial

**Measure Category:** Refrigeration

**Applicable Building Types:** Commercial

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Algorithms

**Savings Methodology:** Algorithms

### Measure Description

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

### Eligibility Criteria

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

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<sup>440</sup> 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 203**

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

**Equation 204**

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

**Equation 205**

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

**Equation 206**

Where:

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

<sup>441</sup> Operating hours taken from TRM Volume 3, Table 8, hours for refrigerated warehouse.

3,790	=	Constant <sup>442</sup>
$q_s/A$	=	Sensible heat load of infiltration air per square foot of door opening, ton/ft <sup>2</sup> , see Table 212
$R_s$	=	Sensible heat ratio of the infiltration air heat gain, see Table 213
$\Delta D_t$	=	Change in percent of time the doorway is open, 0.33 <sup>443</sup>
$DFF$	=	Doorway flow factor, varies based on temperature delta between cold room and infiltration air, 0.8 for delta T $\geq$ 20°F, 1.1 for delta T < 20°F <sup>444</sup>
$\Delta E$	=	Change in door effectiveness, 0.2 <sup>445</sup>
$COP$	=	Coefficient of performance, assume 2.8 COP <sup>446</sup>
3,412	=	Constant to convert from Btu to kWh and from Btuh to kW

**Table 207. High-Speed Doors—Energy Factors for Door to Unconditioned Area**

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

<sup>442</sup> From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

<sup>443</sup> 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.

<sup>444</sup> ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 17 notes.

<sup>445</sup> 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.

<sup>446</sup> Air cooled chiller efficiency from IECC 2009.

**Table 208. High-Speed Doors—Energy Factors for Door to Conditioned Area**

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

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

Climate zone	All temperatures
All climate zones	1.0

**Table 210. High-Speed Doors—Summer Coincidence Factors for Door to Unconditioned Area**

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

**Table 211. High-Speed Doors—Winter Coincidence Factors for Door to Unconditioned Area**

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

**Table 212. High-Speed Doors—Sensible Heat Load of Infiltration Air<sup>447</sup>**

Cold room temperature	Climate zone							
	Z1-2, winter peak	Z3-5, winter peak	Z1, annual	Z2, Z5, annual	Z3-4, annual	Z4, summer peak	Z1, Z5, summer peak	Z2-3, summer peak
	Infiltration air temperature							
	15°F	30°F	63°F	70°F	75°F	96°F	99°F	103°F
-20°F	0.2	0.40	0.85	0.94	1.02	1.31	1.38	1.45
0°F	–	0.18	0.55	0.62	0.68	0.95	1.03	1.08
20°F	–	0.08	0.30	0.35	0.42	0.65	0.70	0.76
40°F	–	–	0.13	0.17	0.30	0.38	0.45	0.50

**Table 213. High-Speed Doors—Sensible Heat Ratio of Infiltration Air<sup>448</sup>**

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			

<sup>447</sup> 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.

<sup>448</sup> Sensible heat ratio determined from psychrometric chart, using values for the air properties of dry bulb Temperature and relative humidity. Relative humidity of the cold room is estimated at 90 percent based on ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, Table 9. Energy factor values for unconditioned space are the average annual values between the expected operating hours of 8 a.m. to 6 p.m. using TMY3 data. Demand factor values for unconditioned space are taken using the highest probability temperatures from TRM Volume 1 and their associated relative humidity from TMY3 data. Energy and demand factor values for conditioned space assume conditioned air temperature of 75°F and 45 percent RH.

## **Deemed Energy and Demand Savings Tables**

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

## **Claimed Peak Demand Savings**

The utilization of the high-speed doors coincident with the peak demand period is uncertain, an average of the total savings over the operating hours per facility type is used (the absence of *hours* in Equation 206 implies Equation 203 can be divided by *hours* to yield *kW savings*).

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

## **Measure Life and Lifetime Savings**

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

## **Program Tracking Data and Evaluation Requirements**

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

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

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

## Document Revision History

Table 214. High-Speed Doors—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

## 2.6 NONRESIDENTIAL: WATER HEATING

### 2.6.1 Heat Pump Water Heaters Measure Overview

**TRM Measure ID:** C-WH-HW

**Market Sector:** Commercial

**Measure Category:** Water heating

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

**Fuels Affected:** Electricity and gas

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure involves the replacement of an electric storage water heater with an ENERGY STAR compliant heat pump water heater (HPWH) in a commercial application.

### Eligibility Criteria

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

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

### Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency uniform energy factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.<sup>449</sup>

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<sup>449</sup> 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](http://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8).

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.<sup>450</sup> The TRM will add an early retirement baseline after the effective date for the new standard.

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

Rated storage volume	Draw pattern	FHR <sup>451,452</sup>	UEF <sup>453</sup>
≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	0.8808 – (0.0008 × V <sub>r</sub> )
	Low usage	18 ≤ FHR < 51	0.9254 – (0.0003 × V <sub>r</sub> )
	Medium usage	51 ≤ FHR < 75	0.9307 – (0.0002 × V <sub>r</sub> )
	High usage	75 ≤ FHR	0.9349 – (0.0001 × V <sub>r</sub> )
> 55 gal and ≤ 120 gal	Very small usage	0 ≤ FHR < 18	1.9236 – (0.0011 × V <sub>r</sub> )
	Low usage	18 ≤ FHR < 51	2.0440 – (0.0011 × V <sub>r</sub> )
	Medium usage	51 ≤ FHR < 75	2.1171 – (0.0011 × V <sub>r</sub> )
	High usage	75 ≤ FHR	2.2418 – (0.0011 × V <sub>r</sub> )

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

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 216.<sup>454</sup>

**Table 216. HPWHs—ENERGY STAR Specification**

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

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

<sup>451</sup> “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>.

<sup>452</sup> Assume FHR equal to that of installed water heater.

<sup>453</sup> V<sub>r</sub> is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

<sup>454</sup> 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](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf).



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

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.<sup>455</sup>

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.<sup>456</sup>

## **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.<sup>457</sup> Temperature data are based on TMY3 dataset.<sup>458</sup> The area served by the HPWH may only be a portion of a commercial building, the area served by the water heater must be documented. Alternately, the daily demand per unit in the table may also be used to estimate consumption and translated to annual consumption.

<sup>455</sup> 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](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).

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

<sup>457</sup> 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>.

<sup>458</sup> TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, <https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here: <https://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

## Energy Savings Algorithm

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

**Equation 207**

Where:

- $\rho$  = Water density [lbs/gal] = 8.33  
 $C_p$  = Specific heat of water [Btu/lb·°F] = 1  
 $GPY$  = Estimated annual hot water use in gallons/year.

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

**Table 217. HPWHs—Water Heater Consumption (Gal/Year)<sup>459</sup>**

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

<sup>459</sup> Osman S, & Koomey, J. G J 1995, National Laboratory 1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting. Table 2.

<https://escholarship.org/uc/item/2j42t2c3>.

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

**Table 218. HPWHs—Water Mains Temperature ( $^{\circ}F$ )<sup>461</sup>**

Climate zone	$T_{supply,annual}$	$T_{supply,seasonal}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

## Demand Savings Algorithm

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

**Equation 208**

Where:

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

<sup>460</sup> 120 $^{\circ}F$  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 $^{\circ}F$ .

<sup>461</sup> Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, <https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here: <https://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

**Table 219. HPWHs—Seasonal Peak CFs<sup>462</sup>**

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

## Deemed Energy Savings Tables

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

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

## Deemed Summer Demand Savings Tables

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

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Upstream/Midstream Delivery

For upstream/midstream program designs where the building type is known, use the GPY identified in Table 217 associated with the proper building type and the area of the building must be reported.

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

<sup>462</sup> Probability weighted seasonal peak CFs are calculated according to the method in Section 4 of Texas TRM Vol. 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values are used for summer calculations. Off Peak Season, Peak Weekday values are used for winter calculations. <http://loadshape.epri.com/enduse>

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 13 years.<sup>463</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 220. Commercial Heat Pump Water Heaters—Revision History**

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

<sup>463</sup> 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, “Heat Pump Water Heaters and American Homes: A Good Fit?” p 9-74.

<https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf>.

## 2.6.2 Central Domestic Hot Water Controls Measure Overview

**TRM Measure ID:** NR-WH-DC

**Market Sector:** Commercial

**Measure Category:** Water heating

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

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

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

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

## Energy and Demand Savings Methodology

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

### Savings Algorithms and Input Variables

#### Circulation Pump Savings Algorithm

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

**Equation 209**

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

**Equation 210**

Where:

$kW_{\text{pump}}$	=	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% <sup>464</sup>
Hours	=	Hours per year = 8,760
CF	=	Seasonal peak coincidence factor, see Table 221

**Table 221. Central DHW Controls—Seasonal Peak CFs<sup>465</sup>**

Building type	Commercial		Lodging <sup>466</sup>	
	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

<sup>464</sup> 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.

<sup>465</sup> Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. <http://loadshape.epri.com/enduse>.

<sup>466</sup> 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 <sup>466</sup>	
	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

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

Equation 211

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

Equation 212

Where:

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

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

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

**Table 222. Central DHW Controls—Reference kWh by Water Heater and Building Type<sup>467</sup>**

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

**Table 223. Central DHW Controls—HDD Adjustment Factors<sup>468</sup>**

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

<sup>467</sup> 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.

<sup>468</sup> HDD Adjustment factors for DHW controls are derived by dividing the HDD for each Texas climate zone by the HDD from the reference climate zone (California Climate Zone 13).



## Deemed Energy Savings Tables

Table 224 presents the energy savings (kWh) for a range of pump sizes for all climate zones. The deemed savings are provided for convenience, but the algorithm may be used for pump sizes that differ from the assumed wattage listed in the tables.

**Table 224. Central DHW Controls—Circulation Pump Energy Savings**

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

Table 225 presents the thermal energy savings (kWh) per dwelling unit for all climate zones. Thermal energy savings only apply to lodging building types where lodging takes place (multifamily, hotels, nursing homes, dormitories, prisons, and similar). For commercial applications, please follow a custom approach.

**Table 225. Central DHW Controls—Thermal Distribution Energy Savings per Dwelling Unit**

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 226. 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 227. Central DHW Controls—Thermal Distribution Peak Demand Savings per Dwelling Unit**

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Climate Zone 1: Amarillo	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Climate Zone 2: Dallas	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Climate Zone 3: Houston	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Climate Zone 4: Corpus Christi	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Climate Zone 5: El Paso	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Time clock.<sup>469</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 228. Central DHW Controls—Revision History**

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

<sup>469</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

### 2.6.3 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

**TRM Measure ID:** NR-WH-SV

**Market Sector:** Commercial

**Measure Category:** Water heating

**Applicable Building Types:** Lodging

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

#### Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)<sup>470</sup> 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.

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<sup>470</sup> 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 213**

Where:

*SHFR* = Showerhead flow rate, gallons per minute [gpm] (see Table 229)

*BW* = Behavioral waste, minutes per shower (see Table 229)

*n<sub>s</sub>* = Number of showers per occupied room per day (see Table 229)

365 = Constant to convert days to years (see Table 229)

*OCC* = Occupancy rate (see Table 229)

*n<sub>SH</sub>* = Number of showerheads per room (see Table 229)

Applying the formula to the values used for Texas from Table 229 returns the following values for baseline behavioral waste in gallons per showerhead per year:

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

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

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

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

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 229.

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

**Equation 214**

Where:

$HW\%$  = Hot water percentage (see Table 229)

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

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 229. Showerhead TSRVs—Hot Water Usage Reduction**

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower) <sup>471</sup>				1.742
Showers/occupied room/day <sup>472</sup>				1.756
Occupancy rate <sup>473</sup>				65.9%
Showerheads/room <sup>474</sup>				1.0
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water <sup>475</sup>	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 215**

<sup>471</sup> 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.

<sup>472</sup> 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.

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

<sup>474</sup> Assuming industry standard for standard one-bathroom rooms.

<sup>475</sup> 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:

$\rho$	=	Water density [lb/gal] = 8.33
$C_p$	=	Specific heat of water [Btu/lb°F] = 1
$V$	=	Hot water saved per year per showerhead [gal] (see Table 229)
$T_{Setpoint}$	=	Water heater setpoint [°F] <sup>476</sup> = 120
$T_{Supply,Avg}$	=	Average supply water temperature [°F] (see Table 230)
$RE$	=	Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric-resistance water heaters, or 2.2 for heat-pump water heaters. <sup>477</sup>
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.

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

**Equation 216**

Where:

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

<sup>476</sup> 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.

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

**Table 230. Showerhead TSRVs—Water Mains Temperatures**

Climate zone	Water mains temperature (°F) <sup>478</sup>		
	T <sub>SupplyAverage</sub>	T <sub>SupplySeasonal</sub>	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

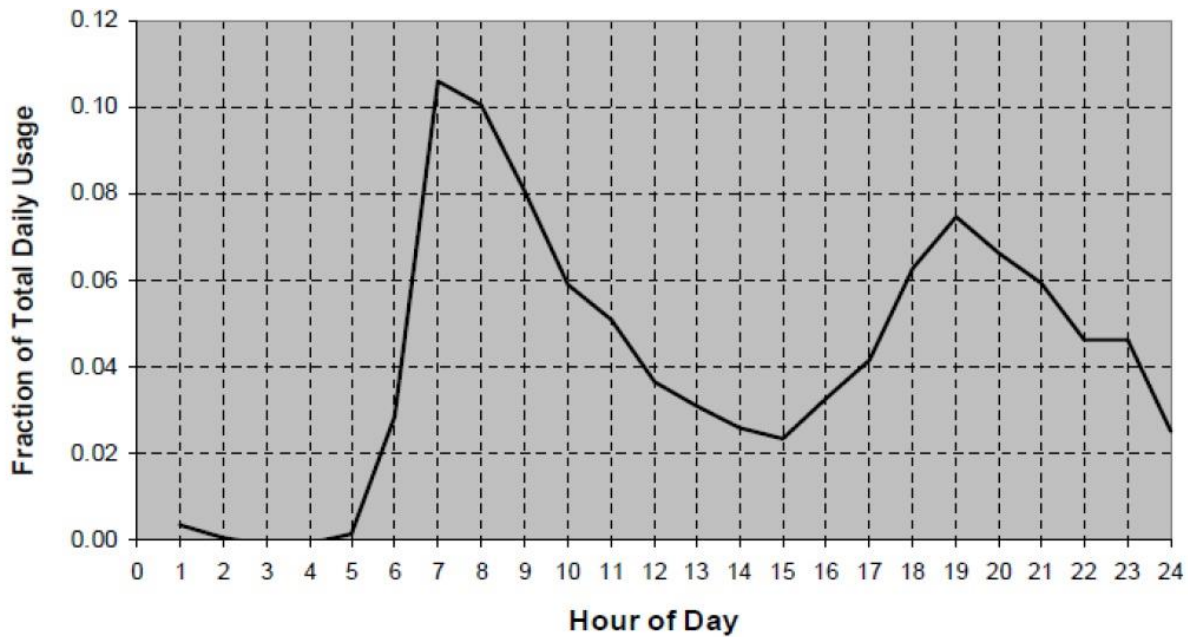
**Table 231. Showerhead TSRVs—Peak Coincidence Factors**

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

<sup>478</sup> Based on typical meteorological year (TMY) dataset for TMY3: <https://sam.nrel.gov/weather-data.html>.



Figure 5. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile<sup>479</sup>



## 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.

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

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

Table 232. Showerhead TSRVs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

<sup>480</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

<sup>481</sup> 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)<sup>482</sup> 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.

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<sup>482</sup> 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 217**

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

**Equation 218**

Where:

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

Applying the formula to the values from Table 233 returns the following values:

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

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

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

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

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

**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 219**

Where:

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

$t_s$  = Shower time (min/shower) (see Table 233)

Applying the formula to the values used for Texas from Table 233 returns the following values:

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

**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 233.

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

**Equation 220**

Where:

SHBW = Showerhead behavioral waste (gal)

TSBW = Tub-spout behavioral waste (gal)

DW = Diverter waste (gal)

$HW\%_{SH,TS}$  = Showerheads and tub-spout hot water percentage (see Table 233)

$HW\%_D$  = Diverter hot-water percentage (see Table 233)

Applying the formula to the values from Table 233 returns the following values:

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

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

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

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

**Table 233. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction**

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			–
Tub-spout flow rate (gpm) <sup>483</sup>	–	5.0		–
Percentage of warm-up events <sup>484</sup>	60%	40%		–
Average behavioral waste (minutes per shower) <sup>485</sup>		1.742		–
Average diverter leakage-rate (gpm) <sup>486</sup>		–	0.80	–
Average shower time (minutes) <sup>487</sup>		–	7.8	–
Showers/occupied room/day <sup>488</sup>				1.756
Occupancy rate <sup>489</sup>				65.9%

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

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

<sup>485</sup> 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.

<sup>486</sup> Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverter.

<sup>487</sup> Cadmus and Opinion Dynamics Evaluation Team, “Memorandum: Showerhead and Faucet Aerator Meter Study”. Prepared for Michigan Evaluation Working Group.

<sup>488</sup> 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.

<sup>489</sup> 2001–2021 U.S. hotel occupancy rates from Statista. <https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/>. Used average of last five pre-COVID years (2015–2019).

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Showerheads/room <sup>490</sup>				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 <sup>491</sup>	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 221**

Where:

- $\rho$  = Water density [lb/gal] = 8.33
- $C_p$  = Specific heat of water [Btu/lb°F] = 1
- $V$  = Hot water saved per year per showerhead [gal] (see Table 233)

<sup>490</sup> Assuming industry standard for standard one-bathroom rooms.

<sup>491</sup> Average percentage of hot water for warm-up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

$T_{Setpoint}$	=	Water heater setpoint [°F] <sup>492</sup> = 120
$T_{Supply,Avg}$	=	Average supply water temperature [°F] (see Table 234)
$RE$	=	Recovery efficiency (or in the case of heat-pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, or 2.2 for heat-pump water heaters <sup>493</sup>
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 222**

Where:

$T_{Supply,Seasonal}$	=	Seasonal-supply water temperature (see Table 234)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 235)

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

Climate zone	Water mains temperature (°F) <sup>494</sup>		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		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

<sup>492</sup> 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.

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

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

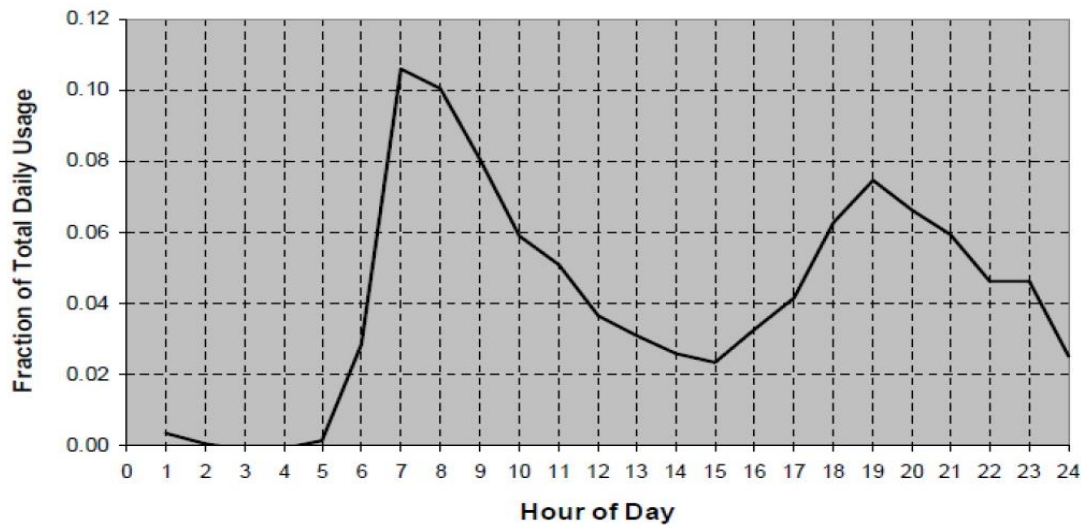


Climate zone	Water mains temperature (°F) <sup>494</sup>		
	T <sub>SupplyAverage</sub>	T <sub>SupplySeasonal</sub>	
		Summer	Winter
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

**Table 235. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors**

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

**Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile<sup>495</sup>**



## 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.

<sup>495</sup> 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.<sup>496</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 236. Tub Spout/Showerhead TSRVs—Revision History**

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

<sup>496</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## 2.7 NONRESIDENTIAL: MISCELLANEOUS

### 2.7.1 Variable Frequency Drives for Water Pumping Measure Overview

**TRM Measure ID:** NR-MS-WP

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

#### Measure Description

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

#### Eligibility Criteria

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

#### Baseline Condition

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

#### High-Efficiency Condition

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

#### Energy and Demand Savings Methodology

#### Savings Algorithms and Input Variables

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

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

Baseline Technology<sup>497</sup>:

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

**Equation 223**

Where:

*%GPM* = Percentage flow rate (see Table 237)

*i* = Each hour of the year

**Table 237. Water Pumping VFDs—Water Demand Profile**<sup>498</sup>

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

VFD Technology<sup>499</sup>:

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

**Equation 224**

<sup>497</sup> 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.

<sup>498</sup> 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>.

<sup>499</sup> 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 225**

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

**Equation 226**

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
- $\eta$  = Motor efficiency of a standard efficiency motor (see Table 238)

**Table 238. Water Pumping VFDs—Motor Efficiencies<sup>500</sup>**

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		

<sup>500</sup> 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](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 227**

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

**Equation 228**

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 229**

Where:

8,760 = Total number of hours in a year

**Step 2** – Subtract Annual kWh<sub>new</sub> from Annual kWh<sub>baseline</sub> to get the energy savings:

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

**Equation 230**

**Deemed Energy and Demand Savings Tables**

Table 275 presents the deemed summer and winter peak kilowatt savings per motor horsepower.

**Table 239. 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.<sup>501</sup>

## 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 240. Water Pumping VFDs—Revision History

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

<sup>501</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## 2.7.2 Premium Efficiency Motors Measure Overview

**TRM Measure ID:** NR-MS-PM

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** 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 245. 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).<sup>502</sup>

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<sup>502</sup> 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)<sup>503</sup> (see Table 244) 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)<sup>504</sup>, as listed in Table 246.

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 244.

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.

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<sup>503</sup> 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>.

<sup>504</sup> Federal Standards for Electric Motors, Tables 3 ( $\leq 200$  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 241 or Table 242 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 231**

#### **Demand Savings Algorithms**

##### **HVAC Applications:**

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

**Equation 232**

##### **Industrial Applications<sup>505</sup>:**

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

**Equation 233**

Where:

HP	=	Nameplate horsepower data of the motor
0.746	=	Constant to convert from hp to kWh <sup>506</sup>
LF	=	Estimated load factor (if unknown, see Table 241 or Table 242)

<sup>505</sup> Assumes three-shift operating schedule

<sup>506</sup> U.S. 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 244)<sup>507</sup>
- $\eta_{post}$  = Efficiency of the newly installed motor [%]
- Hrs = Estimated annual operating hours (if unknown, see Table 241 or Table 242)
- CF = Peak coincidence factor (see Table 241)
- $kWh_{savings,ROB}$  = Total energy savings for a new construction or ROB project
- $kW_{savings,ROB}$  = Total demand savings for a new construction or ROB project

**Table 241. Premium Motors—HVAC Input Assumptions**

Building type	Load factor <sup>508</sup>	CF <sup>509</sup>	HVAC fan hours <sup>510</sup>
Healthcare: Inpatient	0.75	1.00	8,760
Office: Large (>30k sq. ft.)			4,424
Office: Small (≤30k sq. ft.)			4,006
Education: K-12 school			4,173
Education: College/university			4,590
Mercantile: All retail			5,548
Food service: Quick-service restaurant			6,716
Food service: Full-service restaurant			5,256

<sup>507</sup> In the case of rewind motors, in-situ efficiency may be reduced by a percentage as found in Table 243.

<sup>508</sup> Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25.

[http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport\\_ItronVersion.pdf](http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf)

<sup>509</sup> Commercial Prototype Building Models HVAC operating schedules for hours ending 15-18. U.S. Department of Energy. [https://www.energycodes.gov/development/commercial/prototype\\_models](https://www.energycodes.gov/development/commercial/prototype_models)

<sup>510</sup> Factors are equivalent to Table 90 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

**Table 242. Premium Motors—Industrial Input Assumptions**

Industrial processing	Load factor <sup>511</sup>	Hours <sup>512</sup>					
		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 243. Premium Motors—Rewound Motor Efficiency Reduction Factors<sup>513</sup>**

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

**Table 244. Premium Motors—NC/ROB Baseline Efficiencies by Motor Size (%)<sup>502,506,518</sup>**

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

<sup>511</sup> 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](https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf)

<sup>512</sup> 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](https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf)

<sup>513</sup> 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 245); 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 245. Premium Motors—Remaining Useful Life (RUL) of Replaced Motor<sup>514</sup>**

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 <sup>515</sup>	0.0
9	5.9		

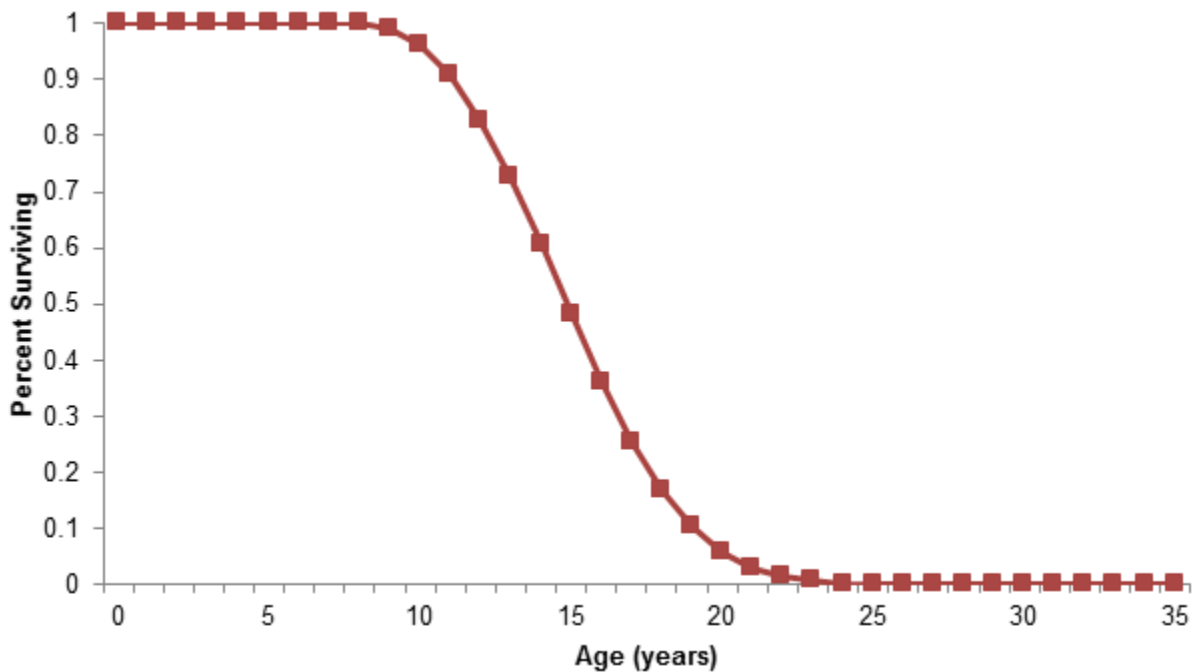
### ***Derivation of RULs***

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.

<sup>514</sup> 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.

<sup>515</sup> 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 Motors<sup>516</sup>**



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 234**

<sup>516</sup> 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](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 235**

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 236**

### ***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 237**

#### **Industrial Applications**

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8,760 \text{ hours}}$$

**Equation 238**

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 239**

#### **Industrial Applications**

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8,760 \text{ hours}}$$

**Equation 240**



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 241**

Where:

- $\eta_{baseline,ER}$  = Assumed original motor efficiency for remaining EUL time period (Table 246 or Table 247)<sup>517</sup>
- $kWh_{savings,RUL}$  = 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 246. Premium Motors—ER Baseline Efficiencies by Motor Size (%)**<sup>504,518</sup>

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

<sup>517</sup> Ibid.

<sup>518</sup> 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 247. Premium Motors—ER Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)<sup>519,520</sup>**

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.

<sup>519</sup> Federal Standards for Electric Motors, Table 4,

<sup>520</sup> 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.<sup>521</sup>

## 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.

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<sup>521</sup> 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 248. 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. Replacement-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.

## 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”<sup>522</sup> occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

### Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number<sup>523</sup> 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.

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<sup>522</sup> 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.

<sup>523</sup> 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*<sup>524</sup> (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*,<sup>525</sup> 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.<sup>526</sup>

## 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 242**

$$\text{Demand Savings } [\Delta kW] = \frac{kWh_{savings}}{8,760}$$

**Equation 243**<sup>527</sup>

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

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

**Equation 244**

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<sup>524</sup> 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).

<sup>525</sup> *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.

<sup>526</sup> The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

<sup>527</sup> 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 245<sup>528</sup>

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 249)
ME	=	Motor efficiency, based on NEMA Standard Efficiency Motor (see Table 250)
SME	=	Mechanical efficiency of sucker-rod pump (see Table 249)
Time Clock%On	=	Stipulated-baseline time clock setting (see Table 249)
$Run_{constant}, Run_{coefficient}$	=	8.336, 0.956, derived from SPE 16363 <sup>529</sup>
VolumetricEfficiency%	=	Average well gross production divided by theoretical production (provided on rebate application)
8,760	=	Total hours per year

<sup>528</sup> 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).

<sup>529</sup> 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 249. Pump-Off Controllers—Savings Calculation Input Assumptions**

Variable	Stipulated/deemed values
LF (Load factor)	25% <sup>530</sup>
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95% <sup>531</sup>
Time clock%On	65% <sup>532</sup>

**Table 250. Pump-Off Controllers—NEMA Premium Efficiency Motor Efficiencies<sup>533</sup>**

Motor horsepower	Nominal full-load efficiency					
	Open motors (ODP)			Enclosed motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%

<sup>530</sup> 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.

<sup>531</sup> Engineering estimate for standard gearbox efficiency.

<sup>532</sup> 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.

<sup>533</sup> 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](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 243.

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.<sup>534</sup>

## Program Tracking Data and Evaluation Requirements

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

- Motor manufacturer
- Motor model number
- Rated motor horsepower
- Motor type (TEFC or ODP)
- Rated motor RPM
- Baseline control type and time clock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times<sup>535</sup>

## 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.

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<sup>534</sup> 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.

<sup>535</sup> 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 251. Pump-Off Controllers—Revision History**

TRM version	Date	Description of change
v2.1	01/30/2015	TRM v2.1 origin.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. 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:** Commercial

**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

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

### Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa<sup>536</sup>.

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.<sup>537</sup> The default pump curves provided in the ENERGY STAR Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

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<sup>536</sup> 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>

<sup>537</sup> Hunt, A. and Easley, S., "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), U.S. DOE. May 2012. <http://www.nrel.gov/docs/fy12osti/54242.pdf>.

## Baseline Condition

The baseline condition is a 1 to 5 horsepower (hp) standard efficiency single-speed pool pump. This measure is only applicable to retrofit applications. New construction applications are not eligible as of July 19, 2021.<sup>538</sup>

## 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.

## 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.<sup>539</sup>

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

Equation 246

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:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times \text{hours} \times \text{days}}{EF_{conv} \times 1,000}$$

Equation 247

$$kWh_{ES} = \frac{V \times TO \times \text{days}}{EF_{ES} \times 1,000}$$

Equation 248

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<sup>538</sup> Federal standard for dedicated-purpose pool pumps.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=67](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67).

<sup>539</sup> The ENERGY STAR Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR website at: <https://www.energystar.gov/productfinder/product/certified-pool-pumps/results>.

Where:

- $PFR_{conv}$  = Conventional single-speed pump flow rate [gal/min] (see Table 252)
- $EF_{conv}$  = Conventional single-speed pump energy factor [gal/W·hr] (see Table 252)
- $EF_{ES}$  = ENERGY STAR-weighted energy factor [gal/W·hr] (see Table 253)
- hours = Conventional single-speed pump daily operating hours (see Table 252)
- 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] (see Table 253)
- $TO$  = Turnovers per day, number of times the volume of the pool is run through the pump per day (see Table 253)
- 60 = Constant to convert between minutes and hours
- 1,000 = Constant to convert from kilowatts to watts

**Table 252. Pool Pumps—Conventional Pump Input Assumptions<sup>540</sup>**

New pump HP	Hours, limited <sup>541</sup>	Hours, 24/7	$PFR_{conv}$ (gal/min)	$EF_{conv}$ (gal/W·h)
≤ 1.25	12	24	75.5000	2.5131
1.25 < hp ≤ 1.75			78.1429	2.2677
1.75 < hp ≤ 2.25			88.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ 5			101.6667	1.9987

<sup>540</sup> 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.

<sup>541</sup> 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.

**Table 253. Pool Pumps—ENERGY STAR Pump Input Assumptions<sup>542,543</sup>**

New pump HP	TO, limited	TO, 24/7	V [gal]	EF <sub>ES</sub> (gal/W·h)
≤ 1.25	2.7	5.4	20,000	8.7
1.25 < hp ≤ 1.75	2.8	5.6	20,000	8.9
1.75 < hp ≤ 2.25	2.9	5.8	22,000	9.3
2.25 < hp ≤ 2.75	2.7	5.4	25,000	7.4
2.75 < hp ≤ 5	2.6	5.2	28,000	7.1

### Demand Savings Algorithms

$$\text{Peak Demand Savings } [\Delta kW] = \frac{kWh_{conv} - kWh_{ES}}{\text{hours}} \times \frac{CF_{S/W}}{\text{days}}$$

**Equation 249**

Where:

$CF_{S/W}$  = Summer/winter seasonal peak coincidence factor (see Table 254)

**Table 254. Pool Pumps—Coincidence Factors<sup>544</sup>**

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 255. Pool Pumps—Energy Savings<sup>545</sup>**

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

<sup>542</sup> ENERGY STAR® turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

<sup>543</sup> Turnovers calculated as TO = hours x 60 x PFR<sub>conv</sub> ÷ V.

<sup>544</sup> Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

<sup>545</sup> 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 256. Pool Pumps—Summer Peak Demand Savings**

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

**Table 257. Pool Pumps—Winter Peak Demand Savings**

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

## Claimed Peak Demand Savings

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

## 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.<sup>546</sup>

## 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

<sup>546</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

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

## **References and Efficiency Standards**

### **Petitions and Rulings**

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

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 258. Pool Pumps—Revision History**

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Added ineligible products list. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General text edits. Corrected turnovers/day values in the assumptions table.
v10.0	10/2022	TRM v10.0 update. Updated for ENERGY STAR Version 3.0 Specification. Increased upper limit for pump horsepower to 5 to better reflect product availability.
v11.0	10/2023	TRM v11.0 update. No revision.



## 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

**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.<sup>547</sup>

### 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 a guest room or dorm room without occupancy controls.

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<sup>547</sup> The original petition also includes savings for HVAC-only control in master-metered multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is significantly different from the transitory occupation of hotel/motels and even dormitories. This measure is not currently being implemented and is not likely to be used in the future, but it can be added to a future TRM if warranted.

## High-Efficiency Condition

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

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

## Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies<sup>548</sup> 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.<sup>549</sup>

## 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.

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<sup>548</sup> 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.

<sup>549</sup> A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

**Table 259. Lodging Occupancy Sensors—Motel per Room Energy and Peak Demand Savings**

Climate zone <sup>550</sup>	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
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
<b>10-degree setup/setback offset</b>								
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

**Table 260. Lodging Occupancy Sensors—Hotel per Room Energy and Peak Demand Savings**

Climate zone <sup>550</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
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

<sup>550</sup> 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.

Climate zone <sup>550</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
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
<b>10-degree setup/setback offset</b>								
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 261. Lodging Occupancy Sensors—Dormitory per Room Energy and Peak Demand Savings**

Climate zone <sup>550</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
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
<b>10-degree setup/setback offset</b>								
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 Study<sup>551</sup>. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

## 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.

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<sup>551</sup> 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.

## Document Revision History

**Table 262. Lodging Occupancy Sensors—Revision History**

TRM version	Date	Description of change
v2.0	04/18/2014	TRM v2.0 origin.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. Changed Climate Zone 4 reference city from McAllen to Corpus Christi.
v11.0	10/2023	TRM v11.0 update. No revision.

## 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 applicable

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** M&V

### Measure Description

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

### Eligibility Criteria

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

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

### Baseline Condition

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

## High-Efficiency Condition

The high-efficiency condition is a 120-volt single-phase refrigerated beverage or non-refrigerated-snack vending machine with occupancy controls and compliant with the current federal standard, effective January 8, 2019.<sup>552</sup>

## 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 263. Vending Controls—Refrigerated Cold Drink Energy and Peak Savings<sup>553</sup>**

Climate zone	kWh savings	Summer kW savings <sup>554</sup>	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

<sup>552</sup> Appliance Standards for Refrigerated Beverage Vending Machines.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=29#current\\_standards](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards).

<sup>553</sup> Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

<sup>554</sup> 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](https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper.pdf).



**Table 264. Vending Controls—Refrigerated Reach-In Energy and Peak Demand Savings<sup>555</sup>**

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 265. Vending Controls—Non-Refrigerated Snack Energy and Peak Demand Savings<sup>556</sup>**

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.<sup>557</sup>

## 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

<sup>555</sup> Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

<sup>556</sup> Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

<sup>557</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A:  
[https://interchange.puc.texas.gov/Documents/40669\\_3\\_735684.PDF](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 266. Vending Controls—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Clarified baseline condition and updated demand savings for compliance with current peak definition.
v9.0	10/2021	TRM v9.0 update. General text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. 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 applicable

**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 Calculator<sup>558</sup>, and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.<sup>559</sup>

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<sup>558</sup> ENERGY STAR Low Carbon IT Calculator available for download at:  
[https://www.energystar.gov/products/low\\_carbon\\_it\\_campaign/put\\_your\\_computers\\_sleep](https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep).

<sup>559</sup> 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.<sup>560</sup>

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

*Energy Savings* [ $\Delta kWh$ ]

$$= \frac{W_{active}(Hrs_{active,pre} - Hrs_{active,post}) + W_{sleep}(Hrs_{sleep,pre} - Hrs_{sleep,post}) + W_{off}(Hrs_{off,pre} - Hrs_{off,post})}{1,000}$$

**Equation 250**

$$\text{Summer Peak Demand Savings } [\Delta kW] = (W_{active} - W_{sleep}) \times CF_{inactive,S}$$

**Equation 251**

$$\text{Winter Peak Demand Savings } [\Delta kW] = 0$$

**Equation 252**

Where:

$W_{active}$	=	Total wattage of the equipment, including computer and monitor, in active/idle mode (see Table 267)
$Hrs_{active,pre}$	=	Annual number of hours the computer is in active/idle mode before computer management software is installed (see Table 268)
$Hrs_{active,post}$	=	Annual number of hours the computer is in active/idle mode after computer management software is installed (see Table 268)
$W_{sleep}$	=	Total wattage of the equipment, including computer and monitor, in sleep mode (see Table 267)
$Hrs_{sleep,pre}$	=	Annual number of hours the computer is in sleep mode before computer management software is installed (see Table 268)
$Hrs_{sleep,post}$	=	Annual number of hours the computer is in sleep mode after computer management software is installed (see Table 268)

<sup>560</sup> 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 267)
$Hrs_{off,pre}$	=	Annual number of hours the computer is in off mode before computer management software is installed (see Table 268)
$Hrs_{off,post}$	=	Annual number of hours the computer is in off mode after computer management software is installed (see Table 268)
1,000	=	Constant to convert from W to kW
$CF_{inactive,S}$	=	Inactive summer peak coincidence factor (see Table 269)

**Table 267. Computer Power Management—Equipment Wattages<sup>561</sup>**

Equipment	$W_{active}$	$W_{sleep}$	$W_{off}$
Conventional monitor <sup>562</sup>	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

<sup>561</sup> 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](https://www.energystar.gov/buildings/save_energy_commercial_buildings/ways_save/energy_efficient_products).

<sup>562</sup> Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR® Office Equipment Calculator.

**Table 268. Computer Power Management—Operating Hours<sup>563</sup>**

Building activity type	Hrs <sub>active,pre</sub>	Hrs <sub>active,post</sub>	Hrs <sub>sleep,pre</sub>	Hrs <sub>sleep,post</sub>	Hrs <sub>off,pre</sub>	Hrs <sub>off,post</sub>
Typical office (8 hours/day, 5 days/week, 22 non-workdays/year)	4,650	1,175	0	2,105	4,110	5,480
Typical school (8 hours/day, 5 days/week, 113 non-school days/year)	4,213	727	0	1,970	4,547	6,063

**Table 269. 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 267, Table 268, and Table 269. The following tables provide these deemed values.

**Table 270. 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

<sup>563</sup> Hours taken from assumptions in the ENERGY STAR calculator. Hours<sub>pre</sub> assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night. Hours<sub>post</sub> assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.

**Table 271. 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.<sup>564</sup>

### 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)

<sup>564</sup> 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](https://www.irs.gov/irm/part1/irm_01-035-006).

## **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 272. Computer Power Management—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Incorporated version 2 baseline adjustments and revised savings.
v9.0	10/2021	TRM v9.0 update. Updated peak demand savings coefficients and deemed savings. Added application type to documentation requirements. Eliminated winter demand savings.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. 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.<sup>565</sup>

## 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

$$= \frac{\text{ENERGY STAR Idle Consumption [kWh]} \times \text{days}_C + \text{Hrs}_{\text{unplug,NC}} \times W_{\text{unplug}} \times \text{days}_{\text{NC}}}{1,000} \quad \text{Equation 253}$$

$$\text{Baseline Idle Consumption [kWh]} = \frac{\text{ENERGY STAR Idle Consumption}}{0.6} \quad \text{Equation 254}$$

$$\text{Energy Savings } [\Delta\text{kWh}] = \text{Baseline Idle Consumption} - \text{ENERGY STAR Idle Consumption} \quad \text{Equation 255}$$

$$\text{Peak Demand Savings } [\Delta\text{kW}] = \frac{\Delta\text{kWh}}{\text{Hrs}_{\text{unplug,C}} \times \text{days}_C + \text{Hrs}_{\text{unplug,NC}} \times \text{days}_{\text{NC}}} \times \text{PDPF} \quad \text{Equation 256}$$

Where:

$\text{Hrs}_{\text{plug}}$  = Time per day the vehicle is plugged into the EVSE and not charging [hours]<sup>566</sup> = 2.8

$W_{\text{plug}}$  = Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging [W]<sup>567</sup> = 6.9 W

<sup>565</sup> 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](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20DC%20EVSE%20Final%20Specification_0.pdf).

<sup>566</sup> 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.

<sup>567</sup> 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]<sup>568</sup> = 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]<sup>569</sup> = 3.3
- $days_C$  = Number of charging days per year [days]<sup>570</sup> = 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<sup>571</sup>
- PDPF = Peak demand probability factor (see Table 273)

**Table 273. EVSE—Peak Demand Probability Factors<sup>572</sup>**

Location type	Public		Workplace		Fleet	
	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

<sup>568</sup> 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.

<sup>569</sup> Average No Vehicle Mode Input Power from ENERGY STAR certified EVSE product list.

<sup>570</sup> 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.  $365 \times 0.56 = 204$ .

<sup>571</sup> 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/other/evse>.

<sup>572</sup> 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 274 presents the deemed annual energy savings per EVSE.

**Table 274. EVSE—Energy Savings**

kWh Savings (all location types)
19.7

Table 275 presents the deemed summer and winter peak kW savings per EVSE.

**Table 275. EVSE—Peak Demand Savings**

Location type	Public		Workplace		Fleet	
	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.<sup>573</sup>

<sup>573</sup> U.S. 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](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)<sup>574</sup>
- 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 276. EVSE—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. Added reference for ENERGY STAR version.
v11.0	10/2023	TRM v11.0 update. No revision.

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<sup>574</sup> 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 277. Battery Chargers—Efficiency Requirements<sup>575</sup>**

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 257**

$$\begin{aligned} \text{Energy Savings [kWh}_{\text{savings}}] &= hours_C \times \frac{W_{C,pre} - W_{C,post}}{1,000} + hours_M \times \frac{W_{M,pre} - W_{M,post}}{1,000} \\ &+ hours_{NC} \times \frac{W_{NC,pre} - W_{NC,post}}{1,000} \end{aligned}$$

**Equation 258**

$$\text{Summer Peak Demand Savings [kW}_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_S$$

**Equation 259**

$$\text{Winter Peak Demand Savings [kW}_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_W$$

**Equation 260**

Where:

$$8,760 = \text{Annual hours per year}$$

<sup>575</sup> 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>.

$DC_{C/M/NB}$	=	Duty cycle in charging, maintenance, and no battery mode (see Table 278)
$hours_{C/M/NB}$	=	Annual number of hours in charging, maintenance, and no battery mode (see Table 278)
$W_{C/M/NB}$	=	Wattage draw in charging, maintenance, and no battery mode (see Table 279)
$CF_{S/W}$	=	Seasonal peak coincidence factor (see Table 280)
1,000	=	Conversion constant for W to kW

**Table 278. Battery Chargers—Charging and Idle Hours Assumptions<sup>576</sup>**

Equipment	DC <sub>C</sub>	DC <sub>M</sub>	DC <sub>NB</sub>	hours <sub>C</sub>	hours <sub>M</sub>	hours <sub>NB</sub>
Single phase	45%	31%	24%	3,942	2,716	2,102
Three phase	94%	–	6%	8,234	–	526

**Table 279. Battery Chargers—Pre/Post Charging and Idle Wattage Assumptions<sup>577</sup>**

Equipment	W <sub>C,pre</sub>	W <sub>M,pre</sub>	W <sub>NB,pre</sub>	W <sub>C,post</sub>	W <sub>M,post</sub>	W <sub>NB,post</sub>
Single phase	2,000	50	50	1,767	10	10
Three phase	5,785	89	34	5,111	10	10

**Table 280. Battery Charging System—Coincidence Factors<sup>578</sup>**

Equipment	Summer	Winter
Single phase	0.19	–
Three phase	1	–

## Deemed Energy and Peak Demand Savings Tables

The deemed energy and seasonal peak savings values are presented in the following table.

<sup>576</sup> “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](https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf).

<sup>577</sup> “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. W<sub>pre</sub>: Table 7, W<sub>post</sub>: Table 10. [https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11\\_Battery\\_Charger\\_Title\\_20\\_CASE\\_Report\\_v2-2-2.pdf](https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf).

<sup>578</sup> “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](https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf).



**Table 281. 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.<sup>579</sup>

## 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 282. Industrial High-Frequency Battery Chargers—Revision History**

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

<sup>579</sup> “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](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**

$$Energy\ Savings\ [\Delta kWh] = \Delta Water\ (gallons) / 1,000,000 \times E_{water\ supply}$$

**Equation 261**

$$\Delta Water = \frac{S_L\ (lb/hr)}{8.33\ (lbs/gal)} \times Hours \times L$$

**Equation 262**

$$S_L = 24.24 \times P_{ia} \times D^2 \times A \times FF$$

**Equation 263**

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

**Equation 264**

Where:

$E_{water\ supply}$	=	Water supply energy factor: 2,300 kWh/million gallons
$S_L$	=	Average steam loss per trap (lb/hr) (see Table 283)
Hours	=	Annual hours when steam system is operational, equal to heating degree days by climate zone (see Table 284)
$L$	=	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 283
24.24	=	Constant lb/(hr-psia-in <sup>2</sup> )
$P_{ia}$	=	Average steam trap inlet pressure, absolute (psia), $P_{ig} + P_{atm}$
$P_{ig}$	=	Average steam trap inlet pressure, gauge (psig) (see Table 283)
$P_{atm}$	=	Atmospheric pressure, 14.7 psia

- D* = Diameter of orifice (inches), use actual if possible, or defaults in Table 283
- A* = 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)
- FF* = Flow factor for medium- and high-pressure steam systems to address industrial float and thermodynamic style traps where additional blockage is possible
- CF* = Peak coincidence factor, assume value of 1 for industrial and process steam applications; for commercial heating applications, see Table 36 through Table 40 in Section 2.2.2; for commercial dry cleaners, use *CF* for stand-alone retail

**Table 283. Steam Traps—Savings Calculation Input Assumptions<sup>580</sup>**

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, S <sub>L</sub> (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 284	0.27

<sup>580</sup> 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](https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf)

**Table 284. Steam Traps—Commercial Heating Hours**

Climate zone	Hours (HDD) <sup>581</sup>
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 285. 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 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

<sup>581</sup> Heating degree days are calculated from TMY3 Hourly Weather Data by Climate Zone, available at <http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

## Claimed Peak Demand Savings

**Table 286. Steam Traps—Peak Demand Savings, Without Audit**

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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
	Food service	Full-service restaurant	2.21E-04	2.57E-04	2.26E-04	1.80E-04	1.44E-04

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
		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
	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
	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
	Service	Service: Excluding food	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	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
	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 287. Steam Traps—Peak Demand Savings, With Audit**

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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
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



Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
		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
	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
	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

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	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.<sup>582</sup>

## 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 288. Steam Traps—Revision History**

TRM version	Date	Description of change
v9.0	10/2021	TRM 9.0 origin.
v10.0	10/2022	TRM 10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

<sup>582</sup> 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](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 265

Where:

$HP_{motor}$	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
$LF$	=	Motor load factor <sup>583</sup> = 75%
$\eta$	=	Motor efficiency (use default from Table 289 if actual is not available)
hours	=	Operating hours per year, actual
$EI$	=	Efficiency increase = 1.0% per gear mesh <sup>584</sup>

Table 289. Hydraulic Gear Lubricants—Motor Efficiencies<sup>585</sup>

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		

<sup>583</sup> 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.

<sup>584</sup> 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](https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf). Accessed September 2022.

<sup>585</sup> 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](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 equipment that the lubricant is used with.<sup>586</sup>

## 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 290. Hydraulic Gear Lubricants—Revision History**

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

<sup>586</sup> U.S. 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 266

Where:

$HP_{motor}$	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor, 75% <sup>587</sup>
$\eta$	=	Motor efficiency (use default from Table 291 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase <sup>588</sup> = 3.2%

Table 291. Hydraulic Oils—Motor Efficiencies<sup>589</sup>

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		

<sup>587</sup> 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.

<sup>588</sup> Focus on Energy Lubricant Study, <https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study>.

<sup>589</sup> 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](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.<sup>590</sup>

## 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 292. Hydraulic Oils—Revision History**

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

<sup>590</sup> U.S. 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>

## 2.7.13 Hand Dryers Measure Overview

**TRM Measure ID:** NR-MS-HD

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** Retail, commercial, and industrial settings

**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 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

To qualify for this measure, existing hand dryer equipment must currently utilize more than 5 watt-hour (Wh) or more per use and replacement hand dryers must consume no more than 5 Wh per use. This measure is applicable in retail, commercial and industrial settings.

### Baseline Condition

The baseline efficiency case is a hand dryer which utilizes more than 5 Wh or more per use. These hand dryers are often push-button activated.

### High-Efficiency Condition

Eligible high-efficiency equipment is a hand dryer equipped with motion sensors that uses 5 Wh or less per use.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

The energy savings from the installation of efficient hand dryers are a result of savings due to decrease in power and or runtime of the efficient hand dryers over the pre-retrofit equipment. The energy and demand savings are calculated using the following equations:

$$\text{Energy Savings } [\Delta kWh] = \frac{UPD \times DPY \times \Delta Wh}{1,000} \times IEF_E$$

**Equation 267**

$$\Delta Wh = Wh_{Baseline} - Wh_{Efficient}$$

**Equation 268**

Where:

*UPD* = Number of uses per day (see Table 274)

*DPY* = Number of days the facility operates per year (if unknown, see Table 274)

*IEF<sub>E</sub>* = Interactive effects factor for energy (see Table 293 )

**Table 293. Hand Dryers—Deemed Energy and Demand Interactive Factors<sup>591</sup>**

Space conditioning type	IEF <sub>E</sub>	IEF <sub>D</sub>
Refrigerated air	1.05	1.10
Evaporative cooling	1.02	1.04
None (unconditioned/uncooled)	1.00	1.00

*Wh<sub>Baseline</sub>* = Baseline energy consumption in watt-hours, 20.65<sup>592</sup>

*Wh<sub>Efficient</sub>* = Efficient energy consumption in watt-hours, 3.94<sup>593</sup>

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF \times IEF_D$$

**Equation 269**

<sup>591</sup> Texas Technical Reference Manual, Volume 2, Section 2.1, Table 11, Nonresidential Lighting.

<sup>592</sup> Baseline and efficient Wh per use are averages of the energy consumption of 48 surveyed individual hand dryer units by CLEAResult in Arkansas which consume either greater than 5 Wh or less than 5 Wh per use, respectively. The difference between these equals the assumed Wh savings per use.

<sup>593</sup> Ibid.

Where:

*AOH* = Annual operating hours (see Table 294)

*CF* = Peak coincidence factor (see Table 294)

*IEF<sub>D</sub>* = Interactive effects factor for demand (see Table 293)

**Table 294. Hand Dryers—Savings Calculation Input Assumptions**

Usage level	Building type	Coincidence factor <sup>594</sup>					AOH <sup>595</sup>	UPD <sup>596</sup>	DPY <sup>597</sup>
		CZ 1	CZ 2	CZ 3	CZ 4	CZ 5			
Low	Office	0.87	0.88	0.86	0.90	0.90	36	50	250
	Warehouse	0.79	0.81	0.79	0.80	0.85			
Medium/moderate	Grocery (small)	0.90	0.90	0.90	0.90	0.90	235	225	365
	Restaurant	0.90	0.90	0.90	0.90	0.90			
	Retail	0.90	0.90	0.90	0.90	0.90			
High	Conference center	0.65	0.65	0.65	0.65	0.65	339	500	237
	School <sup>598</sup>	0.39	0.39	0.90	0.87	0.40			
	Stadium	0.65	0.65	0.65	0.65	0.65			
	Theater	0.65	0.65	0.65	0.65	0.65			
	University	0.90	0.90	0.90	0.90	0.90			
High (grocery)	Grocery/retail (large)	0.90	0.90	0.90	0.90	0.90		500	365
Heavy duty/extreme	Airport	0.90	0.90	0.90	0.90	0.90	2,614	2,500	365
	Transportation center	0.90	0.90	0.90	0.90	0.90			

<sup>594</sup> Coincidence factors from the Texas TRM Volume 3, Section 2.1, Table 8, Nonresidential Lighting. It is assumed that building occupancy with respect to lighting is an appropriate proxy for occupants' utilization of hand dryers.

<sup>595</sup> The assumed annual operating hours per building type are calculated as a simple average of 16 surveyed efficient hand dryers' cycle times multiplied by the assumed uses per day and days per year per usage level (as indicated in Table 294), then converted to hours by dividing this product by 3,600.

<sup>596</sup> Industry Standard. Medium/Moderate Uses per day is supported by both Excel Dryer Data (Cost Savings with Hand Dryers vs Average Cost of Paper Towels <https://www.exceldryer.com/calculator-dial/>) and World Dryer Data (<http://staging.worlddryer.com/savings-calculator>)

<sup>597</sup> 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>.

<sup>598</sup> Assuming K–12 without summer session

## Deemed Energy and Demand Savings Tables

The deemed energy and demand savings for hand dryers with unknown number of operating days per year, base/efficient cycles times, and base/efficient unit wattages are as follows:

**Table 295. Hand Dryers—Energy Savings**

Usage level	Building type	Deemed energy savings
Low	Office	223
	Warehouse	223
Medium/moderate	Grocery (small)	1,468
	Restaurant	1,468
	Retail	1,468
High	Conference center	2,118
	School <sup>599</sup>	2,118
	Stadium	2,118
	Theater	2,118
	University	2,118
High (grocery)	Grocery/retail (large)	3,262
Heavy duty/extreme	Airport	16,312
	Transportation center	16,312

<sup>599</sup> Assuming K–12 without summer session.

**Table 296. Hand Dryers—Peak Demand Savings**

Usage level	Building type	Deemed demand savings				
		CZ 1	CZ 2	CZ 3	CZ 4	CZ 5
Low	Office	5.43	5.49	5.37	5.62	5.62
	Warehouse	4.93	5.05	4.93	4.99	5.30
Medium/moderate	Grocery (small)	5.62	5.62	5.62	5.62	5.62
	Restaurant	5.62	5.62	5.62	5.62	5.62
	Retail	5.62	5.62	5.62	5.62	5.62
High	Conference center	4.06	4.06	4.06	4.06	4.06
	School <sup>600</sup>	2.43	2.43	5.62	5.43	2.50
	Stadium	4.06	4.06	4.06	4.06	4.06
	Theater	4.06	4.06	4.06	4.06	4.06
	University	5.62	5.62	5.62	5.62	5.62
High (grocery)	Grocery/retail (large)	8.65	8.65	8.65	8.65	8.65
Heavy duty/extreme	Airport	5.62	5.62	5.62	5.62	5.62
	Transportation center	5.62	5.62	5.62	5.62	5.62

## 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<sup>601</sup> 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:

- Climate zone or county
- Building type
- Cooling type

<sup>600</sup> Assuming K–12 without summer session.

<sup>601</sup> 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).

- Hand dryer quantity
- Hand dryer make 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 297. Hand Dryers—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v10.0	10/2022	TRM v10.0 origin
v11.0	10/2023	TRM v11.0 update. No revision.

## 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.

$$\text{Energy Savings [kWh]} = (kW_{pre} - kW_{installed}) \times \text{Hours} \quad \text{Equation 270}$$

$$\text{Summer Peak Demand Savings [kW}_S] = (kW_{pre} - kW_{installed}) \times CF_S \quad \text{Equation 271}$$

$$\text{Winter Peak Demand Savings [kW}_W] = (kW_{pre} - kW_{installed}) \times CF_W \quad \text{Equation 272}$$

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 <sup>602</sup> (use actual hours if known)
$CF_S$	=	Summer peak coincidence factor = 0.65 (all climate zones) <sup>603</sup>
$CF_W$	=	Winter peak coincidence factor = 0 (all climate zones) <sup>604</sup>

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<sup>602</sup> "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.

<sup>603</sup> Refer to Lamps and Fixtures measure for the public assembly building type, which is applicable to motion picture theaters.

<sup>604</sup> 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.<sup>605,606,607</sup>

**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 298. Laser Projectors—Revision History**

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

<sup>605</sup> Average rated life of 18 Barco and Christie cinema laser projectors = 41,667 hours. Dividing by annual operating hours yields EUL.

<sup>606</sup> Barco cinema projector product listing. <https://www.barco.com/en/products/projection/overview?facets=barco-dxp%3Aproduct%2Fproduct-category%2Fprojection%2Fcinema-projectors>.

<sup>607</sup> Christie cinema projector product listing. <https://www.christiedigital.com/products/cinema/projection/>.

## APPENDIX A: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

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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:

$$\text{First Tier (FT) Period} = ML_{FT} = RUL \quad \text{Equation 273}$$

$$\text{Second Tier (ST) Period} = ML_{ST} = EUL - RUL \quad \text{Equation 274}$$

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:

$$\Delta kW_{FT} = kW_{retired} - kW_{installed} \quad \text{Equation 275}$$

$$\Delta kW_{ST} = kW_{baseline} - kW_{installed} \quad \text{Equation 276}$$

$$\Delta kWh_{FT} = kWh_{retired} - kWh_{installed} \quad \text{Equation 277}$$

$$\Delta kWh_{ST} = kWh_{baseline} - kWh_{installed}$$

**Equation 278**

Where:

$\Delta kW_{FT}$	=	First-tier demand savings
$\Delta kW_{ST}$	=	Second-tier demand savings
$kW_{retired}$	=	Demand of the first-tier baseline system, usually the retired system <sup>608</sup>
$kW_{baseline}$	=	Demand of the second-tier baseline system, usually the baseline ROB system <sup>609</sup>
$kW_{installed}$	=	Demand of the replacement system <sup>610</sup>
$\Delta kWh_{FT}$	=	First-tier energy savings
$\Delta kWh_{ST}$	=	Second-tier energy savings
$kWh_{retired}$	=	Energy usage of the first-tier baseline system, usually the retired system <sup>608</sup>
$kWh_{baseline}$	=	Energy usage of the second-tier baseline system, usually the baseline ROB system <sup>609</sup>
$kWh_{installed}$	=	Energy usage of the replacement system <sup>610</sup>

**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 279**

$$NPV_{ST,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[ \frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kW_{ST}$$

**Equation 280**

$$NPV_{FT,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[ \frac{1+e}{1+d} \right]^{ML_{FT}} \right\} \times \Delta kWh_{FT}$$

**Equation 281**

<sup>608</sup> Retired system refers to the existing equipment that was in use before the retrofit has occurred.

<sup>609</sup> 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).

<sup>610</sup> Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

$$NPV_{ST,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[ \frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kWh_{ST}$$

**Equation 282**

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 <sup>611</sup>
- $d$  = Discount rate weighted average cost of capital (per utility) <sup>611</sup>
- $AC_{kW}$  = Avoided cost per kW (\$/kW) <sup>611</sup>
- $AC_{kWh}$  = Avoided cost per kWh (\$/kWh) <sup>611</sup>
- $ML_{FT}$  = First-tier measure life (calculated in Equation 273)
- $ML_{ST}$  = Second-tier measure life (calculated in Equation 274)

**Step 4:** Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total, kW} = NPV_{FT, kW} + NPV_{ST, kW}$$

**Equation 283**

$$NPV_{Total, kWh} = NPV_{FT, kWh} + NPV_{ST, kWh}$$

**Equation 284**

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

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<sup>611</sup> 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.

**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 285**

$$NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[ \frac{1+e}{1+d} \right]^{EUL} \right\}$$

**Equation 286**

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:

$$\begin{aligned} \text{Weighted } kW &= \frac{NPV_{Total \text{ } kW}}{NPV_{EUL, kW}} \\ &= \frac{\left[ \left( 1 - \left( \frac{1+e}{1+d} \right)^{RUL} \right) \times (kW_{retired} - kW_{installed}) \right] + \left[ \left( 1 - \left( \frac{1+e}{1+d} \right)^{EUL-RUL} \right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kW_{baseline} - kW_{installed}) \right]}{\left( 1 - \left( \frac{1+e}{1+d} \right)^{EUL} \right)} \end{aligned}$$

**Equation 287**

$$\begin{aligned} \text{Weighted } kWh &= \frac{NPV_{Total \text{ } kWh}}{NPV_{EUL, kWh}} \\ &= \frac{\left[ \left( 1 - \left( \frac{1+e}{1+d} \right)^{RUL} \right) \times (kWh_{retired} - kWh_{installed}) \right] + \left[ \left( 1 - \left( \frac{1+e}{1+d} \right)^{EUL-RUL} \right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kWh_{baseline} - kWh_{installed}) \right]}{\left( 1 - \left( \frac{1+e}{1+d} \right)^{EUL} \right)} \end{aligned}$$

**Equation 288**

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 283

- $NPV_{Total, kWh}$  = Total energy contributions to NPV of both ER and ROB component, calculated in Equation 284
- $NPV_{EUL, kW}$  = Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 285
- $NPV_{EUL, kWh}$  = Energy contributions to NPV without weighting, using original EUL, calculated in Equation 286

**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 289**

$$EUL_{kWh} = \frac{\ln \left[ \frac{NPV_{Total, kWh} \times (d - e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1 + e)} \right]}{\ln \left[ \frac{(1 + e)}{(1 + d)} \right]}$$

**Equation 290**

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.