Public Utility Commission of Texas

Texas Technical Reference Manual

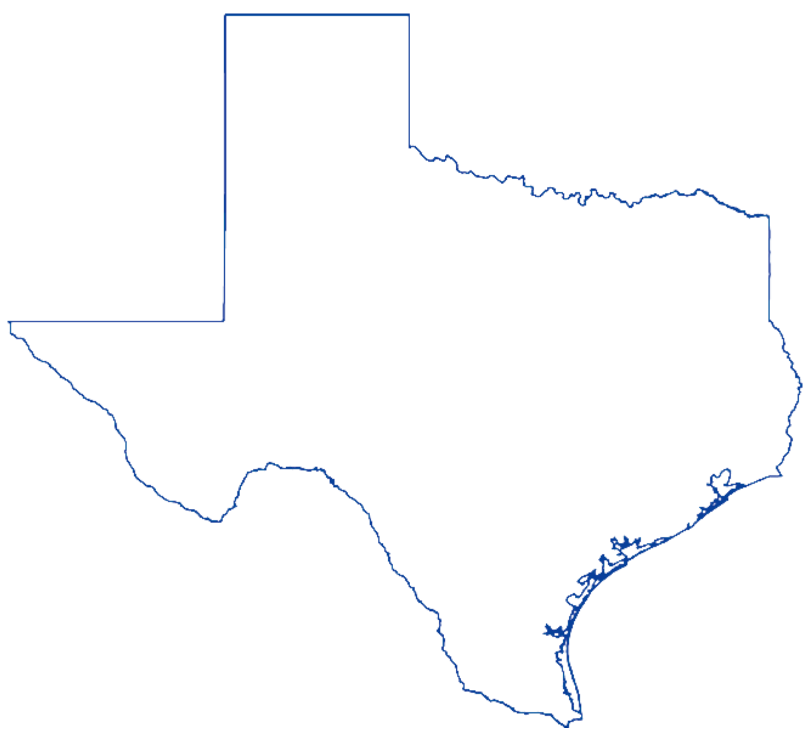
Version 9.0

Volume 3: Nonresidential Measures

Program Year 2022

Last Revision Date:

November 2021



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Acknowledgments

The Technical Reference Manual is maintained by the Public Utility Commission of Texas' independent Evaluation, Monitoring, and Verification (EM&V) team led by Tetra Tech.

This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Energy (TXu 1-904-705), ICF, CLEAResult and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2017 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2018 by Frontier Energy. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as consistent structure and level of information

TRM Technical Support

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

1. INTRODUCTION

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

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

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

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

Table 1. Nonresidential Deemed Savings by Measure Category

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	9.0 update
Lighting	Lamps and Fixtures	–	–	X	X	X	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
	Lighting Controls	–	–	X	X	X	Added eligibility criteria for new construction applications
	LED Traffic Signals	–	–	X	X	X	No revisions

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	9.0 update
HVAC	Air conditioning and heat pump tune-ups	–	–	X	–	X	Updated EUL reference
	Split and packaged air conditioners and heat pumps	–	–	X	X	X	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/packaged AC systems; updated EUL methodology; incorporated building type weighted savings coefficients for upstream/midstream; incremented RUL table for code compliance
	HVAC chillers	–	–	X	X	X	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
	Package terminal air conditioners/heat pumps, and room air conditioners	–	–	X	X	X	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
	Computer room air conditioners	–	–	X	X	–	Updated baseline table citation; added capacity conversion from kW to btu/hr
	Computer room air handler motor efficiency	–	–	X	X	–	No revisions
	HVAC variable frequency drives	–	X	X	–	–	Expanded available building types and updated occupancy schedules
	Condenser air evaporative pre-cooling	–	–	X	–	X	Specified that formulas use tons and kW/ton values and added conversion factors from other units
	High-volume low-speed fans	–	–	X	–	–	No revisions
	Small commercial evaporative cooling	–	X	X	–	–	TRM v9.0 origin

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	9.0 update
Building envelope	ENERGY STAR® cool roofs	X	–	X	X	–	Added building type to tracking data requirements; updated EUL reference
	Window treatments	X	–	X	X	–	Corrected footnote for SC to SHGC conversion; updated performance factors to 2017 ASHRAE Fundamentals; updated EUL reference
	Entrance and exit door air infiltration	–	X	X	–	–	Updated EUL reference
Food service	ENERGY STAR® combination ovens	–	X	X	–	–	Incorporated March 2021 calculator updates; corrected ENERGY STAR® idle rate formulas; updated tracking system requirements and EUL reference
	ENERGY STAR® electric convection ovens	–	X	X	–	–	Incorporated changes from March 2021 calculator update; updated EUL reference
	ENERGY STAR® dishwashers	–	X	X	–	–	General reference checks and text edits; incorporated March 2021 calculator update; updated variable definitions
	ENERGY STAR® hot food holding cabinets	–	X	X	–	–	Incorporated March 2021 calculator update; updated EUL reference
	ENERGY STAR® electric fryers	–	X	X	–	–	Incorporated March 2021 calculator update; updated EUL reference
	ENERGY STAR® electric steam cookers	–	X	X	–	–	Incorporated March 2021 calculator update; corrected formula errors; updated EUL reference
	ENERGY STAR® ice makers	–	X	X	–	–	Incorporated March 2021 calculator update
	Demand controlled kitchen ventilation	–	X	X	–	–	Updated EUL reference
	Pre-rinse spray valves	–	X	X	–	–	General reference checks; updates to input assumptions; updated peak demand savings; updated EUL reference
	Vacuum-sealing and packaging machines	–	X	–	–	–	No revisions

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	9.0 update
Refrigeration	Door heater controls	–	X	X	–	–	Updated peak demand methodology to follow Volume 1 methods; changed Zone 4 reference location from McAllen to Corpus Christi; updated EUL reference
	ECM evaporator fan motors	–	–	X	–	–	Updated methodology based on the load shape from original workpaper; updated EUL reference
	Electronic defrost controls	–	–	X	–	–	Updated methodology based on the load shape from original workpaper
	Evaporator fan controls	–	–	X	–	–	Updated EUL reference
	Night covers for open refrigerated display cases	–	X	X	–	–	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
	Solid and glass door reach-ins	–	–	X	–	–	Updated EUL reference
	Strip curtains for walk-in refrigerated storage	–	X	–	–	–	Added documentation for calculation methodology; updated tracking data requirements; updated EUL reference
	Zero-energy doors for refrigerated cases	–	X	X	–	–	Clarified energy and demand savings are in kW/door rather than kW/feet; updated EUL reference
	Door gaskets for walk-in and reach-in coolers and freezers	–	X	X	–	–	General reference checks and text edits; updated EUL reference
	High speed doors for cold storage	–	X	X	–	–	General reference checks and text edits

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	9.0 update
Water heating	Central domestic hot water controls	–	X	X	–	–	Updated EUL reference
	Showerhead temperature sensitive restrictor valves	–	–	X	–	–	Restricted measure to electricity savings and removed gas savings coefficients; updated EUL reference
	Tub spout and showerhead temperature sensitive restrictor valves	–	–	X	–	–	Restricted measure to electricity savings and removed gas savings coefficients; updated EUL reference
Miscellaneous	Vending machine controls	–	X	X	–	–	General text edits
	Lodging guest room occupancy sensor controls	–	X	–	–	–	No revisions
	Pump-off controllers	–	X	X	–	–	General text edits
	ENERGY STAR® pool pumps	–	X	X	–	–	General text edits; corrected turnovers/day values in the assumptions table
	Computer power management	–	X	X	–	–	Updated peak demand savings coefficients and deemed savings; added application type to documentation requirements; eliminated winter demand savings
	Premium efficiency motors	–	–	X	–	–	General reference checks and text edits
	ENERGY STAR® electric vehicle supply equipment	–	X	X	–	–	General reference checks and text edits
	Variable frequency drives for water pumping	–	X	X	–	–	TRM v9.0 origin
	Steam trap repair and replacement	–	X	X	–	–	TRM v9.0 origin
	Hydraulic gear lubricants	–	–	X	–	–	TRM v9.0 origin
	Hydraulic Oils	–	–	X	–	–	TRM v9.0 origin

2. NONRESIDENTIAL MEASURES

2.1 NONRESIDENTIAL: LIGHTING

2.1.1 Lamps and Fixtures Measure Overview

TRM Measure ID: NR-LT-LF

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial, multifamily common areas

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

Decision/Action Types: Retrofit, and new construction

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

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[1] 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[2], 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.

[1] Delamping energy savings are eligible if done in conjunction with T-8 lamp and electronic ballast retrofits.
[2] 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 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.[3] See the High-efficiency Condition section for additional details.
- LED lamps and fixtures must have their input power (wattage) and an L70 rated life (hours) verified through some combination of the following references: DesignLights Consortium® (DLC), ENERGY STAR®, or independent lab testing[4] (e.g., LM-79, LM-80,

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

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

TM-21, ISTMT). Rated life for LED fixtures should be greater than or equal to 50,000 hours[5] and greater than or equal to 10,000 hours[6] for integrated-ballast LED lamps.

- 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.
    - New construction: permit date
    - Small business: date of customer acceptance or project proposal
    - All other: installation date
- 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.

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

1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power

    1.1. Professional sports arena playing-field lighting

    1.2. Sleeping-unit lighting in hotels, motels, boarding houses, or similar buildings

    1.3. Emergency lighting automatically off during normal building operation

    1.4. Lighting in spaces specifically designed for use by occupants with special lighting needs including visual impairment and other medical and age-related issues

[5] Equivalent to the L70 rated life requirement for all categories as specified in DesignLights Consortium™ (DLC) technical requirements v4.3. https://www.designlights.org/default/assets/File/Workplan/DLC_Technical-Requirements-V-4-3.pdf.

[6] Equivalent to the rated life requirement for all lamps as specified in the ENERGY STAR® lamps specification v2.1. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

[7] IECC 2015, Section C405.4.1.

1.5. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark

1.6. Casino gaming areas

1.7. Mirror lighting in dressing rooms

2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device

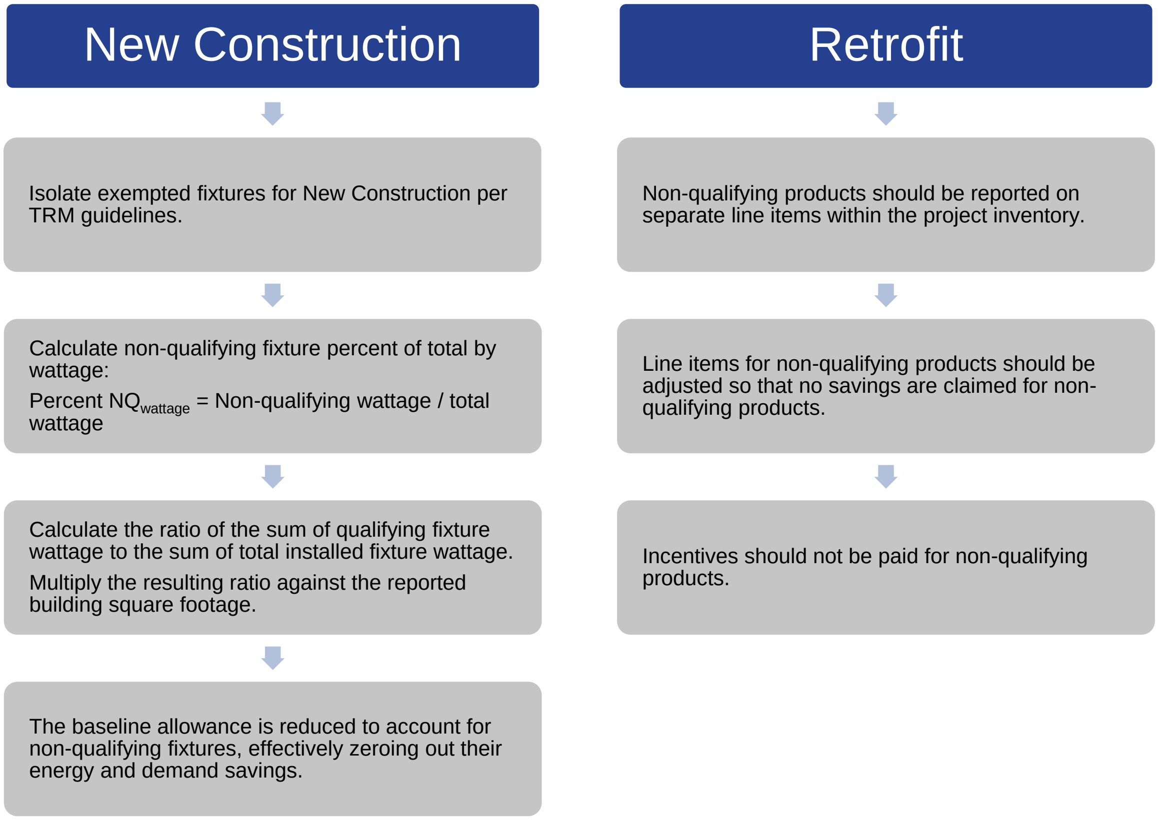
   2.1. Task lighting for medical and dental purposes

   2.2. Display lighting for exhibits in galleries, museums, and monuments

3. Lighting for theatrical purposes, including performance, stage, film production, and video production
4. Lighting for photographic processes
5. Lighting integral to equipment or instrumentation and installed by the manufacturer
6. Task lighting for plant growth or maintenance
7. Advertising signage or directional signage
8. In restaurant building and areas, lighting for food warming or integral to food preparation equipment
9. Lighting equipment that is for sale
10. Lighting demonstration equipment in education facilities
11. Lighting approved because of safety or emergency considerations, inclusive of exit lights
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. Non-Qualifying LED Process for Lighting Projects



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

- Based as a percentage of demand (percent $NQ_{wattage}$ = wattage of non-qualifying fixtures / 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 lighting power density (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 lighting power density (LPD) in watts per square foot by building 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, with the exception of 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 U.S. Energy Policy Act of 1992 (EPACT) set energy efficiency standards that preclude certain lamps and ballasts from being manufactured or imported into the U.S. 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. 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
2-foot u-tube	1	32	32
	2	32	60
	3	32	89

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

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

General Service Lamps

The baseline is assumed to be the first-tier Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 3).

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. A potential second-tier EISA baseline adjustment was scheduled to go into effect beginning January 2020. At that time, general service lamps would need to comply with a 45 lumen-per-watt efficacy standard. However, the Department of Energy (DOE) issued a definition for general service lamps on September 5, 2019, concluding that "no backstop energy conservation has been imposed."[8] Therefore, no additional baseline adjustment will be imposed starting in 2020. However, standard practice must also be considered in determining an appropriate baseline for this measure. To account for a rapidly changing market, measure life assumptions have been reduced as described later in this measure.

Table 3. EISA 2007 Baseline Adjustment for GSILs[9]

Minimum lumens	Maximum lumens	Incandescent equivalent wattage pre-EISA 2007	1st Tier EISA 2007 baseline wattage
310	749	40	29
750	1,049	60	43
1,050	1,489	75	53
1,490	2,600	100	72

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,[10] 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.

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[8] "Energy Conservation Program: Definition for General Service Lamps", Department of Energy. 9/5/2019. https://www.federalregister.gov/documents/2019/09/05/2019-18940/energy-conservation-program-definition-for-general-service-lamps.

[9] Energy Independence and Security Act of 2007. https://www.govinfo.gov/content/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf.

[10] 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.

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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Retrofit[11,12]

$$Energy\ Savings = \left(kW_{pre} \times Hours_{pre} \times EAF_{pre} - kW_{installed} \times Hours_{installed}\right) \times HVAC_{energy}$$

Equation 1

$$Peak\ Summer\ Demand\ Savings = \left(kW_{pre} \times CF_{pre} \times PAF_{pre} - kW_{installed} \times CF_{installed}\right) \times HVAC_{demand}$$

Equation 2

New Construction

$$Energy\ Savings = \left(\frac{LPD \times FloorArea}{1000} - kW_{installed}\right) \times Hours \times HVAC_{energy}$$

Equation 3

$$Peak\ Summer\ Demand\ Savings = \left(\frac{LPD \times FloorArea}{1000} - kW_{installed}\right) \times CF \times HVAC_{demand}$$

Equation 4

[11] 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.

[12] 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.

Where:

kW_{pre}	=	*Total kW of existing measure(s) (Approved baseline fixture code wattage from deemed savings tool divided by 1000 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 1000 and multiplied by fixture/lamp quantity)* [13]

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

LPD	=	*Acceptable Lighting Power Density based on building type from efficiency codes from Table 4 (W/ft2)*
Floor Area	=	*Floor area of the treated space where the lights were installed*
Hours	=	*Hours by building type from Table 8*
EAF	=	*Energy Adjustment Factor from Lighting Controls measure (set equal to 1 if no controls are installed on the existing fixture)*
CF	=	*Coincidence factor by building type from Table 9 or Table 10*
PAF	=	*Power Adjustment Factor from Lighting Controls measure (set equal to 1 if no controls are installed on the existing fixture)*
$HVAC_{energy}$	=	*Energy Interactive HVAC factor by building type*
$HVAC_{demand}$	=	*Demand Interactive HVAC factor by building type*
ISR	=	*In-Service Rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating = 1.0 unless otherwise specified for midstream/upstream applications (see Table 12)*

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

[13] 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.

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

Existing construction: standard fixture wattage table.[14] Another example of standard fixture wattage can be found in the Fixture Codes tab of the latest version of the LSF. This table is used to assign identification codes and demand values (watts) to common fixture types (e.g., fluorescent, incandescent, HID, LED) used in commercial applications. The table is subdivided into lamp types (e.g., linear fluorescent, compact fluorescent, mercury vapor) with each subdivision sorted by fixture code. Each record (or row) in the table contains a fixture code, serving as a unique identifier. A legend explains the rules behind the fixture codes.

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

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

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

New construction: lighting power density 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 a lighting power density (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 5 the 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.

[14] Maintained by EUMMOT/Frontier Energy: http://texasefficiency.com/index.php/regulatory-filings/lighting.

Table 4. New Construction LPDs for Interior Space Types by Building Type[15]

Facility type	Lighting power density (W/ft²)	Facility type	Lighting power density (W/ft²)
Automotive facility	0.80	Multifamily	0.51
Convention center	1.01	Museum	1.02
Courthouse	1.01	Office	0.82
Dining: bar/lounge/leisure	1.01	Parking garage	0.21
Dining: cafeteria/fast food	0.90	Penitentiary	0.81
Dining: family	0.95	Performing arts	1.39
Dormitory	0.57	Police stations	0.87
Exercise center	0.84	Post office	0.87
Fire station	0.67	Religious buildings	1.00
Gymnasium	0.94	Retail	1.26
Health care/clinic	0.90	School/university	0.87
Hospital	1.05	Sports arena	0.91
Hotel/motel	0.87	Town hall	0.89
Library	1.19	Transportation	0.70
Manufacturing facility	1.17	Warehouse	0.66
Motion picture theater	0.76	Workshop	1.19

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 5.

Table 5. New Construction LPDs for Exterior Space Types[16]

Facility type	Lighting power density (W/ft²)			
	Zone 1	Zone 2	Zone 3	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 ≥ 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

[15] IECC 2015 Table C405.4.2(1) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.5.1.
[16] 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.

Facility type	Lighting power density (W/ft²)			
	Zone 1	Zone 2	Zone 3	Zone 4
Building grounds: Landscaping (ASHRAE 90.1-2013 only)[17]	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)[18]	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[19]	--	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

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 6. 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

17 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.

18 Ibid.

19 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.

Equivalent MH wattage	Number of lamps	LED rated lumen range
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 8 through
Table 10. The building types used in this table are based on Commercial Buildings Energy Consumption Survey (CBECS)[20] 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 "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).

"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 for athletic fields and courts) may be claimed separately using the "Outdoor Less than Dusk-to-Dawn" building type or using a custom timer schedule.

These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The hours and CF values used for other are the most conservative values 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.

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.

[20] DOE-EIA Commercial Building Energy Consumption Survey.

Table 7. Commercial Lighting Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[21]
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.	1) 24-hour grow house 2) Non-24-hour grow house
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

[21] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building type	Principal building activity	Definition	Detailed business type examples[21]
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[21]
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[21]
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[21]
Public Assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Public Order and Safety	Jail and prison	Government establishments engaged in justice, public order, and safety.	1) Correctional institutions 2) Prison administration and operation
	Other		1) Police protection 2) Legal counsel and prosecution 3) Fire protection 4) Public order and safety, not elsewhere classified
Religious Worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.

Building type	Principal building activity	Definition	Detailed business type examples[21]
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning salon 11) Copy center or printing shop 12) Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	1) Refrigerated warehouse 2) Non-refrigerated warehouse 3) Distribution or shipping center
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

Table 8. Operating Hours by Building Type

Building type	Operating hours
Agriculture: Long-day lighting[22]	6,209
Agriculture: Non-24 hour grow lighting[23]	5,479
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[24]	3,177
Education: K-12 without summer session	2,777
Food Sales: Non-24-hour supermarket or convenience store	4,706
Food service: Full-service restaurant	4,368
Food service: Quick-service restaurant	6,188
Food service: 24-hour restaurant	7,311
Health care: Inpatient	5,730
Health care: Outpatient	3,386
Health care: Resident care and nursing home	4,271
Lodging: Hotel/motel/dorm, common area	6,630
Lodging: Hotel/motel/dorm, room	3,055
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 center and non-enclosed mall	3,965
Mercantile/food sales: 24-hour stand-alone retail, supermarket, or convenience store	6,900
Multifamily: Common area	4,772
Office	3,737
Outdoor: Athletic field and court[25]	767

[22] 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.

[23] 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.

[24] Assuming a partial summer session in June with no summer session in July.

[25] "2015 U.S. Lighting Market Characterization", U.S. Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours/year.

Building type	Operating hours
Outdoor: Billboard[26]	3,470
Outdoor: Dusk-to-dawn[27]	4,161
Outdoor: Less than dusk-to-dawn[28]	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 9. Summer Peak Coincidence Factors by Building Type[29]

Building type	Summer peak CF				
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Agriculture: Long-day lighting	1.00	1.00	1.00	1.00	1.00
Agriculture: Non-24-hour grow lighting	1.00	1.00	1.00	1.00	1.00
Data center	0.85	0.85	0.85	0.85	0.85
Education: K-12 with summer session, college, university, vocational, and day care	0.90	0.90	0.90	0.90	0.90
Education: K-12 with partial summer session[30]	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

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[26] Ibid.

[27] 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. http://aa.usno.navy.mil/data/docs/RS_OneYear.php.

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

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

[30] Assuming a partial summer session in June with no summer session in July.

Building type	Summer peak CF				
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Food sales: Non-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
Health care: Inpatient	0.80	0.83	0.81	0.80	0.90
Health care: Outpatient	0.70	0.75	0.72	0.71	0.90
Health care: Resident care and nursing home	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
Manufacturing: 1 Shift (<70 hr/week)	0.83	0.84	0.83	0.85	0.85
Manufacturing: 2 Shift (70-120 hr/week)	0.85	0.85	0.85	0.85	0.85
Manufacturing: 3 Shift (>120 hr/week)	0.85	0.85	0.85	0.85	0.85
Multifamily: Common area	0.90	0.90	0.90	0.90	0.90
Office	0.87	0.88	0.86	0.90	0.90
Outdoor: Athletic field and court	--	--	--	--	--
Outdoor: Billboard	--	--	--	--	--
Outdoor: Dusk-to-dawn	--	--	--	--	--
Outdoor: Less than dusk-to-dawn	--	--	--	--	--
Parking garage	1.00	1.00	1.00	1.00	1.00
Public assembly	0.65	0.65	0.65	0.65	0.65
Public order and safety: Jail and prison	0.90	0.90	0.90	0.90	0.90
Public order and safety: Other	0.70	0.75	0.72	0.71	0.90
Religious worship	0.65	0.65	0.65	0.65	0.65

Building type	Summer peak CF				
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Retail: All Non-24-hour retail excluding mall and strip	0.90	0.90	0.90	0.90	0.90
Retail: Enclosed mall	0.90	0.90	0.90	0.90	0.90
Retail: Strip center and non-enclosed mall	0.90	0.90	0.90	0.90	0.90
Retail/food sales: 24-hour retail or supermarket	0.90	0.90	0.90	0.90	0.90
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 10. Winter Peak Coincidence Factors by Building Type[31]

Space type	Winter peak CF				
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
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[32]	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn[33]	0.67	0.71	0.61	0.75	1.00
Parking garage	1.00	1.00	1.00	1.00	1.00

[31] 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.
[32] This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule.
[33] This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

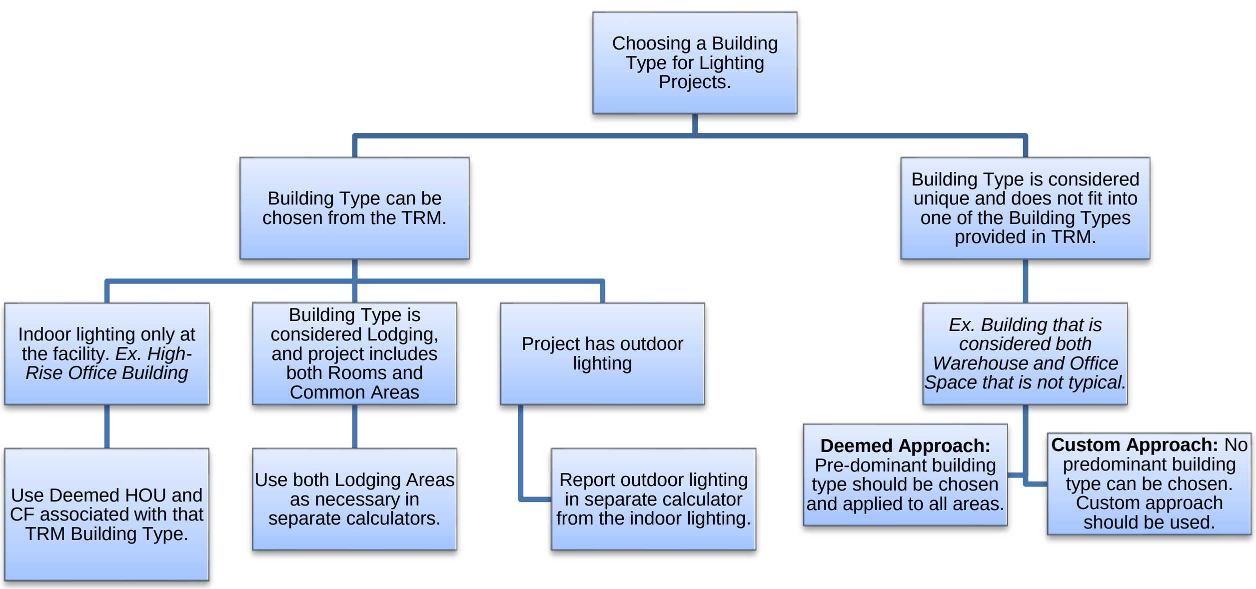
Lighting Calculator Building Type

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.[34]

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 8 through
Table 10. 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.[35] Therefore, the deemed HOU and CFs are representative of an entire building type, across all activity areas that are in a "typical" building for this type.

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

Figure 2. 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.

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

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

Outdoor Lighting Projects that involve outdoor lighting should be claimed in a separate 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).

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.
- **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 are only applicable 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 can be reviewed by the EM&V team.

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 11 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 11. Deemed Energy and Demand Interactive HVAC Factors[36]

Space conditioning type	Energy interactive HVAC factor	Demand interactive HVAC factor
Refrigerated air	1.05	1.10
Evaporative cooling[37]	1.02	1.04
Medium-temperature refrigeration (33 to 41ºF)	1.25	1.25
Low-temperature refrigeration (-10 to 10ºF)	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[38] and 2014 MECS[39] as well as lamp density and lamp type distribution survey data from the DOE 2015 U.S. Lighting Market Characterization (LMC)[40].

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed though 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.[41] 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.

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[36] PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).
[37] 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.
[38] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[39] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[40] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.
[41] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs.

Table 12. Upstream/Midstream Assumptions by Lamp Type[42]

Lamp type	AOH	Coincidence factors					ISR
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	
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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) values are defined for the following lamp/fixture types.[43] 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[44]
- LED fixtures: 15 years

[42] 2012 CBECS and 2014 MECS.
[43] PUCT Docket 36779.
[44] PUCT Docket 38023.

- LED corn cob lamps: 15 years
- LED tubes: 15 years
- Modular CFL and CCFL fixtures: 15 years
- T8 and T5 linear fluorescents: 15 years
- New construction interior fixtures/controls[45]: 14 years
- New construction exterior fixtures[46]: 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.

- Decision/action type: retrofit or new construction
- Building or space type
- Optional: building or space funding source (state or private)
- **For new construction only:** light power density factor
- **For new construction only:** interior and/or exterior space square footage
- **For new construction only:** if applicable, verify if SECO compliance certification forms were filed[47]
- Conditioned space type: cooling equipment type, refrigerated space temperature range, heating fuel type, percent heated/cooled for NC 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

[45] Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.
[46] Ibid.
[47] 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.

- Post-retrofit manufacturer and model number[48]
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage[49]
- 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
- 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.

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

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

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

- 2015 International Energy Conservation Code. (Commercial Buildings)
- ANSI/ASHRAE/IESNA Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. (Public/State buildings[50])
- ENERGY STAR® requirements for Commercial LED Lighting. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG.
- DesignLights Consortium. www.designlights.org.
- Consortium for Energy Efficiency. Commercial Lighting Qualifying Products List (for 4-foot lamps). http://library.cee1.org/content/Commercial-lighting-qualifying-products-lists.
- National Electrical Manufacturers Association. NEMA Premium Electronic Ballast Program. https://www.nema.org/Technical/Pages/NEMA-Premium.aspx.
- U.S. Lighting Market Characterization report, September 2002, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lmc_vol1_final.pdf..
- United Illuminating Company and Connecticut Light and Power. Final Report, 2005 Coincidence Factor Study. https://library.cee1.org/content/united-illuminating-company-and-connecticut-light-power-final-report-2005-coincidence-factor.
- COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules. Updated 07/25/2016.

[50] https://comptroller.texas.gov/programs/seco/code/state-funded.php. All state-funded agencies and institutions of higher education must comply with all errata sheets, as published by the ASHRAE Standard committee, so applicable values may differ from those shown in the tables as Errata are issued.

Document Revision History

Table 13. Nonresidential Lamps and 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. *Measure Life section*: Added additional energy efficiency measures for consistency with the EUMMOT maintained list. *Calculator and Tools section*: Eliminated description of calculator output comparisons. *Tracking Data Requirements section:* Added lighting category requirements for measure summary reports.
v3.0	04/10/2015	TRM v3.0 update. Revised to eliminate T12 lamps as a valid baseline. *Measure Description section:* General clean-up of technology descriptions. *Program Tracking Data section:* Minor changes and clarifications.
v3.1	11/05/2015	TRM v3.1 update. *Revised to eliminate* T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. *Eligibility Criteria:* Adding sources for LED lamp and fixture eligibility.
v3.1	03/23/2016	TRM v3.1 March revision. Updated *Linear Fluorescent T12 Special Conditions* baseline table to include HO and VHO lamps. Updated criteria for miscellaneous length (e.g., 2-ft, 3-ft) T8s. Added footnote to explain how to account for non-rebated fixture lighting controls in savings calculations. Clarified some tracking data requirements.
v4.0	10/10/2016	TRM v4.0 update. Added LPD values and tracking data requirements for exterior space type 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.

TRM version	Date	Description of change
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.
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.

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 14. Savings may be claimed for control types that exceed the minimum code-required controls, mainly occupancy sensors for interior spaces.

For new construction applications, lighting systems are required to be installed with controls.[51] For the areas of a building where occupancy sensor control is required, time switch controls may be substituted for occupancy sensor controls.

Exceptions: Lighting controls are not required in the following:

- Areas designated as security or emergency areas that are required to be continuously lighted
- Interior exit stairways, interior exit ramps, and exit passageways
- Emergency egress lighting that is normally off

[51] IECC 2015, Section C405.

Occupant sensor controls shall be installed to control lights in the following space types; lighting controls savings are not allowed for these space types:

- Classrooms/lecture/training rooms
- Conference/meeting/multipurpose rooms
- Copy/print rooms
- Lounges
- Employee lunch and break rooms
- Private offices
- Restrooms
- Storage rooms
- Janitorial closets
- Locker rooms
- Other spaces 30 square feet or less that are enclosed by floor-to-ceiling height partitions
- Warehouses

Baseline Condition

The baseline condition assumes no existing or code required (for new construction) 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.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The equations for lighting controls are similar to those used for lighting lamps and fixtures, with the addition of the EAF and PAF 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).

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

Equation 5

$$Peak\ Summer\ Demand\ Savings = kW_{controlled} \times \mathrm{PAF} \times CF \times HVAC_{demand}$$

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 8*
EAF	=	*Lighting control Energy Adjustment Factor, see Table 15*
PAF	=	*Lighting control Power Adjustment Factor, see Table 15*
CF	=	*Coincidence factor by building type, see Table 9 or Table 10*
$HVAC_{energy}$	=	*Energy Interactive HVAC factor by building type, see Table 11*
$HVAC_{demand}$	=	*Demand Interactive HVAC factor by building type, see Table 11*

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 15. 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 demand factors.

Table 14. Lighting Controls Definitions

Control type	Description
None	No control
Occupancy	Adjusting light levels according to the presence of occupants • Wall or ceiling-mounted occupancy sensors • Integrated fixture occupancy sensors • Time clocks • Energy management systems
Daylighting (indoor)	Adjusting light levels automatically in response to the presence of natural light • Photosensors
Outdoor	Outdoor on/off photosensor/time clock controls; no savings attributed because already required by code

Control type	Description
Personal tuning	Adjusting individual light levels by occupants according to their personal preference; applies to private offices, workstation-specific lighting in open-plan offices, and classrooms • Dimmers • Wireless ON/OFF switches • Personal computer-based controls • Pre-set scene selection
Institutional tuning	Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants • Dimmable ballasts • ON/OFF or dimmer switches for non-personal tuning
Multiple types	Any combination of the types described above

Table 15. Lighting Controls Energy and Power Adjustment Factors[52]

Control type	Sub-category	Control codes	EAF	PAF
None	Not applicable.	None	0.00	0.00
Occupancy	Not applicable.	OS	0.24	0.24
Daylighting (indoor)	Continuous dimming	DL-Cont	0.28	0.28
	Multiple-step dimming	DL-Step		
	ON/OFF	DL-ON/OFF		
Outdoor[53]	Not applicable.	Outdoor	0.00	0.00
Personal tuning	Not applicable.	PT	0.31	0.31
Institutional tuning	Not applicable.	IT	0.36	0.36
Multiple/combined types	Various combinations	Multiple[54]	0.47	0.47

Deemed Energy and Demand Savings Tables

Not applicable.

[52] 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.

[53] 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.

[54] For multiple control types, specify the installed control types by combining the control codes for the individual control types. Savings factor based on: "Energy Savings from Networked Lighting Control (NLC) Systems", Prepared by Energy Solutions for DesignLights Consortium. September 21, 2017. https://www.designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/.

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 a 14-year estimated useful life (EUL).[55] Lighting controls savings are not eligible for exterior new construction applications.

For retrofit applications, the EUL for lighting controls is provided by the 2007 GDS Associates Report.[56]

- Occupancy Sensor: 10 years
- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 years
- New Construction Interior Fixtures/Controls[57]: 14 years

Program Tracking Data and Evaluation Requirements

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

- Building type
- Decision/action type: retrofit or new construction
- Conditioned Space Type: cooling equipment type, refrigerated space temperature range (specified per control)
- Location of controlled lighting: interior or exterior (specified per control)
- Baseline & installed lighting control type code[58]
- Lighting control mount type: wall, ceiling, integrated fixture, etc.

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

[56] 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.

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

[58] For a control type that combines multiple features (e.g., occupancy + daylighting), specify the installed control types by combining the control codes for the individual control types.

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- 2015 International Energy Conservation Code (Commercial Buildings)
- ANSI/ASHRAE/IESNA Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. (Public/State buildings.[59])

[59] https://comptroller.texas.gov/programs/seco/code/state-funded.php. All state-funded agencies and institutions of higher education must comply with all errata sheets, as published by the ASHRAE Standard committee, so applicable values may differ from those shown in the tables as Errata are issued.

Document Revision History

Table 16. Nonresidential 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 revisions.
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 revisions.
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.

2.1.3 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[60], 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[61] 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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60 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.

61 Memorandums related to this decision can be found on the ENERGY STAR® website at: https://www.energystar.gov/index.cfm?c=archives.traffic_signal_spec.

Table 17. Federal Standard Maximum Wattages[62] and Nominal Wattages[63]

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.

$$Energy\ Savings = \left(kW_{pre} - kW_{installed}\right) \times Hours$$

Equation 7

$$Peak\ Summer\ Demand\ Savings = \left(kW_{pre} - kW_{installed}\right) \times CF$$

Equation 8

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 18*

CF = *Coincidence factor from Table 18*

[62] 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.

[63] 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 18. Incandescent and LED Traffic Signal Savings Assumptions[64]

Fixture type	Incandescent wattage	LED wattage	AOH	CF[65]
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

[64] 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.

[65] 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.

Deemed Energy and Demand Savings Tables

Table 19. LED Traffic Signal Deemed Savings per Fixture

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

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 20. Incandescent and LED Traffic Signal EULs by Fixture Type[66]

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	

[66] 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.

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.

Relevant Standards and Reference Sources

- Traffic Signal Modules and Pedestrian Modules Federal Standard. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12.
- Regional Technical Forum LED Traffic Signals savings workbook. https://rtf.nwcouncil.org/measure/led-traffic-signals?id=114&decisionid=37.

Document Revision History

Table 21. Nonresidential 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 revisions.

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 30 through Table 36

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[67]

- 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

[67] Based on ENERGY STAR® HVAC Maintenance Checklist. 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

All commercial customers are eligible for this measure if they have direct expansion refrigerated air conditioning that has not been serviced in the last 5 years. This measure does not apply to chillers.

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 9

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

Equation 10

Where:

EER_{pre}	=	*Efficiency of the cooling equipment before tune-up*
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. See Table 22.*

$HSPF_{pre}$	=	*Heating efficiency of the air source heat pump before tune-up*
$HSPF_{post}$	=	*Deemed heating efficiency of air source heat pumps after tune-up. See Table 22.*

Table 22. Default EER and HSPF per Size Category[68]

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

High-Efficiency Condition

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

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[69], and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER[70] 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 $HSPF = 3.412 \times COP$.

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

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

70 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.[71]

Heating energy savings are only applicable to heat pumps.

$$Energy\ Savings\ \left[kWh_{savings}\right] = kWh_{Savings,C} + kWh_{Savings,H}$$

Equation 11

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

Equation 12

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

Equation 13

Where:

Capacity	=	*Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)*
EER_{pre}	=	*Cooling efficiency of the equipment pre-tune-up using Table 22 [Btuh/W]*
EER_{post}	=	*Cooling efficiency of the equipment after the tune-up [Btuh/W]*
$HSPF_{pre}$	=	*Heating efficiency of the equipment pre-tune-up using Table 22 [Btuh/W]*
$HSPF_{post}$	=	*Heating efficiency of the equipment after the tune-up [Btuh/W]*

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

$$Summer\ Peak\ Demand\ [kW_{Savings,C}] = Capacity \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times DF_C \times \frac{1\ kW}{1{,}000\ W}$$

Equation 14

$$Winter\ Peak\ Demand\ [kW_{Savings,H}] = Capacity \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times DF_H \times \frac{1\ kW}{1{,}000\ W}$$

Equation 15

Where:

$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone [hours]; see Table 32 through Table 36 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.

Where:

DF_C	=	*Cooling Demand factor; see Table 32 through Table 36 in Section 2.2.2*
DF_H	=	*Heating Demand factor; see Table 32 through Table 36 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.[72]

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:

- Manufacturer
- Model number
- Cooling capacity of the installed unit (tons)
- Climate zone or county of the site
- Type of unit
    - Air conditioner
    - Air source heat pump
- 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

Not applicable.

[72] 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.

Document Revision History

Table 23. Nonresidential AC-HP Tune-Ups Revision History

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 origin.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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 30 through Table 36

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 air conditioners (DX or air-cooled)
- Packaged and split heat pumps (air-cooled)

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 32 through Table 36. Building type descriptions and examples are provided in Table 30 and Table 31.

- 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 AHRI or DOE CCMS certification must be provided.[73,74]

Baseline Condition

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

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 24 through Table 28 according to the capacity, system type, and age (based on year manufactured) of the replaced system.[75] When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in Table 24 through Table 28 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.[76] A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

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

[73] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[74] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

[75] 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.

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

ER baseline efficiency values represent the code-specified efficiency in effect at the time the system was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010 and 2018, coinciding with the IECC 2009 and IECC 2015 code increases. The baseline efficiency levels shown in Table 24 through Table 28 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 heat pumps, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type.

Table 24. ER Baseline Full-Load Efficiency for ACs

Year installed (replaced system)	Split systems < 5.4 tons (EER)[77]	Package system < 5.4 tons (EER)[78]	All systems 5.4 to < 11.3 tons (EER)[79]	All systems 11.3 to < 20 tons (EER)[53]	All systems 20 to < 63.3 tons (EER)[53]	All systems ≥ 63.3 tons (EER)[53]
≤ 2005	9.2	9.0	10.1	9.5	9.3	9.0
2006–2009	11.2	11.2	10.1	9.5	9.3	9.0
2010–2017	11.2	11.2	11.0	10.8	9.8	9.5
≥ 2018	11.2	11.8	11.0	10.8	9.8	9.5

Table 25. ER Baseline Part-Load Efficiency for ACs[80]

Year installed (replaced system)	Split systems < 5.4 tons (SEER)	Package system < 5.4 tons (SEER)	All systems 5.4 to < 11.3 tons (IEER)[81]	All systems 11.3 to < 20 tons (IEER)	All systems 20 to < 63.3 tons (IEER)	All systems ≥ 63.3 tons (IEER)[81]
≤ 2005	10.0	9.7	10.3	9.7	9.4	9.1
2006–2009	13.0	13.0	10.3	9.7	9.4	9.1
2010–2017	13.0	13.0	11.2	11.0	9.9	9.6
≥ 2018	13.0	14.0	12.6	12.2	11.4	11.0

[77] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x 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

[78] Ibid.

[79] 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 greater than or equal to 11.3 tons, 0.2 EER may be added for no heating.

[80] 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.

[81] Baseline IEER 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 IEER may be added for "Electric Resistance (or None)" heating types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 IEER may be added for no heating.

Table 26. ER Baseline Full-Load Cooling Efficiency for HPs

Year installed (replaced system)	Split systems < 5.4 tons (EER)[82]	Package system < 5.4 tons (EER)[83]	All systems 5.4 to < 11.3 tons (EER)[84]	All systems 11.3 to < 20 tons (EER)[84]	All systems 20 to < 63.3 tons (EER)[84]	All systems ≥ 63.3 tons (EER)[84]
≤ 2005	9.2	9.0	10.1	9.3	9.0	9.0
2006–2009	11.2	11.2	10.1	9.3	9.0	9.0
2010–2017	11.2	11.2	11.0	10.6	9.5	9.5
≥ 2018	11.8	11.8	11.0	10.6	9.5	9.5

Table 27. ER Baseline Part-Load Cooling Efficiency for HPs[85]

Year installed (replaced system)	Split systems < 5.4 tons (SEER)	Package system < 5.4 tons (SEER)	All systems 5.4 to < 11.3 tons (IEER)[86]	All systems 11.3 to < 20 tons (IEER)[86]	All systems 20 to < 63.3 tons (IEER)[86]	All systems ≥ 63.3 tons (IEER)[86]
≤ 2005	10.0	9.7	10.3	9.5	9.1	9.1
2006–2009	13.0	13.0	10.3	9.5	9.1	9.1
2010–2017	13.0	13.0	11.2	10.7	9.6	9.6
≥ 2018	14.0	14.0	12.0	11.6	10.6	10.6

[82] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x 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.

[83] Ibid.

[84] Baseline EER values shown from ASHRAE/IECC assume Electric Resistance as the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 EER may be subtracted for all other heating section types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 EER may be subtracted for no heating.

[85] 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.

[86] Baseline IEER values shown from ASHRAE/IECC assume Electric Resistance as the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 IEER may be subtracted for all other heating section types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 IEER may be subtracted for no heating.

Table 28. ER Baseline Heating Efficiency for HPs

Year installed (replaced system)	Split systems < 5.4 tons (HSPF)	Package system < 5.4 tons (HSPF)	All systems 5.4 to < 11.3 tons (COP)	All systems ≥ 11.3 tons (COP)
≤ 2005	6.8	6.6	3.2	3.1
2006–2009	7.7	7.7	3.2	3.1
2010–2017	7.7	7.7	3.3	3.2
≥ 2018	8.2	8.0	3.3	3.2

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

Baseline efficiency levels for package and split DX air conditioners and heat pumps are provided in Table 29. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.

For air conditioners, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For heat pumps, 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 29. Baseline Efficiency Levels for ROB and NC Air Conditioners and Heat Pumps[87]

System type	Capacity (tons)	Baseline efficiencies	Source[88]
Air conditioner	< 5.4	11.2 EER (split)[89] 13.0 SEER (split) 11.8 EER (packaged)[90] 14.0 SEER (packaged)	DOE Standards/ IECC 2015
	5.4 to < 11.3	11.0 EER 12.6 IEER	
	11.3 to < 20	10.8 EER 12.2 IEER	
	20 to < 63.3	9.8 EER 11.4 IEER	
	≥ 63.3	9.5 EER 11.0 IEER	IECC 2015

[87] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[88] 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.
[89] There is no code specified EER for this size category. The code specified SEER value was converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER for systems < 5.4 tons. 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.
[90] IECC 2015 Table C403.2.3(1) and C403.2.3(2).

System type	Capacity (tons)	Baseline efficiencies	Source[88]
Heat pump (cooling)[91]	< 5.4	11.8 EER[92] 14.0 SEER	DOE Standards/ IECC 2015
	5.4 to < 11.3	11.0 EER 12.0 IEER	
	11.3 to < 20	10.6 EER 11.6 IEER	
	≥ 20	9.5 EER 10.6 IEER	
Heat pump (heating)[93]	< 5.4	8.2 HSPF (split) 8.0 HSPF (packaged)	DOE Standards/ IECC 2015
	5.4 to < 11.25	3.3 COP	
	≥ 11.3	3.2 COP	

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 29. 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®[94] and the Consortium for Energy Efficiency (CEE)[95] offer suggested guidelines for high-efficiency equipment. Additional conditions for replace-on-burnout, ER 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 ER, such as units that are replaced after natural failure.

[91] 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”.

[92] There is no code specified EER for this size category. The code specified SEER value converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ for systems < 5.4 tons. 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.

[93] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

[94] ENERGY STAR® Heating & Cooling, https://www.energystar.gov/products/heating_cooling.

[95] CEE Program Resources, http://www.cee1.org/content/cee-program-resources.

Early Retirement

The high-efficiency retrofits must meet the following criteria:[96]

- 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, demand 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

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

Equation 16

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

Equation 17

$$Energy\ Savings\ [kWh_{savings}] = kWh_{Savings,C} + kWh_{Savings,H}$$

Equation 18

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

Equation 19

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

Equation 20

[96] From PUCT Docket #41070.

Where:

$Cap_{C/H,pre}$	=	*For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh*
$Cap_{C/H,post}$	=	*Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh*
$\eta_{baseline,C}$	=	*Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]*
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment (kW /Ton)—(Must exceed ROB/NC baseline efficiency standards in Table 29) [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 29) [COP]*

Note: Use EER for kW savings calculations and SEER/IEER and COP for kWh 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 21

$DF_{C,/H}$	=	*Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 32 through Table 36)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 32 through Table 36)*

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

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 30 and Table 31. These building types are derived from the EIA CBECS study.[97]

The DF and EFLH values for packaged and split AC and HP units are presented in Table 32 through Table 36. These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The DF 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.

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

[97] 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 30. Commercial HVAC Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[98]
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
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

[98] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building type	Principal building activity	Definition	Detailed business type examples[98]
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	1) Motel or inn 2) Hotel 3) Dormitory, fraternity, or sorority 4) Retirement home, nursing home, assisted living, or other residential care 5) Convent or monastery
	Nursing home		
	Small hotel/motel		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	1) Retail store 2) Beer, wine, or liquor store 3) Rental center 4) Dealership or showroom for vehicles or boats 5) Studio or gallery
	Strip 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[98]
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Religious worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning talon 11) Copy center or printing shop 12) Kennel

Building type	Principal building activity	Definition	Detailed business type examples[98]
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 31. Commercial HVAC Floor Area and Floor Assumptions by Building Type[99]

Building type	Principal building activity	Average floor area (ft^2)	Average number of floors
Data center	Data center	Not specified	Not specified
Education	College/university	Not specified	Not specified
	Primary school	73,960	1
	Secondary school	210,887	2
Food sales	Convenience	Not specified	1
	Supermarket	45,000	1
Food service	Full-service restaurant	5,500	1
	Quick-service restaurant	2,500	1
Healthcare	Hospital	241,351	5
	Outpatient healthcare	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 mall	22,500	1
Office	Large office	498,588	12
	Medium office	53,628	3
	Small office	5,500	1

[99] 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 (ft²)	Average number of floors
Public assembly	Public assembly	Not specified	Not specified
Religious worship	Religious worship	Not specified	Not specified
Service	Service	Not specified	Not specified
Warehouse	Warehouse	52,045	1

Table 32. DF and EFLH Values for Amarillo (Climate Zone 1)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[100]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.89	2,048	0.89	2,048	--	--
Education	College/university	0.69	787	0.69	787	--	--
	Primary school	0.64	740	0.64	740	0.43	701
	Secondary school	0.69	535	0.69	535	0.43	736
Food sales	Convenience	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	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	0.74	817	0.74	817	0.48	1,300
Healthcare	Hospital	0.72	2,185	0.72	2,185	--	--
	Outpatient healthcare	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 stand-alone retail	0.80	820	0.80	820	0.43	1,277
	Strip mall	0.75	687	0.75	687	0.39	753

[100] 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[100]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Office	Large office	0.90	2,058	0.90	2,058	--	--
	Medium office	0.64	925	0.64	925	0.72	576
	Small office	0.72	711	0.72	711	0.29	340
Public assembly	Public assembly	0.64	995	0.64	995	--	--
Religious worship	Religious worship	0.57	387	0.57	387	--	--
Service	Service	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 33. DF and EFLH Values for Dallas (Climate Zone 2)

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump[101]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
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	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	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	1.08	1,765	1.08	1,765	0.60	794
Healthcare	Hospital	0.92	3,097	0.92	3,097	--	--
	Outpatient healthcare	0.80	2,532	0.80	2,532	0.28	310
Large multifamily	Midrise apartment	1.04	1,709	1.04	1,709	--	--
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

[101] 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[101]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Mercantile	Stand-alone retail	0.95	1,157	0.95	1,157	0.55	352
	24-hour stand-alone retail	1.01	1,539	1.01	1,539	0.57	632
	Strip 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	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 34. DF and EFLH Values for Houston (Climate Zone 3)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[102]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
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	1.03	2,142	1.03	2,142	--	--
	Supermarket	0.60	744	0.60	744	--	--
Food service	Full-service restaurant	1.05	2,135	1.05	2,135	0.44	429
	24-hour full-service	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	1.05	2,059	1.05	2,059	0.50	483
Healthcare	Hospital	0.90	3,490	0.90	3,490	--	--
	Outpatient healthcare	0.80	2,844	0.80	2,844	0.29	196
Large multifamily	Midrise apartment	1.00	2,031	1.00	2,031	--	--

[102] 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[102]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
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 stand-alone retail	0.97	1,804	0.97	1,804	0.41	374
	Strip 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	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 35. DF and EFLH Values for Corpus Christi (Climate Zone 4)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[103]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.97	4,499	0.97	4,499	--	--
Education	College/university	0.96	2,211	0.96	2,211	--	--
	Primary school	0.88	1,680	0.88	1,680	0.30	156
	Secondary school	0.96	1,503	0.96	1,503	0.35	196
Food sales	Convenience	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	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	0.93	2,440	0.93	2,440	0.34	296

[103] 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[103]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Healthcare	Hospital	0.86	3,819	0.86	3,819	--	--
	Outpatient healthcare	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 stand-alone retail	0.86	2,118	0.86	2,118	0.25	255
	Strip 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	0.98	1,959	0.98	1,959	--	--
Warehouse	Warehouse	0.73	665	0.73	665	--	--
Other	Other	0.54	629	0.54	629	0.08	39

Table 36. DF and EFLH Values for El Paso (Climate Zone 5)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[104]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.88	2,547	0.88	2,547	--	--
Education	College/university	0.87	1,092	0.87	1,092	--	
	Primary school	0.91	996	0.91	996	0.37	408
	Secondary school	0.87	742	0.87	742	0.43	431
Food sales	Convenience	0.76	1,251	0.76	1,251	--	
	Supermarket	0.38	347	0.38	347	--	--

[104] 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[104]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Food service	Full-service restaurant	0.76	1,276	0.76	1,276	0.28	613
	24-hour full-service	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	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Hospital	0.81	2,555	0.81	2,555	--	--
	Outpatient healthcare	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 stand-alone retail	0.86	1,228	0.86	1,228	0.28	808
	Strip 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	0.76	988	0.76	988	--	--
Warehouse	Warehouse	0.75	324	0.75	324	--	--
Other	Other	0.38	324	0.38	324	0.04	146

Claimed Peak Demand Savings

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

Upstream/Midstream Delivery

For upstream/midstream program delivery, use the EFLH and DF assumptions outlined in Table 37 and Table 38. Assumed values have been weighted based on building-type survey data from 2012 CBECS[105] and 2014 MECS[106].

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 32 through Table 36. For program designs where the building type is unknown, you may use the savings coefficients from Table 37 and Table 38. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 37. Upstream/Midstream Assumptions for DX HVAC Cooling[107]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,062	1,543	1,752	1,947	1,338
DF_C	0.68	0.92	0.91	0.84	0.84

Table 38. Upstream/Midstream Assumptions for DX HVAC Heating[108]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_H$	504	245	130	79	243
DF_H	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 air conditioners and heat pumps is 15 years.[109]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 39. 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

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105 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
106 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
107 2012 CBECS and 2014 MECS.
108 Ibid.
109 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.

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 39. Remaining Useful Life Early Retirement Systems[110,111]

Age of replaced system (years)	Split/packaged AC/HP systems RUL (years)	Age of replaced system (years)	Split/packaged 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[112]	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
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities

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

[111] 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.

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

- **For ER only**: 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 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

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-1 and Table 6.8.1-2.
- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75&action=viewlive.

Document Revision History

Table 40. Nonresidential Split-System/Single-Packaged AC-HP 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	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/packaged AC systems. Updated EUL methodology. Incorporated building type weighted savings coefficients for upstream/midstream. 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 54 through Table 58.

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:[113]

- 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 54 through Table 58. Building type descriptions and examples are provided in Table 30 and Table 31.
- 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.

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.[114, 115]

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.

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[113] 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

[114] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[115] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

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 41 through Table 52 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.[116] When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 41 through Table 52 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,[117] coinciding with the IECC 2009 and IECC 2015 code increases.

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

ER Baseline: Air-Cooled Chillers

Table 41. ER Baseline Full-Load Efficiency of All Path A Air-Cooled Chillers[118]

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

[116] 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.
[117] IECC 2015 not enforced in Texas until program year 2018.
[118] Code-specified efficiencies in effect prior to 2002 were given in COP and have been converted to EER using EER = COP x 3.412. Values in the "≤ 2001" row have been converted and are expressed in italics.

Table 42. ER Baseline Full-Load Efficiency of All Path B Air-Cooled Chillers[119]

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

Table 43. ER Baseline Part-Load Efficiency (IPLV) of All Path A Air-Cooled Chillers[120]

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

Table 44. ER Baseline Part-Load Efficiency (IPLV) of All Path B Air-Cooled Chillers[121]

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 45. ER Baseline Full-Load Efficiency of Centrifugal Path A Water-Cooled Chillers[122]

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

[119] Ibid.
[120] Ibid.
[121] Ibid.
[122] Ibid.

Table 46. ER Baseline Full-Load Efficiency of Centrifugal Path B Water-Cooled Chillers[123]

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

Table 47. ER Baseline Part-Load Efficiency (IPLV) of Centrifugal Path A Water-Cooled Chillers[124]

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 48. ER Baseline Part-Load Efficiency (IPLV) of Centrifugal Path B Water-Cooled Chillers[125]

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

123 Ibid.
124 Ibid.
125 Ibid.

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

Table 49. ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path A Water-Cooled Chillers[126]

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

Table 50. ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path B Water-Cooled Chillers[127]

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 51. ER Baseline Part-Load Efficiency (IPLV) of Screw/Scroll/Recip. Path A Water-Cooled Chillers[128]

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

126 Ibid.
127 Ibid.
128 Ibid.

Table 52. ER Baseline Part-Load Efficiency (IPLV) of Screw/Scroll/Recip. Path B Water-Cooled Chillers[129]

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 53, which includes both full load and integrated part load value (IPLV) ratings. The IPLV accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard ASHRAE 90.1-2010. This standard contains two paths for compliance, Path A or Path B. According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller). Path A chillers are eligible to claim savings using the full-load efficiency conditions in the energy and demand savings algorithms.[130] 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 53. Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers[131]

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

[129] Ibid.

[130] 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).

[131] IECC 2015 Table C403.2.3(7).

High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 53 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:[132]

- 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, path A/B full and part-load baseline efficiency, demand 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

$$Peak\ Demand\ [kW_{Savings}] = \left(Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}\right) \times DF$$

Equation 22

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

Equation 23

[132] From PUCT Docket #41070.

Where:

$Cap_{C,pre}$	=	*For ER, rated equipment cooling capacity of the existing equipment at $AHRI_{standard}$ conditions; for ROB & NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [tons]*
$Cap_{C,post}$	=	*Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions [tons]*
$\eta_{baseline}$	=	*Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/ton] – default values, based on system type, are given in Table 41 through Table 53; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 24 [kW/ton]*
$\eta_{installed}$	=	*Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 53; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 24 [kW/ton]*

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

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

Equation 24

DF	=	*Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 54 through Table 58)*
$EFLH_C$	=	*Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 54 through Table 58)*

Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment[133]

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:

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

Equation 25

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

Equation 26

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 27

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

Equation 28

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 over the lifetime (EUL) of the measure." These savings calculations are explained in Appendix A.

Table 54 through Table 58 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.

[133] This extra adjustment is noted in PUCT Docket No. 41070.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 30 and Table 31. These building types are derived from the EIA CBECS study.[134]

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone for chillers in Table 54 through Table 58. These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF 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 54. DF and EFLH for Amarillo (Climate Zone 1)

Building type	Principal building activity	Chiller[135]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.56	2,807	0.73	5,100
Education	College	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	Hospital	0.70	2,006	0.65	2,711
Large multifamily	Midrise apartment	0.41	421	0.50	1,098
Lodging	Large hotel	0.58	1,283	0.59	1,553
	Nursing home	0.41	428	0.50	1,115
Mercantile	Stand-alone retail	0.52	489	0.54	719
	24-hour retail	0.67	681	0.62	974

[134] 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/.

[135] 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[135]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
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 55. DF and EFLH for Dallas (Climate Zone 2)

Building type	Principal building activity	Chiller[136]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.54	2,791	0.77	4,906
Education	College	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	Hospital	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 56. DF and EFLH for Houston (Climate Zone 3)

Building type	Principal building activity	Chiller[137]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.53	2,824	0.76	5,075
Education	College	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
Healthcare	Hospital	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

[136] Ibid.
[137] Ibid.

Building type	Principal building activity	Chiller[137]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
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 57. DF and EFLH for Corpus Christi (Climate Zone 4)

Building type	Principal building activity	Chiller[138]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.48	2,881	0.77	5,266
Education	College	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	Hospital	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

Table 58. DF and EFLH for El Paso (Climate Zone 5)

Building type	Principal building activity	Chiller[139]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.56	2,950	0.71	5,137
Education	College	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	Hospital	0.71	2,355	0.59	2,992
Large multifamily	Midrise apartment	0.56	841	0.52	1,553

138 Ibid.
139 Ibid.

Building type	Principal building activity	Chiller[139]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
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 DF assumptions outlined in Table 59 and Table 60. Assumed values have been weighted based on building type survey data from 2012 CBECS[140] and 2014 MECS[141].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 54 through Table 58. For program designs where building type is unknown, you may use the savings coefficients from Table 59 and Table 60. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 59. Upstream/Midstream Assumptions for Air-Cooled Chillers[142]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_c$	967	1,408	1,575	1,789	1,211
DF_c	0.62	0.80	0.78	0.72	0.71

Table 60. Upstream/Midstream Assumptions for Water-Cooled Chillers[143]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,349	1,941	2,232	2,511	1,578
DF_C	0.58	0.68	0.70	0.70	0.59

140 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
141 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
142 2012 CBECS and 2014 MECS.
143 Ibid.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years[144]
- Centrifugal chillers: 25 years.[145]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 61. 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.

[144] 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.

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

Table 61. Remaining Useful Life of Early Retirement Systems[146,147]

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
1	18.7	23.9
2	17.7	22.9
3	16.7	21.9
4	15.7	20.9
5	14.7	19.9
6	13.7	18.9
7	12.7	17.9
8	11.8	16.9
9	10.9	15.9
10	10.0	14.9
11	9.1	13.9
12	8.3	12.9
13	7.5	11.9
14	6.8	10.9
15	6.2	10.1
16	5.5	9.3
17	5.0	8.7
18	4.5	8.1
19	4.0	7.5
20	3.6	7.1
21	3.0	6.6
22	2.0	6.3
23	1.0	5.9
24[148]	0.0	5.6
25	N/A	5.4
26	N/A	5.0
27	N/A	4.0
28	N/A	3.0
29	N/A	2.0
30	N/A	1.0
31[149]	N/A	0.0

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

[147] 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.

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

[149] 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
- 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)
- 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

- ANSI/ASHRAE/IES Standard 90.1-1989. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 10-7.
- ANSI/ASHRAE/IES Standard 90.1-2004. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1C.

- ANSI/ASHRAE/IES Standard 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings, Addendum M. Table 6.8.1C.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- 2015 International Energy Conservation Code. Table C403.2.3(7).

Document Revision History

Table 62. Nonresidential HVAC 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.

2.2.4 Packaged Terminal 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 66 through Table 70

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), 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^2. 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^2.

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, 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. A 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.[150,151]

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.[152] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 63, 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.[153] A default RUL may be used exclusively if applied consistently for all

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

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

152 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.

153 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.

projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing systems manufactured as of February 2013 are not eligible for early retirement.

Table 63. ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units[154]

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (No built-in resistance heat)	Baseline heating efficiency (COP) (with built-in resistance heat)
PTAC	<7,000	11.0	--	1.0
	7,000-15,000	$12.5 - (0.213 \times \mathrm{Cap}/1000)$		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	--
	7,000-15,000	$12.3 - (0.213 \times \mathrm{Cap}/1000)$	$3.2 - (0.026 \times \mathrm{Cap}/1000)$	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 64 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for packaged terminal air conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 64. Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units[155,156]

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTAC	Standard Size	<7,000	11.9	--
		7,000-15,000	$14.0 - (0.300 \times Cap/1000)$	--
		>15,000	9.5	--
	Non-Standard Size	<7,000	9.4	--
		7,000-15,000	$10.9 - (0.213 \times Cap/1000)$	--
		>15,000	7.7	--

154 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.

155 IECC 2015 Table C403.2.3(3).

156 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)
PTHP	Standard Size	<7,000	11.9	3.3
		7,000-15,000	$14.0 - (0.300 \times Cap/1000)$	$3.7 - (0.052 \times Cap/1000)$
		>15,000	9.5	2.9
	Non-Standard Size	<7,000	9.3	2.7
		7,000-15,000	$10.8 - (0.213 \times Cap/1000)$	$2.9 - (0.026 \times Cap/1000)$
		>15,000	7.6	2.5

Table 65 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b).

Table 65. Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units[157]

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

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

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 64 and Table 65.

The high-efficiency retrofits must also meet the following criteria:[158]

- 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, demand 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

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

Equation 29

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

Equation 30

$$Total\ Energy\ [kWh_{Savings}] = kWh_{Savings,C} + kWh_{Savings,H}$$

Equation 31

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

Equation 32

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

Equation 33

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

Where:

$Cap_{C/H,pre}$	=	*For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [BTUH]; 1 ton = 12,000 Btuh*
$Cap_{C/H,post}$	=	*Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh*
$\eta_{baseline,C}$	=	*Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 63 through Table 65)*
$\eta_{baseline,H}$	=	*Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 63 and Table 64)*[159]
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h])—(Must exceed minimum federal standards found in Table 64 and Table 65)*[160]
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 64)*
$DF_{C,H}$	=	*Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 32 through Table 36)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours], see Table 66 through Table 70.*

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 66 through Table 70 present the deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs 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.

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

These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF 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.

Table 66. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Amarillo (CZ 1)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.56	686	0.56	686	0.43	322
	Secondary school	0.61	496	0.61	496	0.43	338
Food sales	Convenience	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	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	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 67. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Dallas (CZ 2)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.85	1,016	0.85	1,016	0.66	231
	Secondary school	0.99	912	0.99	912	0.59	285
Food sales	Convenience	1.05	1,544	1.05	1,544	0.61	318

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Food service	Full-service restaurant	1.06	1,534	1.06	1,534	0.50	401
	24-hour full-service	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	1.05	1,485	1.05	1,485	0.60	463
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 68. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Houston (CZ 3)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.71	1,186	0.71	1,186	0.50	52
	Secondary school	0.79	1,030	0.79	1,030	0.54	63
Food sales	Convenience	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	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	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 69. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Corpus Christi (CZ 4)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.70	1,355	0.70	1,355	0.30	73
	Secondary school	0.76	1,212	0.76	1,212	0.35	92
Food sales	Convenience	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	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	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 70. PTAC/PTHP or RAC Equipment: DF and EFLH Values for El Paso (CZ 5)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.88	1,009	0.88	1,009	0.37	271
	Secondary school	0.84	751	0.84	751	0.43	286
Food sales	Convenience	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	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	0.75	1,186	0.75	1,186	0.26	463
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

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
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 following EFLH and DF assumptions. Assumed values have been weighted based on building type survey data from 2012 CBECS[161] and 2014 MECS[162].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 66 through Table 70. For program designs where building type is unknown, you may use the savings coefficients from Table 71 and Table 72. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 71. Upstream/Midstream Assumptions for PTAC/PTHP or RAC Cooling[163]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,019	1,661	1,774	1,916	1,562
DF_C	0.55	0.78	0.68	0.60	0.73

Table 72. Upstream/Midstream Assumptions for PTHP Heating[164]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_H$	247	193	40	46	176
DF_H	0.43	0.52	0.23	0.14	0.12

161 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
162 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
163 2012 CBECS and 2014 MECS.
164 Ibid.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of PTAC/PTHP units is 15 years, as specified in DEER 2014.[165]

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.[166]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 73.

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 73. Remaining Useful Life of ER PTAC/PTHP Systems[167, 168]

Age of replaced system (years)	PTAC/PTHP RUL (years)	Age of replaced system(years)	PTAC/PTHP 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[169]	0.0

165 http://www.deeresources.com/

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

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

168 Current federal standard effective date is 2/2013. 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.

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

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
- 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, 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

- ANSI/ASHRAE/IES Standard 90.1-2001 through ASHRAE 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=46
- Code of Federal Regulations. Title 10. Part 430—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52
- 2015 International Energy Conservation Code. Table C403.2.3(3).

Document Revision History

Table 74. Nonresidential PTAC/PTHP and Room AC 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).

TRM version	Date	Description of change
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 revisions.
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.
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.

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 76 and Table 77

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.[170,171]

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 75. 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.

Table 75. Baseline Efficiency Levels for ROB and NC CRACs[172]

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	
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	

170 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
171 Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
172 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) with fluid economizer	< 65,000	2.45 / 2.34	
	$\geq$ 65,000 and < 240,000	2.10 / 1.99	
	$\geq$ 240,000	2.05 / 1.94	

High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 29.

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

$$Peak\ Demand\ [kW_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF_C \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 34

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

Equation 35

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 29) [SCOP]*

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

DF = *Seasonal peak demand factor for appropriate climate zone, and equipment type (Table 77)*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, and equipment type [hours] (Table 77)*

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 peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. This measure is restricted to the data center building types, derived from the EIA CBECS study.[173]

The DF and EFLH values for CRAC units are presented in Table 77. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

Table 76. Commercial CRAC Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[174]
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

[173] 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.*

[174] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Table 77. DF and EFLH Values for All Climate Zones

Climate zone reference city	Building type and principal building activity	CRACs	
		DF_C	$EFLH_C$
Climate Zone 1: Amarillo	Data center	0.89	2,048
Climate Zone 2: Dallas		1.08	3,401
Climate Zone 3: Houston		1.05	4,022
Climate Zone 4: Corpus Christi		0.97	4,499
Climate Zone 5: El Paso		0.88	2,547

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

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

Effective Useful Life (EUL)

The EUL for CRACs is 15 years, consistent with the EUL specified for split and packaged air conditioners and heat pumps.[175]

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.

Program Tracking Data and Evaluation Requirements

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

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

[175] 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.

- 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

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-1 and Table 6.8.1-2.
- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=31.

Document Revision History

Table 78. Nonresidential Computer Room Air Conditioners 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.

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[176].

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).

[176] 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.[177]

Energy Savings Algorithms

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

Equation 36

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

Equation 37

Where:

hp_{pre} = *Rated horsepower of the existing motor*

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

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

Table 79. Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM

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

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

0.746	=	*HP to kW conversion factor*
kW/hp_{post}	=	*Efficient kW per motor hp, 0.27*[178]
hp_{post}	=	*Total efficient motor horsepower*
$hours$	=	*Annual operating hours, 8760*

Demand Savings Algorithms

$$Demand\ Savings\ (kW) = \frac{Annual\ Energy\ Savings\ (kWh)}{hours} \times CF$$

Equation 38

Where:

CF	=	*Peak coincidence factor, summer and winter: 0.11*[179]

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.[180]

The EUL for HVAC VFD measure is 15 years.

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[178] Oncor site data. Average kW/hp values are weighted by measure count.

[179] 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.

[180] 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.

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

References and Efficiency Standards

Petitions and Rulings

None.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 80. Nonresidential Computer Room Air Handler Motor Efficiency Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revisions.

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 85 through Table 91

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 pumps

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. 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.

High-Efficiency Condition

The high-efficiency condition is the installation of a VFD on an AHU supply fan, 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 39

Where:

$t_{db,i}$	=	*The hourly dry bulb temperature (DBT) using TMY3[181] data*
m	=	*The slope of the relationship between DBT and CFM, see Table 81*
b	=	*The intercept of the relationship between DSBT and CFM, see Table 81*

The minimum flow rate is set to 60 percent cfm based on common design practice.[182] 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.[183]

[181] 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.

[182] 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%.

[183] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 81. AHU Supply Fan VFD percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Zone 1	Flow rate (%cfm)	60	100	1.19	-17.38
	Dry bulb T (°F)	65	98.6		
Zone 2	Flow rate (%cfm)	60	100	1.10	-11.43
	Dry bulb T (°F)	65	101.4		
Zone 3	Flow rate (%cfm)	60	100	1.23	-20.00
	Dry bulb T (°F)	65	97.5		
Zone 4	Flow rate (%cfm)	60	100	1.26	-21.76
	Dry bulb T (°F)	65	96.8		
Zone 5	Flow rate (%cfm)	60	100	1.11	-12.02
	Dry bulb T (°F)	65	101.1		

For chilled water pumps:

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

Equation 40

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3 data*

m = *The slope of the relationship between DBT and GPM, see Table 82*

b = *The intercept of the relationship between DSBT and GPM, see Table 82*

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.[184] 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.[185]

[184] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[185] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 82. Chilled Water Pump VFD percentage of GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Zone 1	Flow rate (%GPM)	10	100	2.68	-164.11
	Dry bulb T (°F)	65	98.6		
Zone 2	Flow rate (%GPM)	10	100	2.47	-150.71
	Dry bulb T (°F)	65	101.4		
Zone 3	Flow rate (%GPM)	10	100	2.77	-170.00
	Dry bulb T (°F)	65	97.5		
Zone 4	Flow rate (%GPM)	10	100	2.83	-173.96
	Dry bulb T (°F)	65	96.8		
Zone 5	Flow rate (%GPM)	10	100	2.49	-152.05
	Dry bulb T (°F)	65	101.1		

For hot water pumps:

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

Equation 41

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3 data*[181]

m = *The slope of the relationship between DBT and GPM, see Table 83*

b = *The intercept of the relationship between DSBT and GPM, see Table 83*

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.[186] 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.[187]

[186] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[187] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

Table 83. Hot Water Pump VFD %GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Zone 1	Flow Rate (%GPM)	10	100	-1.64	116.56
	Dry Bulb T (°F)	65	10.1		
Zone 2	Flow Rate (%GPM)	10	100	-2.16	150.29
	Dry Bulb T (°F)	65	23.3		
Zone 3	Flow Rate (%GPM)	10	100	-2.65	182.57
	Dry Bulb T (°F)	65	31.1		
Zone 4	Flow Rate (%GPM)	10	100	-3.15	214.55
	Dry Bulb T (°F)	65	36.4		
Zone 5	Flow Rate (%GPM)	10	100	-2.26	156.62
	Dry Bulb T (°F)	65	25.1		

Step 2 - Calculate the %power for the applicable baseline and the new VFD technology:

Baseline Technologies

For AHU supply fan: [188]

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

Equation 42

$$\%power_{i,InletDamper} = 0.00013 \times \%CFM_i^{\ 3} - 0.01452 \times \%CFM_i^{\ 2} + 0.71648 \times \%CFM_i + 50.25833$$

Equation 43

$$\%power_{i,InletGuideVane} = 0.00009 \times \%CFM_i^{\ 3} - 0.00128 \times \%CFM_i^{\ 2} + 0.06808 \times \%CFM_i + 20$$

Equation 44

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.

For chilled and hot water pumps[189]:

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

Equation 45

[188] https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225. Please note, the CFM^2 coefficients in Equation 38 and Equation 39 have the wrong sign in the reference document.

[189] 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.

VFD Technology

For AHU supply fan[190]:

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

Equation 46

For chilled and hot water pumps[191]:

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

Equation 47

Step 3 - Calculate kW_{full} using the hp from the motor nameplate, load factor, and the applicable motor efficiency from ASHRAE 2013, Table 10.8-1 Minimum Nominal Efficiency for General Purpose Electric Motors; Use that result and the %power results to determine power consumption at each hour:

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

Equation 48

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

Equation 49

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)*[192]
kW_{full}	=	*Motor power demand operating at the fan design 100 percent CFM or pump design 100 percent GPM*
kW_i	=	*Fan or Pump real-time power at the i^{th} hour of a year*
HP	=	*Rated horsepower of the motor*
LF	=	*Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent*
η	=	*Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013*

[190] https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225.

[191] 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).

[192] Fan curves by control type are provided in the BPA ASD Calculator, http://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls.

Table 84. Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM

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
75	0.95
100	0.954

0.746 = *HP to kW conversion factor*

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

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

Equation 50

Where:

schedule = *1 when building is occupied, 0.2 when building is unoccupied, see Table 85*

Table 85. Yearly Motor Operation Hours by Building Type[193,194]

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
Restaurants	6am–2am	6am–2am	7,592
Warehouse	7am–7pm	closed	4,258
Assembly, worship	9am–11pm	9am–11pm	5,840
Other[195]	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 51

Where:

PDPF = *Peak demand probability factor from the applicable climate zone table in Volume 1.*

193 Hours for all building types except for Assembly come from the Department of Energy Commercial Building Prototype Models, Scorecards, HVAC Operation Schedule. Motor hours are set to equal 1 when the HVAC Operation Schedule is "on" and 0.2 when the HVAC Operation Schedule is "off." https://www.energycodes.gov/development/commercial/prototype_models. Assembly occupied hours come from COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules, updated 07/25/2016.

194 Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

195 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.

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 51 above:

$$kW_{TotalSaved} = kW_{PDPF,Saved} \times (1 + \frac{3.412}{Cooling_{EER}})$$

Equation 52

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:

$$Annual\ kWh = \sum_{i=1}^{8760} (kW_i \times schedule_i)$$

Equation 53

Where:

8760 = *Total number of hours in a year*

Step 2 - Subtract the Annual kWh_{new} from the Annual $kWh_{baseline}$ to get the Annual Energy Savings:

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

Equation 54

Deemed Energy and Demand Savings Tables[196]

Table 86. AHU Supply Fan Outlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,159	1,101	1,070	1,046	1,121
Office—large, medium	724	682	658	640	695

[196] Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Climate zone				
	1	2	3	4	5
Office—small	575	543	522	506	552
Education	632	596	576	560	606
Convenience store, service, strip Mall	676	637	613	598	648
Stand-alone retail, supermarket	727	685	660	643	698
Restaurants	994	941	912	891	958
Warehouse	548	516	495	480	525
Assembly, worship	750	707	683	667	720
Other	548	516	495	480	525
Summer kW savings (kW per motor HP)					
All building types	0.040	0.023	0.021	0.063	0.042

Table 87. AHU Supply Fan Inlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,824	1,672	1,596	1,533	1,722
Office—large, medium	1,125	1,024	967	922	1,051
Office—small	893	813	765	726	833
Education	983	895	847	807	916
Convenience store, service, strip mall	1,045	950	896	857	975
Stand-alone retail, supermarket	1,126	1,025	966	924	1,051
Restaurants	1,555	1,420	1,351	1,296	1,461
Warehouse	849	773	726	689	793
Assembly, worship	1,163	1,057	1,001	960	1,085
Other	849	773	726	689	793
Summer kW Savings (kW per Motor HP)					
All building types	0.044	0.026	0.024	0.069	0.047

Table 88. AHU Supply Fan Inlet Guide Vane Baseline Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388	345	324	307	359
Office—large, medium	237	209	194	182	216
Office—small	188	166	153	143	171
Education	207	183	170	159	189
Convenience store, service, strip mall	219	194	179	168	200
Stand-alone retail, supermarket	237	209	193	182	216
Restaurants	329	292	273	258	303
Warehouse	179	158	145	135	163
Assembly, worship	244	216	201	189	223
Other	179	158	145	135	163
Summer kW savings (kW per motor HP)					
All building types	0.010	0.009	0.005	0.012	0.013

Table 89. AHU Supply Fan No Control Baseline Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	3,299	3,034	2,902	2,791	3,123
Office—large, medium	2,035	1,856	1,755	1,675	1,906
Office—small	1,615	1,473	1,387	1,318	1,510
Education	1,778	1,622	1,538	1,465	1,661
Convenience store, service, strip mall	1,890	1,721	1,624	1,554	1,766
Stand-alone retail, supermarket	2,038	1,856	1,752	1,676	1,906
Restaurants	2,814	2,577	2,455	2,357	2,650
Warehouse	1,536	1,401	1,316	1,248	1,437
Assembly, worship	2,104	1,916	1,817	1,742	1,967
Other	1,536	1,401	1,316	1,248	1,437
Summer kW savings (kW per motor HP)					
All building types	0.0029	0.004	0.026	0.086	0.024

Table 90. Chilled Water Pump Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	777	1,154	1,337	1,479	1,049
Office—large, medium	562	775	880	966	734
Office—small	455	624	702	766	591
Education	490	683	767	841	646
Convenience store, service, strip mall	552	747	847	917	705
Stand-alone retail, supermarket	585	795	904	980	753
Restaurants	721	1,030	1,181	1,295	959
Warehouse	433	594	669	728	563
Assembly, worship	599	818	931	1,009	772
Other	433	594	669	728	563
Summer kW savings (kW per motor HP)					
All building types	0.046	0.018	0.029	0.091	0.043

Table 91. Hot Water Pump Savings per Motor HP

Building type	Climate zone				
	1	2	3	4	5
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,304	912	723	597	1,044
Office—large, medium	777	536	419	332	609
Office—small	612	423	329	261	475
Education	679	468	369	295	528
Convenience store, service, strip mall	708	482	376	301	560
Stand-alone retail, supermarket	767	527	411	330	608
Restaurants	1,091	757	600	491	867
Warehouse	581	403	310	246	451
Assembly, worship	794	544	427	345	632
Other	581	403	310	246	451
Winter kW savings (kW per motor HP)					
All building types	0.123	0.045	0.047	0.108	0.229

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.[197]

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
- 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).

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

- ASHRAE Fundamentals 1997: Chapter 26, Table 1B—Cooling and Dehumidification Design Conditions—United States.
- ASHRAE Standard 90.1-2013: Table 10.8-1 Minimum Nominal Full-load Efficiency for General Purpose Electric Motors (Subtype I), Except Fire-Pump Electric Motors and Table 10.8-2 Minimum Nominal Full-load Efficiency for General Purpose Electric Motors (Subtype II), Except Fire-Pump Electric Motors.
- 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.

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

- California Public Utility Commission. Database for Energy Efficiency Resources, 2005.
- Bonneville Power Authority Adjustable Speed Drive Calculator—Fan curves utilized from that calculator were derived from "Flow Control," a Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121. http://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls.

Document Revision History

Table 92. Nonresidential HVAC VFD 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 revisions.
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 46.
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.

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 94 through Table 98

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 93 contains values that can be used as a reference for evaluating evaporative effectiveness.

Table 93. Average Weather During Peak Conditions[198]

Climate zone	Temperature (°F)	Humidity (%)
1—Amarillo	95.8	25
2—Dallas	101.2	34
3—Houston	99.1	37
4—Corpus Christi	92.5	49
5—El Paso	97.4	15

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Energy\ Savings\ \left[kWh_{savings}\right] = (Cap_C \times \eta_C) \times EFLH_{reduction}$$

Equation 55

$$Peak\ Demand\ [kW_{Savings}] = (Cap_C \times \eta_C) \times DRF$$

Equation 56

198 Extracted from weather data from building models that were used to create summer peak period value used for this measure.

Where:

Cap_C	=	*Rated equipment cooling capacity of the existing equipment at AHRI-standard conditions [tons]; 1 ton = 12,000 Btuh*
η_C	=	*Cooling efficiency of existing equipment [kW/ton]* *Note: For DX systems, use EER for kW savings calculations and SEER/IEER for kWh savings calculations. For air-cooled chillers, use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. In the cases where the full-load efficiency is provided in terms of EER or SEER/IEER rather than kW/ton and IPLV, a unit conversion to kW/ton needs to be performed using the following conversion:*

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

Equation 57

$EFLH_{reduction}$	=	*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 94 through Table 98.*
DRF	=	*Demand reduction factor. The average peak hour energy reduction divided by the rated full loaded demand. See Table 94 through Table 98.*

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 30. These building types are derived from the EIA CBECS study.[199]

[199] 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.*

The DRF and $EFLH_{reduction}$ values for packaged and split AC are presented in Table 94 through Table 98. 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 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 94. DRF and EFLH Reduction Values for Amarillo (Climate Zone 1)

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Education	College	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	0.18	125	-	-
	Supermarket	0.08	37	-	-
Food service	Full-service restaurant	0.21	134	-	-
	Quick-service restaurant	0.18	109	-	-
Healthcare	Hospital	0.21	160	0.18	151
	Outpatient healthcare	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	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Service	Service	0.21	104	-	-
Warehouse	Warehouse	0.12	34	-	-
Other	Other	0.08	34	0.10	45

Table 95. DRF and EFLH Reduction Values for Fort Worth (Climate Zone 2)

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Education	College	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	0.24	214	-	-
	Supermarket	0.15	78	-	-
Food service	Full-service restaurant	0.23	194	-	-
	Quick-service restaurant	0.24	185	-	-
Healthcare	Hospital	0.24	230	0.22	216
	Outpatient healthcare	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	0.23	150	-	-
Warehouse	Warehouse	0.20	93	-	-
Other	Other	0.15	78	0.12	72

Table 96. DRF and EFLH Reduction Values for Houston (Climate Zone 3)

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Education	College	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	0.22	193	-	-
	Supermarket	0.14	76	-	-
Food service	Full-service restaurant	0.21	171	-	-
	Quick-service restaurant	0.22	167	-	-
Healthcare	Hospital	0.21	202	0.19	187
	Outpatient healthcare	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	0.21	132	-	-
Warehouse	Warehouse	0.18	81	-	-
Other	Other	0.13	76	0.10	74

Table 97. DRF and EFLH Reduction Values for Corpus Christi (Climate Zone 4)

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Education	College	0.13	161	0.11	160
	Primary school	0.14	113	0.07	68
	Secondary school	0.13	110	0.11	109
Food sales	Convenience	0.14	188	-	-
	Supermarket	0.08	74	-	-
Food service	Full-service restaurant	0.13	157	-	-
	Quick-service restaurant	0.14	162	-	-
Healthcare	Hospital	0.15	199	0.09	169
	Outpatient healthcare	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	0.13	122	-	-
Warehouse	Warehouse	0.12	74	-	-
Other	Other	0.08	74	0.07	68

Table 98. DRF and EFLH Reduction Values for El Paso (Climate Zone 5)

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRF	$EFLH_{reduction}$	DRF	$EFLH_{reduction}$
Education	College	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	0.25	232	-	-
	Supermarket	0.12	76	-	-
Food service	Full-service restaurant	0.25	223	-	-
	Quick-service restaurant	0.25	201	-	-
Healthcare	Hospital	0.26	273	0.20	247
	Outpatient healthcare	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	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.[200]

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
- Building type
- Climate zone
- 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

Not applicable.

[200] 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.

Document Revision History

Table 99. Nonresidential Condenser Air 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 revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Specified that formulas use tons and kW/ton values and added conversion factors from other units.

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.[201] 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

$$Energy\ Savings\ (kWh) = \left(\frac{W_{base} - W_{HVLS}}{1000}\right) \times Hours$$

Equation 58

$$Summer\ Demand\ Savings\ (kW) = \left(\frac{W_{base} - W_{HVLS}}{1000}\right) \times CF$$

Equation 59

[201] Motor hp from manufacturer product specification sheets available from https://macroairfans.com/architects-engineers/ and https://www.bigassfans.com/aedownloads/. Airflow range from Kammel et al, "Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns," available at https://www.researchgate.net/publication/271433461_Design_of_high_volume_low_speed_fan_supplemental_cooling_system_in_dairy_freestall_barns, and from MacroAir Fans "Horse Barn Ventilation Systems" white paper, available at https://macroairfans.com/wp-content/uploads/2012/03/Horse-Barn-Ventilation-White-Paper.pdf.

Where:

W_{base}	=	*power input required to move replaced fans at rated speed*
W_{HVLS}	=	*power input required to move installed HVLS fans at rated speed*
Hours	=	*hours of operation in the project application, as described below*
CF	=	*coincidence factor (1.0, as fans are always operating in summer peak conditions)*

Retrofit (Early Retirement)

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

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

Equation 60

Where:

CFM_{base}	=	*airflow rate produced by replaced fans*
η_{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.[202]

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

Equation 61

[202] Database of circulating fans tested by the Bioenvironmental and Structural Systems Laboratory of the Agricultural and Biological Engineering Dept., University of Illinois at Urbana-Champagne 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.

Hours of Operation

Table 100 provides the hours to be used in calculating energy savings for HVLS fan installation by climate zone.

Table 100. Hours of Circulating Fan Operation by Barn Type[203]

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[204] 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.

[203] 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).

[204] DOE Motor Systems Tip Sheet #3 available at 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
- 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

None.

Relevant Standards and Reference Sources

- Kammel, David and Raabe, and Kappelman, J. (2003). Design of high-volume low-speed fan supplemental cooling system in dairy freestall barns. Proceedings of the Fifth International Dairy Housing Conference. 10.13031/2013.11628. Online. Available: https://www.researchgate.net/publication/271433461_Design_of_high_volume_low_speed_fan_supplemental_cooling_system_in_dairy_freestall_barns.
- https://macroairfans.com/wp-content/uploads/2012/03/Horse-Barn-Ventilation-White-Paper.pdf
- BESS Laboratory Database of Agricultural Fans. Bioenvironmental and Structural Systems Laboratory of the Agricultural and Biological Engineering Dept., University of Illinois at Urbana-Champagne. Online. Data for Circulating Fans available: http://www.bess.illinois.edu/currentc.asp.

Document Revision History

Table 101. Nonresidential High-Volume Low-Speed Fans 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 revisions.

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 30 through Table 36

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

Table 102. Baseline Efficiency Levels for ROB and NC Air Conditioners[205]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[206]
Packaged air conditioner	< 5.4	All	11.8 EER[207] 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

$$Peak\ Demand\ (Summer)\ [kW_{Savings,C}] = Cap_C \times \frac{1}{\eta_{baseline,C}} \times DF_C \times \frac{1\ kW}{1{,}000\ W} \times CRF$$

Equation 62

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = Cap_C \times \frac{1}{\eta_{baseline,C}} \times EFLH_C \times \frac{1\ kW}{1{,}000\ W} \times CRF$$

Equation 63

Where:

Cap_C = *Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh[208]; 1 ton = 12,000 Btuh*

$\eta_{baseline,C}$ = *Cooling efficiency of standard equipment (ROB/NC) [Btuh/W]; see Table 29*

Note: Use EER for kW savings calculations and SEER for kWh savings calculations.

DF_C = *Seasonal peak demand factor; see Table 36*

$EFLH_C$ = *Cooling/heating equivalent full-load hours [hours]; see Table 36*

CRF = *Consumption reduction factor[209] = 75%*

[205] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[206] 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.
[207] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[208] New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.
[209] Department of Energy, https://www.energy.gov/energysaver/evaporative-coolers.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) 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 103. DF and EFLH Values for El Paso (Climate Zone 5)

Building type	Principal building activity	DX AC	
		DF_C	$EFLH_C$
Data center	Data center	0.88	2,547
Education	College/university	0.87	1,092
	Primary school	0.91	996
	Secondary school	0.87	742
Food sales	Convenience	0.76	1,251
	Supermarket	0.38	347
Food service	Full-service restaurant	0.76	1,276
	24-hour full-service	0.74	1,413
	Quick-service restaurant	0.76	1,082
	24-hour quick-service	0.77	1,171
Healthcare	Hospital	0.81	2,555
	Outpatient healthcare	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 stand-alone 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
Public assembly	Public assembly	0.91	1,339
Religious worship	Religious worship	0.63	478

Building type	Principal building activity	DX AC	
		DF_C	$EFLH_C$
Service	Service	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.[210]

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 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
- **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

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

References and Efficiency Standards

Petitions and Rulings

None.

Relevant Standards and Reference Sources

- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75&action=viewlive.

Document Revision History

Table 104. Nonresidential Small Commercial Evaporative Cooling Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

2.3 NONRESIDENTIAL: BUILDING ENVELOPE

2.3.1 ENERGY STAR® 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

Measures installed through utility programs must be a roof that is compliant with the current ENERGY STAR® specification, effective July 2017.[211] For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under high-efficiency condition 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[212]
- An initial solar reflectance of greater than or equal to 65 percent

[211] ENERGY STAR® Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

[212] As defined in proposed ASTN Standard E 1918-97.

- Maintenance of solar reflectance of greater than or equal to 50 percent three years after installation under normal conditions
- 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 cooling, heating, or both
- Be listed on the ENERGY STAR® list of qualified products[213] or have a performance rating that is validated by the Cool Roof Rating Council (CRRC). ENERGY STAR® test criteria[214] allows for products already participating in the CRRC Product Rating Program[215] to submit solar reflectance and thermal emittance product information derived from CRRC certification.
- The ENERGY STAR® specification for roof products will sunset effective June 1, 2022.[216] No new roof products will be certified as of June 1, 2021. At this point, ENERGY STAR® legacy or CRRC product certification will be required to demonstrate compliance with the previous ENERGY STAR® specification.

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 make-up and the solar reflectance and emissivity of the surface layer. The R-value is estimated based on code envelope requirements applicable in the year of construction. 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 LBLN Roofing Materials Database.[217]

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building and are based on typical code requirements applicable in the year of construction.

213 ENERGY STAR® Certified Roofs. http://www.energystar.gov/productfinder/product/certified-roof-products/.

214 ENERGY STAR® Program Requirements for Roof Products v2.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.

215 CRRC Rated Products Directory: https://coolroofs.org/directory.

216 ENERGY STAR® Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.

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

Table 105. Cool Roofs—Assumed Cooling and Heating Efficiencies (COP)

Year of construction; 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

High-Efficiency Condition

The high-efficiency condition depends on the project scope. The project scope is defined as one of:

- Adding surface layer only
- Adding insulation and surface layer
- Rebuilding entire roof assembly

If the project scope is only to add a new ENERGY STAR® 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 an ENERGY STAR® 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 ENERGY STAR® certified roof product performance specifications for the relevant roof application. Initial and 3-year reflectance ratings must meet or exceed the minimum thresholds specified in Table 106.

Table 106. Cool Roofs—ENERGY STAR® Specification[218]

Roof slope	Characteristic	Performance specification
Low slope ≤ 2/12	Initial solar reflectance	≥ 0.65
	3-year solar reflectance	≥ 0.50

[218] ENERGY STAR® Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

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 demand factors and EFLH and can be found from
Table 108 through
Table 112. 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:

$$Energy\ Savings = Roof\ Area \times ESF$$

Equation 64

$$Peak\ Summer\ Demand\ Savings = Roof\ Area \times PSDF \times 10^{-5}$$

Equation 65

$$Peak\ Winter\ Demand\ Savings = Roof\ Area \times PWDF \times 10^{-6}$$

Equation 66

Where:

Roof Area = *Total area of ENERGY STAR® roof in square feet*

ESF = *Energy Savings Factor from Table 108 through Table 112 by building type, pre/post insulation levels, and heating/cooling system*

PSDF = *Peak Summer Demand Factor from Table 108 through Table 112 by building type, pre/post insulation levels, and heating/cooling system*

PWDF = *Peak Winter Demand Savings Factor from Table 108 through Table 112 by building type, pre/post insulation levels, and heating/cooling system*

If the insulation levels are unknown, use the mapping in Table 107 to estimate the R-value based on the year of construction.

Table 107. Cool Roofs—Estimated R-Value based on Year of Construction

Year of construction	Estimated R-value[219]
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

Table 108. Cool Roofs—Savings Factors for Amarillo (Climate Zone 1)

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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

[219] Estimates R-values are based on applicable code requirements in the year of construction.

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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 109. Cool Roofs—Savings Factors for Dallas (Climate Zone 2)

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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 110. Cool Roofs—Savings Factors for Houston (Climate Zone 3)

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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 111. Cool Roofs—Savings Factors for Corpus Christi (Climate Zone 4)

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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 112. Cool Roofs—Savings Factors for El Paso (Climate Zone 5)

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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

Building type	Pre-R-value	Post R-value	ESF	PSDF	PWDF
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
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) READI tool for EUL ID BldgEnv-CoolRoof.[220]

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

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 location
- 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 3-year solar reflectance
- New roofing rated life
- Copy of ENERGY STAR® certification or alternative
- 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

- ENERGY STAR® Certified Cool Roof Products. http://www.energystar.gov/productfinder/product/certified-roof-products/.
- IECC 2000 Table 802.2(17), 2009 Table 502.2(1), and 2015 Table C402.1.4

Document Revision History

Table 113. Nonresidential ENERGY STAR® 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 revisions.

TRM version	Date	Description of change
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 revisions.
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.

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 114). 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 (DX or chilled water).

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).

Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatments.

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 EUMMOT utilities, as presented in the EUMMOT program manual *Commercial Standard Offer Program: Measurement and Verification Guidelines for Retrofit and New Construction Projects.* The method estimates the reduction in solar heat gain/insolation attributable to a given window treatment using shading coefficients for the treated and untreated window and solar heat gain estimates by window orientation, according to ASHRAE Fundamentals. The reduction in building energy use attributable to the reduction in cooling system energy use is estimated based on the reduced heat removal requirement for a standard efficiency cooling system.

Savings Algorithms and Input Variables

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

Equation 67

$$Peak\ Demand\ Savings\ [kW] = DemandSaving_{o,max}$$

Equation 68

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

Equation 69

$$Energy\ Savings\ [kWh] = \sum Energy\ Savings_o$$

Equation 70

Where:

Demand Savings	=	*Peak demand savings per window orientation*
Energy Savings	=	*Energy savings per window orientation*
$A_{film,o}$	=	*Area of window film applied to orientation [ft^2]*
$SHGF_o$	=	*Peak solar heat gain factor for orientation of interest [Btu/hr-ft^2-year]; see Table 114*
SHG_o	=	*Solar heat gain for orientation of interest [Btu/ft2-year]; see Table 114*
$SHGC_{pre}$	=	*Solar heat gain coefficient for existing glass with no interior-shading device; see Table 115*

$SHGC_{post}$	=	*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.[221]

COP	=	*Cooling equipment COP based on Table 116 or actual COP equipment, whichever is greater; if building construction year is unknown, assume IECC 2009 as applicable code*
3,412	=	*Conversion factor [Btu/kWh]*

Table 114. Windows Treatments—Solar Heat Gain Factors[222]

Orientation	Solar heat gain (SHG) (Btu/ft^2-year)	Peak hour solar heat gain (SHGF) (Btu/hr-ft^2-year)				
		Zone 1[223]	Zone 2	Zone 3	Zone 4	Zone 5
South-East	158,844	28	30	26	27	35
South-South-East	134,794	28	31	28	28	37
South	120,839	37	44	47	45	56
South-South-West	134,794	88	94	113	113	101
South-West	158,844	152	151	170	173	141
West-South-West	169,696	191	184	201	206	160
West	163,006	202	189	201	207	155
West-North-West	139,615	183	167	171	178	128
North-West	107,161	136	120	115	121	85

Table 115. Windows Treatment—Recommended Clear Glass $SHGC_{pre}$ by Window Thickness[224]

Existing window thickness (inches)	$SHGC_{pre}$
Single-pane 1/8-inch clear glass	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

221 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

222 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 32ºN Latitude for the 21st day of each month by hour of day and solar orientation. The SHG values listed above have been aggregated into daily totals for weekdays during the months of April through October.

223 Coincidence factors specific to Climate Zone 1 could not be calculated since utility load data are not currently available for this region. In their absence, Climate Zone 2 values may be used.

224 2017 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC).

Table 116. Recommended COP by HVAC System Type[225]

Year of construction; applicable code	AC/HP	PTAC/PTHP	Air-cooled chiller	Water-cooled chiller
Before 2011; 2000 IECC	2.9	2.9	2.5	4.2
Between 2011-2016; 2009 IECC	3.8	3.1	2.8	5.5
After 2016; 2015 IECC	3.8	3.1	2.8	5.5

Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GlazDaylt-WinFilm.[226]

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:

- 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)
- Year of construction, if available
- Cooling equipment type
- Cooling equipment rated efficiency

[225] Based on review applicable codes, including IECC 2000, 2009, and 2015.
[226] 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 reflective window films and sunscreens.

Relevant Standards and Reference Sources

- 1997 ASHRAE Fundamentals, Chapter 29, Table 17.
- International Energy Conservation Code (IECC) 2000, 2009, and 2015

Document Revision History

Table 117. Nonresidential Window 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.
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 revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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 at least 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).[227] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,[228] and an average building height of 20 feet is assumed for the deemed savings approach.

Because air infiltration is a function of differential pressure due to stack effect, wind speed, velocity head, and the design conditions of the building, TMY3 for each Texas weather zone reference city was applied to account for the varying weather conditions that are characteristic throughout an average year.

Figure 5.13 from the ASHRAE CHLCM provides the infiltration rate based on various crack width and the corresponding pressure difference across a door. Figures 5.1 and 5.2 (CHLCM) provide the differential pressure due to stack and wind pressure necessary to determine the total pressure difference across the door.

Applying a regression analysis to Figure 5.1 returns an equation that allows solving for the pressure difference due to stack effect, Δp_s. The aggregate curve fit for Figure 5.1 is shown below where 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 71

Where C_d is an assumed constant, 0.63, and the neutral pressure distance is 10 feet.

From Figure 5.2, $\Delta p_w/C_p$ is determined by applying a polynomial regression, which returns an equation for solving for the pressure difference due to wind, Δp_w. The curve fit for Figure 5.2 is shown below where x is the wind velocity based on TMY3 data.

$$\Delta p_w / C_p = 0.00047749x^2 - 0.00013041x$$

Equation 72

Where C_p is an assumed constant, 0.13 (average wind pressure coefficient from Table 5.5 from CHLCM).

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[227] ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980. http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf.

[228] 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.

This yields the total pressure difference across the door, Δp_{Total}:

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

Equation 73

Solving for Δp_{Total} allows for the air infiltration rate per linear foot to be determined in Figure 5.13 (CHLCM). Applying a power regression analysis for each crack width (described in inches) represented in Figure 5.13 (CHLCM) returns the equations listed below. In these equations, *Q* is the infiltration rate in cubic feet per minute through cracks around the door, and *P* is the perimeter of the door in feet.

$$Q/P_{1/8"} = 41.572x^{0.5120}$$

Equation 74

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

Equation 75

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

Equation 76

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

Equation 77

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 78

Where:

T_{design}	=	*Daytime and nighttime design temperature (°F, see Table 119)*
$T_{avg\ outside\ ambient}$	=	*Average outside ambient temperature, specified by month (°F, see Table 118)*

Table 118. Average Monthly Ambient Temperatures (°F)[229]

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 119. Daytime and Nighttime Design Temperatures

Temperature description	T_{design} (°F)
Daytime cooling design temperature	74
Daytime heating design temperature	72
Nighttime cooling design temperature[230]	78
Nighttime heating design temperature[231]	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

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

Equation 79

[229] TMY3 climate data.
[230] Assuming 4-degree setback.
[231] Ibid.

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

Equation 80

$$Cooling\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}$$

Equation 81

Electric Heating Energy Savings

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

Equation 82

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

Equation 83

$$Heating\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}$$

Equation 84

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

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

Equation 85

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

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

Equation 86

Where:

CFM_{pre}	=	*Calculated pre-retrofit air infiltration (cubic feet per minute)*
$CFM_{reduction}$	=	*59%[232] x TDF*
TDF	=	*Technical degradation factor = 85%[233]*
1.08	=	*Sensible heat equation conversion[234]*
ΔT	=	*Change in temperature across gap barrier (°F)*
$Hours_{day}$	=	*12-hour cycles per day, per month = 4,380 hours*
$Hours_{night}$	=	*12-hour cycles per night, per month = 4,380 hours*
COP	=	*Heating coefficient of performance; 1.0 for electric resistance and 3.3 for heat pumps*

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings per 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 120 through Table 125. 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 120. Deemed Cooling Energy Savings per Linear Foot of Weather Stripping/Door Sweep

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

232 CLEAResult, "Commercial Door Air Infiltration Memo". March 18, 2015. Average reduction in Arkansas based on test results from the CLEAResult Brush Weather Stripping Testing Method and Results (59% infiltration reduction).

233 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.

234 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

Table 121. Deemed ER Heating Energy Savings per Linear Foot of Weather Stripping/Door Sweep

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

Table 122. Deemed HP Heating Energy Savings per Linear Foot of Weather Stripping/Door Sweep

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

Table 123. Deemed Summer Demand Savings per Linear Foot of Weather Stripping/Door Sweep

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

Table 124. Deemed ER Winter Demand Savings per Linear Foot of Weather Stripping/Door Sweep

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

Table 125. Deemed HP Winter Demand Savings per Linear Foot of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Zone 1: Amarillo	0.0138	0.0277	0.0550	0.0825
Zone 2: Dallas	0.0178	0.0357	0.0710	0.1066
Zone 3: Houston	0.0102	0.0207	0.0410	0.0615
Zone 4: Corpus Christi	0.0087	0.0175	0.0348	0.0523
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) READI tool for EUL ID BS-Wthr.[235] 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
- 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.

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

Relevant Standards and Reference Sources

- Not applicable.

Document Revision History

Table 126. Nonresidential Entrance and Exit Door 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.

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 ≥ 5 and ≤ 20.[236, 237]

- Half-size combination oven: capable of accommodating a single 12 x 20 x 2½-inch steam table pan per rack position, loaded from front-to-back or lengthwise.
- Full-size combination oven: capable of accommodating two 12 x 20 x 2½-inch steam table pans per rack position, loaded from front-to-back or lengthwise.

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[236] ENERGY STAR® Program Requirements for Commercial Ovens. Eligibility Criteria Version 2.2. https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf.

[237] 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.[238]

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

- 2/3-sized combination ovens
- Dual-fuel heat source combination ovens
- Gas combination ovens
- Electric combination ovens with a pan capacity < 5 or > 20
- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Electric rack ovens
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie

Baseline Condition

The baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20 that does not meet ENERGY STAR® key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v2.2 specification, effective October 7, 2015. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 127.

Table 127. Combination Ovens—ENERGY STAR® Specification[239]

Operation	Idle rate (kW)[240]	Cooking energy efficiency (%)
Steam mode	≤ 0.133P + 0.6400	≥ 55
Convection mode	≤ 0.080P + 0.4989	≥ 76

[238] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.
[239] ENERGY STAR® Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.
[240] P = Pan Capacity.

Furthermore, Pan Capacity[241] must be ≥ 5 and ≤ 20 (for both half- and full-size combination ovens).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

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

Equation 87

$$kWh_{base} = kWh_{ph,base} + kWh_{conv,base} + kWh_{st,base}$$

Equation 88

$$kWh_{ES} = kWh_{ph,ES} + kWh_{conv,ES} + kWh_{st,ES}$$

Equation 89

kWh_{ph}, kWh_{conv} and kWh_{st} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 90, except they require their respective input assumptions relative to preheat, cooking and idle operation in convection and steam modes as seen in Table 128.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food} \times 50\%}{\eta_{cook}}\right) + E_{idle} \times \left(\left(t_{on} - \frac{W_{food}}{PC}\right) \times 50\%\right)\right) \times \frac{t_{days}}{1000}$$

Equation 90

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 91

Where:

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

[241] 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]*
η_{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]*
1000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 128. Combination Ovens—ENERGY STAR® Commercial Food Service Calculator Inputs[242]

<table>
<tr><th colspan="2" rowspan="2">Parameter</th><th colspan="2">Convection mode</th><th colspan="2">Steam mode</th></tr>
<tr><th>Baseline</th><th>ENERGY STAR®</th><th>Baseline</th><th>ENERGY STAR®</th></tr>
<tr><td rowspan="2">E_{ph}</td><td>P < 15</td><td colspan="2">3,000</td><td colspan="2">1,500</td></tr>
<tr><td>P ≥ 15</td><td colspan="2">3,750</td><td colspan="2">2,000</td></tr>
<tr><td rowspan="2">W_{food}</td><td>P < 15</td><td colspan="4">200</td></tr>
<tr><td>P ≥ 15</td><td colspan="4">250</td></tr>
<tr><td colspan="2">E_{food}</td><td colspan="2">73.2</td><td colspan="2">30.8</td></tr>
<tr><td colspan="2">η_{cook}</td><td>72%</td><td>76%</td><td>49%</td><td>55%</td></tr>
<tr><td rowspan="2">E_{idle}</td><td>P < 15</td><td>1,320</td><td rowspan="2">(0.080P + 0.4989) x 1000</td><td>5,260</td><td rowspan="2">(0.133P + 0.6400) x 1000</td></tr>
<tr><td>P ≥ 15</td><td>2,280</td><td>8,710</td></tr>
<tr><td rowspan="2">PC[243]</td><td>P < 15</td><td>79</td><td>119</td><td>126</td><td>177</td></tr>
<tr><td>P ≥ 15</td><td>166</td><td>201</td><td>295</td><td>349</td></tr>
<tr><td colspan="2">t_{on}</td><td colspan="4">12</td></tr>
<tr><td colspan="2">t_{days}</td><td colspan="4">365</td></tr>
<tr><td colspan="2">CF[244]</td><td colspan="4">0.90</td></tr>
</table>

242 ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.
243 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.
244 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

The following deemed energy and demand savings are based on the input assumptions from Table 128:

Table 129. Combination Ovens—Deemed Energy and Demand Savings Values[245]

Pan capacity	Annual energy savings (kWh)	Peak demand savings (kW)
5	4,015	0.723
6	4,677	0.857
7	5,356	0.994
8	6,051	1.134
9	6,761	1.278
10	7,488	1.425
11	8,231	1.575
12	8,990	1.729
13	9,765	1.886
14	10,556	2.046
15	11,363	2.210
16	12,187	2.376
17	13,026	2.546
18	13,881	2.720
19	14,753	2.897
20	15,640	3.077

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-ElecCombOven.[246]

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[245] 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.

[246] 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
- 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

- ENERGY STAR® Equipment Standards for Commercial Ovens. http://www.energystar.gov/products/certified-products/detail/Commercial-ovens
- DEER 2014 EUL update.

Document Revision History

Table 130. Nonresidential ENERGY STAR® 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 revisions.
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 revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
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. Incorporated March 2021 calculator updates. Corrected ENERGY STAR® idle rate formulas. Updated tracking system requirements and EUL reference.

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:[247, 248]

- 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.

[247] ENERGY STAR® Program Requirements for Commercial Ovens. https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf.

[248] 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.[249]

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:

- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Electric rack ovens
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie

Baseline Condition

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

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v2.2 specification, effective October 7, 2015. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 131.

Table 131. Convection Ovens—ENERGY STAR® Specification[250]

<table>
<tr><th>Oven size</th><th>Idle rate (W)</th><th>Cooking energy efficiency (%)</th></tr>
<tr><td>Full size</td><td>≤ 1,600</td><td rowspan="2">≥ 71</td></tr>
<tr><td>Half size</td><td>≤ 1,000</td></tr>
</table>

[249] CEE Commercial Kitchens Initiative's overview of the food service industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf

[250] ENERGY STAR® 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:

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

Equation 92

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

Equation 93

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

Equation 94

kWh_{ph}, kWh_{cook}, and *kWh_{idle}* are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 95, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 132.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{\text{cook}}}\right) + E_{idle} \times \left(t_{on} - \frac{W_{food}}{PC}\right)\right) \times \frac{t_{days}}{1000}$$

Equation 95

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 96

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/BTU]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR® preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%]*

PC	=	*Production capacity [lb/hr]*
t_{on}	=	*Operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1000	=	*Constant to convert from W to kW*
CF	=	*Coincidence factor*

Table 132. Convection Ovens—ENERGY STAR® Commercial Food Service Calculator Inputs[251]

Parameter	Full size		Half size	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
E_{ph}	1,563	890	1,389	700
W_{food}	100			
E_{food}	73.2			
η_{cook}	65%	71%	68%	70.67%
E_{idle}	2,000	1,600	1,030	1,000
PC	90	90	45	50
t_{on}	12			
t_{days}	365			
CF[252]	0.90			

Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings are based on the input assumptions from Table 132:

Table 133. Convection Ovens—Deemed Energy and Demand Savings Values

Oven size	Annual energy savings (kWh)	Peak demand savings (kW)
Full size	2,001	0.398
Half size	244	0.036

[251] ENERGY STAR® Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.
[252] 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-ElecConvOven.[253]

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
- 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

- ENERGY STAR® requirements for Commercial Ovens. http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens.
- ENERGY STAR® list of Qualified Commercial Ovens. https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.
- DEER 2014 EUL update.

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

Document Revision History

Table 134. Nonresidential ENERGY STAR® Convection Oven 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR® Commercial Ovens Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR® Measure.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
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.

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.[254, 255] These categories are described in Table 135:

- Under counter dishwasher
- Stationary rack, single tank, door type dishwasher
- Single tank conveyor dishwasher

[254] ENERGY STAR® Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/Commercial%20Dishwashers%20Final%20Version%203.0%20Specification_0.pdf.

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

- Multiple tank conveyor dishwasher
- Pot, pan, and utensil

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[256]

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

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

Table 135. 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.

[256] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf

Equipment type	Equipment description
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.

Baseline Condition

Baseline equipment is either a low-temperature[257] or high-temperature[258] machine as defined by Table 135, 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 136.

Table 136. Dishwashers—ENERGY STAR® Specification[259]

Machine type	Low-temperature efficiency requirements		High-temperature efficiency requirements	
	Idle energy rate (kW)	Water consumption (gal/rack)	Idle energy rate (kW)	Water consumption (gal/rack)
Under counter	≤ 0.25	≤ 1.19	≤ 0.30	≤ 0.86
Stationary single-tank door	≤ 0.30	≤ 1.18	≤ 0.55	≤ 0.89
Single-tank conveyor	≤ 0.85	≤ 0.79	≤ 1.20	≤ 0.70
Multiple-tank conveyor	≤ 1.00	≤ 0.54	≤ 1.85	≤ 0.54
Pot, pan, and utensil	N/A	N/A	≤ 0.90	≤ 0.58[260]

257 Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

258 High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

259 ENERGY STAR® Commercial Dishwashers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria.

260 Water consumption for pot, pan, and utensil is specified in gallons-per-square-foot rather than gallons-per-rack.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values are calculated using the following algorithms:

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

Equation 97

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

Equation 98

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

Equation 99

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

Equation 100

Where:

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

60	=	*Constant to convert from minutes to hours*
CF	=	*Peak coincidence factor*

Table 137. Dishwashers—ENERGY STAR® Commercial Food Service Calculator Inputs[261]

Inputs	Under counter	Single-door type	Single-tank conveyor	Multiple-tank conveyor	Pot, pan, and utensil
ρ_{water}	61.4 ÷ 7.48 = 8.2				
C_p	1.0				
ΔT_{DHW}	Gas water heaters: 0ºF Electric water heaters: 70 ºF				
ΔT_{boost}	Gas booster heaters: 0 ºF Electric booster heaters: 40 ºF				
η_{DHW}	98%				
t_{on}	18				
t_{days}	365				
CF[262]	0.90				
Low-temperature units					
N_{racks}	75	280	400	600	--
$V_{rack,base}$	1.73	2.10	1.31	1.04	--
$V_{rack,ES}$	1.19	1.18	0.79	0.54	--
$E_{idle,base}$	0.50	0.60	1.60	2.00	--
$E_{idle,ES}$	0.25	0.30	0.85	1.00	--
t_{wash}	2.0	1.5	0.3	0.3	--
High-temperature units					
N_{racks}	75	280	400	600	280
$V_{rack,base}$	1.09	1.29	0.87	0.97	0.70
$V_{rack,ES}$	0.86	0.89	0.70	0.54	0.58
$E_{idle,base}$	0.76	0.87	1.93	2.59	1.20
$E_{idle,ES}$	0.30	0.55	1.20	1.85	0.90
t_{wash}	2.0	1.0	0.3	0.2	3.0

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

[262] 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

The following deemed energy and demand savings are based on the input assumptions from Table 137:

Table 138. Dishwashers—Deemed Energy and Demand Savings Values

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) varies per eligible dishwasher type, as stated in the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.

Table 139. 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

- ENERGY STAR® requirements for Commercial Dishwashers. http://www.energystar.gov/sites/default/files/specs//private/Commercial_Dishwasher_Program_Requirements%20v2_0.pdf.
- ENERGY STAR® maintains an online list of qualified Commercial dishwashers meeting or exceeding ENERGY STAR® requirements at http://www.energystar.gov/productfinder/product/certified-Commercial-dishwashers/results.
- ENERGY STAR® v2.0 Calculator (Commercial Kitchen Equipment Savings Calculator). http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

Document Revision History

Table 140. Nonresidential ENERGY STAR® Dishwashers Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Update savings based on the newest version of ENERGY STAR® deemed input variables.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Water Use per Rack in Table 2-90.

TRM version	Date	Description of change
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 revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
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. General reference checks and text edits. Incorporated March 2021 calculator update. Updated variable definitions.

2.4.4 ENERGY STAR® Hot Food Holding Cabinets Measure Overview

TRM Measure ID: NR-FS-HC

Market Sector: Commercial

Measure Category: Food Service Equipment

Applicable Building Types: See Eligibility Criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

HFHCs must be compliant with the current ENERGY STAR® specification.[263, 264] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[265]

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263 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.

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

265 CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.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 141 summarizes idle energy rate requirement based on cabinet interior volume.

Table 141. HFHCs—ENERGY STAR® Specification[266, 267]

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

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

Deemed values are calculated using the following algorithms:

$$Energy\ Saving\ [\Delta kWh] = \left(E_{Idle,base} - E_{Idle,ES}\right) \times \frac{1}{1000} \times t_{on} \times t_{days}$$

Equation 101

$$Peak\ Demand\ [\Delta kW] = \left(E_{Idle,base} - E_{Idle,ES}\right) \times \frac{1}{1000} \times CF$$

Equation 102

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

[267] V = Interior Volume = Interior Height x Interior Width x Interior Depth.

Where:

V	=	*Product interior volume [ft³]*
$E_{Idle,base}$	=	*Baseline idle energy rate [W]*
$E_{Idle,ES}$	=	*ENERGY STAR® idle energy rate after installation [W]*
t_{on}	=	*Equipment operating hours per day [hrs/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 142. HFHCs—ENERGY STAR® Commercial Food Service Calculator Inputs[268]

Input variable	Product interior volume range		
	0 < V < 13	13 ≤ V < 28	28 ≤ V
V[269]	8	22	53
$E_{Idle,base}$	30 × V		
$E_{Idle,ES}$	21.5 × V	2 × V + 254	3.8 × V + 203.5
t_{on}	9		
t_{days}	365		
CF[270]	0.90		

Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings are based on the input assumptions from Table 142:

Table 143. HFHCs—Deemed Energy and Demand Savings Values

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

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

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

270 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.[271]

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

- ENERGY STAR® requirements for Hot Food Holding Cabinets. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_HFHC_Program_Requirements_2.0.pdf.
- DEER 2014 EUL update.

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

Document Revision History

Table 144. Nonresidential ENERGY STAR® Hot Food Holding Cabinets 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR® Hot Food Holding Cabinet Program Requirements Version 2.0. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
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.

2.4.5 ENERGY STAR® Electric Fryers Measure Overview

TRM Measure ID: NR-FS-EF

Market Sector: Commercial

Measure Category: Cooking Equipment

Applicable Building Types: See Eligibility Criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Eligible units must meet be compliant with the current ENERGY STAR® specification, either counter-top or floor type designs, with standard-size and large vat fryers as defined below:[272, 273]

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[274]

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

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

[274] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.

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

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

Baseline Condition

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

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v3.0 specification, effective October 1, 2016. New electric standard fryers ≥ 12 inches and < 18 inches wide and large vat fryers > 18 inches and < 24 inches wide that meet or exceed the requirements listed in Table 145.

Table 145. Fryers—ENERGY STAR® Specification[275]

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed values are calculated using the following algorithms:

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

Equation 103

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

Equation 104

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

Equation 105

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 106, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 146.

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

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{\text{cook}}}\right) + E_{idle} \times \left(t_{on} - \frac{t_{ph}}{60} - \frac{W_{food}}{PC}\right)\right) \times \frac{t_{days}}{1000}$$

Equation 106

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 107

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/BTU]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR® preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity [lb/hr]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 146. Fryers—ENERGY STAR® Commercial Food Service Calculator Inputs[276]

Parameter	Standard-sized vat		Large vat	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
E_{ph}	2,400	1,900	2,400	1,900
W_{food}	150			
E_{food}	167			
η_{cook}	75%	83%	70%	80%
E_{idle}	1,200	800	1,350	1,100
PC	65	70	100	110
t_{on}	16		12	
t_{days}	365			
CF[277]	0.90			

Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings of are based on the assumptions from Table 146:

Table 147. Fryers—Deemed Energy and Demand Savings Values

Fryer type	Annual energy savings (kWh)	Peak demand savings (kW)
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.[278]

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

277 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.

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Electric Fryers.

Relevant Standards and Reference Sources

- ENERGY STAR® requirements for Electric Fryers https://www.energystar.gov/sites/default/files/specs/private/Commercial_Fryers_Program_Requirements.pdf.
- DEER 2014 EUL update.

Document Revision History

Table 148. Nonresidential ENERGY STAR® Electric Fryers Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
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 revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. Savings and efficiencies revised for ENERGY STAR® 3.0 specifications. 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. Incorporated March 2021 calculator update. Updated EUL reference.

2.4.6 ENERGY STAR® Electric Steam Cookers Measure Overview

TRM Measure ID: NR-FS-SC

Market Sector: Commercial

Measure Category: Cooking Equipment

Applicable Building Types: See Eligibility Criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR® specification.[279, 280] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[281]

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

[279] 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.

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

[281] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.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 149.

Table 149. Steam Cookers—ENERGY STAR® Specification[282]

Pan capacity	Cooking energy efficiency (%)[283]	Idle rate (W)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 108

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

Equation 109

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

Equation 110

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 95, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 150.

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

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

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{\text{cook}}}\right) + \left[(1 - 40\%) \times E_{idle} + \frac{40\% \times PC \times P}{\eta_{\text{cook}}}\right] \times \left(t_{on} - \frac{W_{food}}{PC \times P}\right)\right) \times \frac{t_{days}}{1000}$$

Equation 111

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1000}\right)}{t_{on} \times t_{days}} \times CF$$

Equation 112

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/BTU]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR® preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]. (Differs for boiler-based and steam-generator equipment)*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
η_{cook}	=	*Cooking energy efficiency [%] (Differs for boiler-based or steam generator equipment)*
40%	=	*Percent of time in constant steam mode [%]*
PC	=	*Production capacity [lb/hr]*
P	=	*Pan capacity*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 150. Steam Cookers—ENERGY STAR® Commercial Food Service Calculator Inputs[284]

Parameter	Baseline value	ENERGY STAR® value
E_{ph}	1,776	1,671.7
W_{food}		100
E_{food}		30.8
η_{cook}	Boiler-based: 26% Steam generator: 30%	50%
E_{Idle}	Boiler-based: 1,000 Steam generator: 1,200	3-pan: 400 4-pan: 530 5-pan: 670 6-pan: 800
PC	23.3	16.7
P		3, 4, 5, or 6
t_{on}		9.25
t_{days}		311
CF[285]		0.90

Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings are based on the input assumptions from Table 150:

Table 151. Steam Cookers—Deemed Energy and Demand Savings Values

Steam cooker type	P	Annual energy savings (kWh)	Peak demand savings (kW)
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

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

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

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.[286]

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

- ENERGY STAR® specifications for Commercial Steam Cookers. https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf.
- DEER 2014 EUL update.

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

Document Revision History

Table 152. Nonresidential ENERGY STAR® Electric 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.
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 revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
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.

2.4.7 ENERGY STAR® Ice Makers Measure Overview

TRM Measure ID: NR-FS-IM

Market Sector: Commercial

Measure Category: Food Service Equipment

Applicable Building Types: Any commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Eligible equipment includes air-cooled batch and continuous ice makers with the following design types: ice-making head (IMH), self-contained (SCU), and remote condensing (RCU) units. Eligible units must be compliant with the current ENERGY STAR® specification.[287, 288]

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.[289]

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

[287] 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.

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

[289] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.

Baseline Condition

The baseline condition is an ice maker meeting the federal standards published in 10 CFR 431 listed in Table 153. 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 153. Ice Makers—Federal Standard[290]

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

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

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v3.0 specification, effective January 28, 2018. Qualified products must meet the minimum energy consumption (kWh/100 lbs ice) from Table 154.

Table 154. Ice Makers—ENERGY STAR® Specification[291]

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

Energy and Demand Savings Methodology

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

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

Savings Algorithms and Input Variables

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

Equation 113

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

Equation 114

Where:

E_{base} = *Baseline rated energy consumption (kWh) per 100 pounds of ice, Table 153*

E_{ES} = *ENERGY STAR® rated energy consumption (kWh) per 100 pounds of ice, see Table 154*

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

DC = *Machine duty cycle, 75%*[292]

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

PLS = *Probability-weighted peak load share, see Table 155*

Table 155. Ice Makers—Probability-Weighted Peak Load Share

<table>
<tr><th colspan="3">Probability weighted peak load share (PLS)[293]</th></tr>
<tr><th>Climate zone</th><th>Summer peak</th><th>Winter peak</th></tr>
<tr><td>1</td><td rowspan="5">0.00012</td><td rowspan="3">0.00011</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="2">0.00012</td></tr>
<tr><td>5</td></tr>
</table>

Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure.

[292] 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.

[293] 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.[294]

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

- ENERGY STAR® Commercial Ice Maker Key Product Criteria Version 3.0, https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria.

[294] 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 156. Nonresidential Commercial 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.

2.4.8 Demand-Controlled Kitchen Ventilation Measure Overview

TRM Measure ID: NR-FS-KV

Market Sector: Commercial

Measure Category: Food Service

Applicable Building Types: Restaurants

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.[295] 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).[296] This output is adjusted by population to account for the percentage of sites with electric resistance or heat pump heating.[297] Additionally, because output from the OALC is per 1,000 CFM, a CFM per HP ratio[298] 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

$$kWh_{savings} = HP_{exhaust} \times \left(Savings_{interactive/HP} + AvgSav_{kWh/_{HP}} \times Hrs_{day} \times Days_{yr} \times MAU\right)$$

Equation 115

$$kW_{savings} = kWh_{savings} \times PWPLS$$

Equation 116

Where:

$AvgSav_{kWh/_{HP}}$ = *Average hourly energy savings per horsepower based on the building type, see Table 157*

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

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

296 Food Service Technology Center Outdoor Air Load Calculator. No longer available online.

297 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.

298 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.

Hrs_{day}	=	*Average daily operating hours, facility specific; if unknown, use defaults from Table 157*
$Days_{yr}$	=	*Number of operational days per year, facility specific; if unknown use defaults from Table 157*
MAU	=	*Make-up Air Unit factor applied to account for presence of dedicated MAU; value = 1 if there is a dedicated MAU; see Table 157 for values when there is no dedicated MAU*
$Savings_{interactive/HP}$	=	*Interactive heating savings per 1,000 CFM of outdoor air; see Table 158*
$PWPLS$	=	*Probability Weighted Peak Load Share; see Table 159*

Table 157. Demand Controlled Kitchen Ventilation—Default Assumptions

Building type	$AvgSav_{kWh/HP}$	Hrs_{day}	$Days_{yr}$	MAU factor with no dedicated MAU
Casual dining/fast food[299]	0.650	15	365	0.65
24-hr restaurant/hotel[300]	0.631	24	365	0.65
School café with summer[301]	0.566	11	325	0.51
School café without summer	0.566	11	252	0.51

Table 158. Demand Controlled Kitchen Ventilation—Population-Adjusted Interactive HVAC Savings per hp

Climate zone	Building type	Interactive savings (kWh/hp)
1	Casual dining/fast food	608
	24-hr restaurant/hotel	851
	School café with summer	455
	School café without summer	206
2	Casual dining/fast food	1,123
	24-hr restaurant/hotel	1,758
	School café with summer	838
	School café without summer	409

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

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

301 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 157.

Climate zone	Building type	Interactive savings (kWh/hp)
3	Casual dining/fast food	1,191
	24-hr restaurant/hotel	1,844
	School café with summer	959
	School café without summer	571
4	Casual dining/fast food	1,393
	24-hr restaurant/hotel	2,262
	School café with summer	1,119
	School café without summer	689
5	Casual dining/fast food	1,023
	24-hr restaurant/Hotel	1,510
	School café with summer	775
	School café without summer	450

Table 159. Demand Controlled Kitchen Ventilation—Probability Weighted Peak Load Share[302]

Climate zone	Summer PWPLS	Winter PWPLS
1	1.33E-04	1.46E-04
2	1.36E-04	1.45E-04
3	1.34E-04	1.43E-04
4	1.31E-04	1.45E-04
5	1.45E-04	1.46E-04

Deemed Energy and Demand Savings Tables

Table 160. Demand Controlled Kitchen Ventilation—Deemed Annual Energy Savings per hp

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

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

Climate zone	Building type	Annual savings (kWh/hp)	
		With dedicated MAU	Without dedicated MAU
3	Casual dining/fast food	4,836	3,572
	24-hr restaurant/hotel	7,368	5,410
	School café with summer	2,985	2,002
	School café without summer	2,144	1,381
4	Casual dining/fast food	5,038	3,775
	24-hr restaurant/hotel	7,787	5,829
	School café with summer	3,144	2,162
	School café without summer	2,261	1,499
5	Casual dining/fast food	4,668	3,404
	24-hr restaurant/hotel	7,034	5,077
	School café with summer	2,801	1,818
	School café without summer	2,023	1,260

Table 161. Demand Controlled Kitchen Ventilation—Deemed Summer and Winter Peak Demand Savings per hp

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

Climate zone	Building type	Summer demand savings (kWh/hp)		Winter demand savings (kWh/hp)	
		With dedicated MAU	Without dedicated MAU	With dedicated MAU	Without dedicated MAU
5	Casual dining/fast food	0.68	0.49	0.68	0.50
	24-hr restaurant/hotel	1.02	0.74	1.03	0.74
	School café with summer	0.41	0.26	0.41	0.27
	School café without summer	0.29	0.18	0.30	0.18

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-VSD-fan.[303]

Program Tracking Data and Evaluation Requirements

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

- Kitchen ventilation system exhaust fan horsepower
- Building type
- Kitchen ventilation makeup air unit fan horsepower, if present
- Presence of dedicated makeup air unit
- Testing and balancing report, if available

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

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

Document Revision History

Table 162. Nonresidential Demand Controlled Kitchen Ventilation 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.

2.4.9 Pre-Rinse Spray Valves Measure Overview

TRM Measure ID: NR-FS-SV

Market Sector: Commercial

Measure Category: Food Service Equipment

Applicable Building Types: See Table 164

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Direct install or point of sale

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Units must be used for commercial food preparation only and have flow rates which are no greater than the baseline flow rates specified in Table 163 (on a per product class or spray force in ounce-force (ozf) basis.

Baseline Condition

Effective January 28, 2019, reference baseline equipment is a pre-rinse spray valve with a flow rate that does not exceed the maximum flow rate per product class as specified in Table 163.[304]

Table 163. Pre-Rinse Spray Valve Flow Rate Limits

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

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

High-Efficiency Condition

Following the passing of the Energy Policy Act of 2005, the EPA announced on September 21st, 2005 that it would no longer pursue an ENERGY STAR® specification for pre-rinse spray valves.[305] 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 163 for the pre-rinse spray valve's respective product class. The sprayer should be capable of the same cleaning ability as the old sprayer.[306]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy and demand savings are calculated using the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = \mathrm{U} \times (F_B - F_P) \times \frac{Days}{Year} \times (T_H - T_C) \times C_H \times \frac{C_E}{Eff_E}$$

Equation 117

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

Equation 118

Where:

F_B	=	*Baseline flow rate of sprayer (GPM), see Table 163; post-measure flow rate of sprayer (GPM), use actual value*
U	=	*Water usage duration, see Table 164*
T_H	=	*Average mixed hot water (after spray valve) temperature (ºF), 140.5°F*[307]

[305] "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.

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

[307] Texas Administrative Code for Retail Food Equipment Operations, Title 25, Part 1, Chapter 228, Subchapter D, Rule §228.111. Average of minimum values for manual warewashing equipment, 110°F (paragraph (i)) and 171°F (paragraph (k)). https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=25&pt=1&ch=228&rl=111.

T_C	=	*Average supply (cold) water temperature (ºF), 71.4°F*[308]
Days	=	*Annual facility operating days for the applications, see Table 164*
C_H	=	*Unit conversion for water density: 8.33 lbs/gallon*
C_E	=	*Unit conversion: 1 BTU = 0.00029308 kWh (1/3412)*
Eff_E	=	*Recovery efficiency of electric water heater, 0.98*[309]
P	=	*Hourly peak demand as percent of daily demand probability-weighted peak load share, see Table 165*

Table 164. Assumed Variables for Energy and Demand Savings Calculations

Variable	Assumed value
U[310]	Fast food restaurant: 45 min/day/unit Casual dining restaurant: 105 min/day/unit Institutional: 210 min/day/unit Dormitory: 210 min/day/unit K-12 school: 105 min/day/unit
Days[311]	Fast food restaurant: 360 Casual dining restaurant: 360 Institutional: 360 Dormitory: 270 K-12 school: 193

308 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.

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

310 "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.

311 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 165. Probability-Weighted Peak Load Share[312]

Climate zone	Summer PLS			Winter PLS		
	Full-service restaurant and cafeterias	Fast food	Schools	Full-service restaurants and cafeterias	Fast food	Schools
Zone 1: Amarillo	3.151	6.298	2.537	5.026	6.205	0.666
Zone 2: Dallas	4.767	5.850	2.630	4.279	5.868	0.899
Zone 3: Houston	3.544	6.237	2.627	3.219	5.015	1.556
Zone 4: Corpus Christi	3.092	6.214	2.768	5.462	6.754	1.561
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.[313]

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

[312] Peak load-share factors are developed according to the method described in the Texas TRM Volume 1, using load profiles derived from the American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., ASHRAE Handbook 20112019. HVAC Applications. Chapter 50 51 - Service Water Heating, Section 9 – Hot Water Load and Equipment Sizing, Figure 24 – Hourly Flow Profiles for Various Building Types. PLS values are multiplied by 100,000 to allow for easier readability of the values.

[313] 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_3_735684.PDF.
- PUCT Docket 36779—Provides EUL for pre-rinse sprayers

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 166. Nonresidential Pre-Rinse Spray Valves 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

2.4.10 Vacuum-Sealing and Packaging Machines Measure Overview

TRM Measure ID: NR-MS-VS

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Supermarket, Grocery, Food Store

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

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

Eligibility Criteria

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

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

Baseline Condition

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

High-Efficiency Condition

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

Savings Algorithms and Input Variables

Southern California Edison (SCE) and the Food Service Technology Center (FSTC) conducted a field study to evaluate and compare energy savings and demand reduction potential between baseline and on-demand package sealers in supermarkets.[314] 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.[315] 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 167. Vacuum-Sealing & Packaging Machines—Deemed Energy and 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.[316]

[314] "Vacuum-Sealing and Packaging Machines for Food Service Field Test, ET13SCE1190 Report," SCE & FTSC. December 2014. https://www.etcc-ca.com/reports/commerical-hand-wrap-machines-food-service-applications-field-test.

[315] See Volume 1, Section 4.

[316] "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

None.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 168. Nonresidential Vacuum-Sealing & Packaging Machines Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revisions.

2.5 NONRESIDENTIAL: REFRIGERATION

2.5.1 Door Heater Controls Measure Overview

TRM Measure ID: NR-RF-HC

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

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

Equation 119[317]

The baseline assumes door heaters are running on an 8,760-hour operating schedule. In the post-retrofit case, the duty for each hourly reading is calculated by assuming a linear relationship between indoor DP and duty cycle for each bin reading. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89ºF DP and all on (duty cycle of 100%) at 52.87ºF DP for a typical supermarket.[318] Between these values, the door heaters' duty cycle changes proportionally:

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

Equation 120

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[319] at:

For medium temperature (coolers):

$$kW_{ASH} = 0.109\ per\ door\ or\ 0.0436\ per\ horizontal\ linear\ foot\ of\ door^{320}$$

Equation 121

317 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.

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

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

320 Ibid.

For low temperature (freezers):

$$kW_{ASH} = 0.191 \text{ per door or } 0.0764 \text{ per horizontal linear foot of door}$$[321]

Equation 122

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

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

Equation 123

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

Equation 124

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,[322] the cooling load contribution from door heaters for each hour of the year can be given by:

$$Q_{ASH}(ton - hrs) = 0.35 \times kW_{ASH} \times \frac{3{,}412 \frac{Btu}{hr}}{12{,}000 \frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 125

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.[323]

[321] Ibid.
[322] A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.
[323] 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 126[324]

Where:

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

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

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

Equation 127[325]

Where:

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

[324] 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.

[325] Ibid.

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

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER}$$

Equation 128

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

Equation 129

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 130

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

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

Equation 131

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

Deemed Energy and Demand Savings Tables

The energy and demand savings of anti-sweat door heater controls are deemed values based on city/climate zone and refrigeration temperature, with hourly dry-bulb temperatures and outdoor dew points determined using TMY3 Hourly Weather Data by Climate Zone;[326] Table 169 provides these deemed values.

Table 169. Annual Deemed Energy and Demand Savings Values per Horizontal Linear Foot of Door by Location and Refrigeration Temperature

Climate zone	Medium temperature		Low temperature	
	Annual energy savings (kWh/ft)	Peak demand savings (kW/ft)	Annual energy savings (kWh/ft)	Peak demand savings (kW/ft)
Zone 1: Amarillo	342	0.047	610	0.081
Zone 2: Dallas	232	0.047	413	0.081
Zone 3: Houston	170	0.047	304	0.082
Zone 4: Corpus Christi	131	0.047	234	0.083
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.[327]

Program Tracking Data and Evaluation Requirements

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

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

[326] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings
[327] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Attachment A: https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF. https://interchange.puc.texas.gov/Documents/40669_7_736775.PDF.
- PUCT Docket 36779—Provides EUL for Anti-Sweat Heater Controls

Relevant Standards and Reference Sources

- DEER 2014 EUL update
- TMY3 Hourly Weather Data by Climate Zone[328]

Document Revision History

Table 170. Nonresidential 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. Update Deemed kW_{ASH} for Medium temperature cases and add kW_{ASH} for Low-temperature cases. Added more significant digits to the input variables a-j for Equation 126 and Equation 127.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

[328] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings

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, and convenience stores

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.

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

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

Equation 132

$$\Delta kW_{peak\,per\,unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapCool} \times \left(1 + \frac{1}{COP_{cooler}}\right)$$

Equation 133

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

Equation 134

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

Equation 135

Freezer

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

Equation 136

$$\Delta kW_{peak\,per\,unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapFreeze} \times \left(1 + \frac{1}{COP_{freezer}}\right)$$

Equation 137

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

Equation 138

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

Equation 139

Where:

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

$DC_{EvapFreeze}$	=	*Duty cycle of evaporator fan motor for freezer*
COP_{cooler}	=	$12/EER_{MT}$, *the coefficient of performance of compressor in the cooler*
$COP_{freezer}$	=	$12/EER_{LT}$, *the coefficient of performance of compressor in the freezer*
Hours	=	*The annual operating hours are assumed to be 8,760 for coolers and 8,273*[329] *for walk-ins (see Table 171)*
%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%.*[330]

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.[331]

[329] The Pennsylvania TRM, June 2016, utilizes the Efficiency Vermont source reproduced below this footnoted statement for an assumption of 8,273 hours for walk-in freezers. This is, furthermore, equivalent to stating the freezer's duty cycle is approximately 94.4% (8,273 / 8,760 ≈ 0.944), an assumed value which appears in Table 171 for the $DC_{EvapFreeze}$ variable. The Maine TRM, July 2019, details the derivation of 8,273 and thus approximately 94.4%: "A[n] evaporator fan in a cooler runs all the time, but a freezer runs only 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)".

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

[330] 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."

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

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

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

Equation 140[332]

Where:

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

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 141[333]

332 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.

333 Ibid.

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	$-7.57495453950879 \times 10^{-6}$
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.87*
SCT_{LT}	=	T_{db} *+10*
T_{DB}	=	*Dry-bulb temperature*

Table 171. Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed values
W_{base}	See Table 172
W_{ee}	See Table 172
LF[334]	0.9
$DC_{EvapCool}$[335]	100%
$DC_{EvapFreeze}$[336]	94.4%
COP_{cooler}	$12/EER_{MT}$
$COP_{freezer}$	$12/EER_{LT}$
Hours[337]	8,760 or 8,273
%OFF	0 or 46%

[334] 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.

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

[336] See footnotes 329 and 335.

[337] See footnote 329 for the explanation of the assumption of 8,273 for walk-in freezers.

Table 172. Motor Sizes, Efficiencies, and Input Watts[338,339]

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

Table 173. Compressor Coefficient of Performance Based on Climate and Refrigeration Type (COP_{cooler} or $COP_{freezer}$)

Representative climate city	Summer design dry-bulb temperature[340]	EER_{MT}	COP_{cooler}	EER_{LT}	$COP_{freezer}$
Zone 1: Amarillo	98.6	6.18	1.94	4.77	2.51
Zone 2: Dallas	101.4	5.91	2.03	4.56	2.63
Zone 3: Houston	97.5	6.29	1.91	4.86	2.47
Zone 4: Corpus Christi	96.8	6.36	1.89	4.91	2.44
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.

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338 The first three rows in this table are sourced from the Pennsylvania TRM, June 2016. Pennsylvania TRM, "3.5.2 High-Efficiency Fan Motors for Reach-In Refrigerated Cases". page 366, Table 3-90. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.
The last two rows are estimated using logarithmic linear regression of smaller motor efficiencies.

339 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.

340 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL IDs GrocDisp-FEEvapFanMtr and GrocWlkIn-WEvapFanMtr.[341]

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- DEER 2014 EUL update.

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

Document Revision History

Table 174. Nonresidential 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
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 revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated methodology based on the load shape from original workpaper. Updated EUL reference.

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, and convenience stores

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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of electronic defrost controls are a result of savings due to the increase in operating efficiency and the reduced heat from a reduction in the number of defrosts. The energy and demand savings are calculated using the equations, with the coefficient of performance variable corresponding to low temperature or medium temperature applications:

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

Equation 142

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

Equation 143

Medium temperature:

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

Equation 144

Low temperature:

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

Equation 145

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

Equation 146

Where:

$\Delta kWh_{defrost}$	=	*Energy savings resulting from an increase in operating efficiency due to the addition of electronic defrost controls*
ΔkWh_{heat}	=	*Energy savings due to the reduced heat from reduced number of defrosts*
$kW_{defrost}$	=	*Load of electric defrost, default = 0.9 kW*[342]

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

Hours	=	*Number of hours defrost occurs over a year without defrost controls, 487*[343]
DRF	=	*Defrost reduction factor—percent reduction in defrosts required per year, see Table 175*
0.28	=	*Conversion of kW to tons; 3,412 Btuh/kW divided by 12,000 Btuh/ton*
COP_{MT}	=	$12/EER_{MT}$*, the coefficient of performance of compressor in the cooler*
COP_{LT}	=	$12/EER_{LT}$*, the coefficient of performance of compressor in the freezer*

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data.

For medium-temperature refrigerated cases, the saturated condensing temperature (SCT_{MT}) is calculated as the design dry-bulb temperature plus 15 degrees. For low-temperature refrigerated cases, the SCT_{LT} is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant of 1/1.15 or approximately 0.87.[344]

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

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

Equation 147[345]

Where:

a	=	*3.75346018700468*
b	=	*-0.049642253137389*

[343] 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.

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

[345] 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.

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

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

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

Equation 148[346]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	$-7.57495453950879 \times 10^{-6}$
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.87*

[346] Ibid.

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

T_{DB} = *Dry-bulb temperature*

Table 175. Deemed Variables for Energy and Demand Savings Calculations

Climate zone	DRF[347]	COP_{MT}[348]	COP_{LT}[349]
Zone 1: Amarillo	35%	1.94	2.51
Zone 2: Dallas		2.03	2.63
Zone 3: Houston		1.91	2.47
Zone 4: Corpus Christi		1.89	2.44
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.[350]

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

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

[349] Ibid.

[350] GDS Associates, Inc. (June 2007). *Measure Life Report*. Prepared for The New England State Program Working Group (SPWG). https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf
Additionally, the Pennsylvania TRM Volume 3 Page 162 cites the Vermont TRM, March 16, 2015. Pg. 171: "This is a conservative estimate is based on a discussion with Heatcraft based on the components expected life. https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf"

Program Tracking Data and Evaluation Requirements

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

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

Not applicable.

Document Revision History

Table 176. Nonresidential Electronic 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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, and convenience stores

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.

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:

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

Equation 149

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

Equation 150

Where:

kW_{evap}	=	*Connected load kW of each evaporator fan, see Table 177*
kW_{circ}	=	*Connected load kW of the circulating fan, see Table 177*
n_{fans}	=	*Number of evaporator fans*
DC_{comp}	=	*Duty cycle of the compressor, see Table 177*
DC_{evap}	=	*Duty cycle of the evaporator fan, see Table 177*
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 177*
8,760	=	*Annual hours per year*

Table 177. Deemed Variables for Energy and Demand Savings Calculations[351]

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-WEvapFMtrCtrl.[352]

[351] The Maine Technical Reference Manual was utilized to determine these assumed values. Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019.

- kW_{evap}: Page 78, footnote 366 states this value is determined "based on a weighted average of 80% shaded-pole motors at 132 watts and 20% PSC motors at 88 watts. This weighted average is based on discussions with refrigeration contractors and is considered conservative (market penetration estimated at approximately 10%)."
- kW_{circ}: Page 78, footnote 367 states this value is the "wattage of fan used by Freeaire and Cooltrol"
- DC_{comp}: Page 78, footnote 368 states the reasoning for this value as follows: "A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (35%-65%), Control (35%-65%), Natural Cool (70%), Pacific Gas and Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor."
- DC_{evap}: 94.4% is equivalent to 8,273 / 8,760 annual operating hours. The assumption of 8,273 is the annual total of the assumption that "a[n] evaporator fan in a cooler runs all the time, but a freezer only runs 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)", an explanation given on page 82, footnote 401.
- BF: Page 183, Table 45, footnote A summarizes the Bonus Factor (-1 + 1/COP) as "assum[ing] 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F."

[352] 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

- DEER 2014 EUL update

Document Revision History

Table 178. Nonresidential Evaporator Fan Controls Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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

[353] 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.

$$\Delta kWh = L \times kWh_{baseline} \times 9\%$$

Equation 151

Where:

ΔkWh	=	*Energy savings*
L	=	*Horizontal linear feet of the low- or medium-temperature refrigerated display case*
$kWh_{baseline}$	=	*Average annual unit energy consumption in terms of kWh/horizontal linear foot/year*
9%	=	*The reduction in compressor's electricity usage due to the night cover's decreasing of convection, conduction, and radiation heat transfer*[354]

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

[354] 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"

[355] 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 179.
Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. LCC Summary Statistics: Section 8B2; Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf.

Table 179. Modeled Deemed Savings for Night Covers for Texas (per Linear Foot)

Temperature[356]	Condensing unit configuration	Equipment family	Average annual energy consumption per linear foot ($kWh_{baseline}$)	ΔkWh	Annual demand savings[357]
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.[358]

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)

[356] 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
[357] The demand savings for this measure are 0 because energy savings exist at night only.
[358] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Operating temperature (low or medium as defined in Table 179)

- Horizontal linear feet length of refrigerated case

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications : https://interchange.puc.texas.gov/Documents/40669_7_736774.PDF.

Relevant Standards and Reference Sources

- DEER 2014 EUL update

Document Revision History

Table 180. Nonresidential Night Covers for Open Refrigerated Display Cases 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 revisions.
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 revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

2.5.6 Solid and Glass Door Reach-Ins Measure Overview

TRM Measure ID: NR-RF-RI

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Solid- or glass-door reach-in vertical refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements (See Table 182).

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

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

Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 181.

Table 181. Baseline Energy Consumption[359,360]

Baseline standards	Refrigerator daily consumption (kWh)	Freezer daily consumption (kWh)
Solid door	0.10V + 2.04	0.40V + 1.38
Glass door	0.12V + 3.34	075V + 4.10

High-Efficiency Condition

Eligible high-efficiency equipment for solid- or glass-door reach-in refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements, as shown in Table 182.

Table 182. Efficient Energy Consumption Requirements[361]

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

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 181 and Table 182, based on the volume of the units.

The savings calculations are specified as:

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

Equation 152

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

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

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

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

Equation 153

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 181.*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 182.*
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	=	*Summer peak coincidence factor (1.0)*[362]

Deemed Energy and Demand Savings Tables

Table 183. Deemed Energy and Demand Savings

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume	Energy savings (kWh)	Demand savings (kW)
Refrigerator	Vertical Solid Door	0 < V < 15	8.54	16	0.002
		15 ≤ V < 30	21.00	892	0.102
		30 ≤ V < 50	41.53	1,256	0.143
		V ≥ 50	67.19	1,919	0.219
	Vertical Glass Door	0 < V < 15	8.84	1,137	0.130
		15 ≤ V < 30	21.30	1,355	0.155
		30 ≤ V < 50	42.76	1,782	0.203
		V ≥ 50	68.93	2,002	0.229

[362] The summer peak coincidence factor is assumed equal to 1.0, since the annual kWh savings is divided by the total annual hours (8760), effectively resulting in the average kW reduction during the peak period.

Refrigerator or freezer	Door type	Product volume range (cubic feet)	Average product volume	Energy savings (kWh)	Demand savings (kW)
Freezer	Vertical Solid Door	0 < V < 15	7.76	713	0.081
		15 ≤ V < 30	19.99	1,726	0.197
		30 ≤ V < 50	43.13	3,301	0.377
		V ≥ 50	66.86	5,177	0.591
	Vertical Glass Door	0 < V < 15	5.98	1,766	0.202
		15 ≤ V < 30	19.49	4,321	0.493
		30 ≤ V < 50	42.29	8,630	0.985
		V ≥ 50	65.89	13,093	1.495

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.[363]

Program Tracking Data and Evaluation Requirements

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

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

[363] 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

- ENERGY STAR® Commercial Refrigerators and Freezers. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CRF.
- Association of Home Appliance Manufacturers. HRF-1: Household Refrigerators, Combination Refrigerator-Freezers, and Household Freezers.

Document Revision History

Table 184. Nonresidential Solid and Glass Door Reach-Ins Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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

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

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

Equation 154

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

Equation 155

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*

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

C_{13}	=	*6.5459673E+00*
$°R_{Adj}$	=	*Adjacent absolute temperature,* $t_{DB,Adj} + 459.67$ *(see Table 185)*
$°R_{Refrig}$	=	*Refrigeration box absolute temperature,* $t_{DB,Refrig} + 459.67$ *(see Table 185)*

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

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

Equation 156

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

Equation 157

Where:

W_{Adj}	=	*Humidity ratio of the adjacent space*
W_{Refrig}	=	*Humidity ratio of the refrigerated space*
Rh_{Adj}	=	*Relative humidity of the adjacent space (see Table 185)*
Rh_{Refrig}	=	*Relative humidity of the refrigerated space (see Table 185)*

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

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

Equation 158

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

Equation 159

Where:

h_{Adj}	=	*Air enthalpy of the adjacent space*
h_{Refrig}	=	*Air enthalpy of the refrigerated space*
$t_{DB,Adj}$	=	*Dry-bulb temperature of the adjacent space (see Table 185)*
$t_{DB,Refrig}$	=	*Dry-bulb temperature of the refrigerated space (see Table 185)*

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:

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

Equation 160

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

Equation 161

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

Equation 162

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

Equation 163

$$F_m = \frac{2}{1 + \frac{r_{Refrig}}{r_{Adj}}^{\frac{1}{3}}}^{\frac{3}{2}}$$

Equation 164

$$q = 795.6 * Height * Width * \left(h_{Adj} - h_{Refrig}\right) * r_{Refrig} * \left(1 - \frac{r_{Adj}}{r_{Refrig}}\right)^{\frac{1}{2}} * (32.174 * Height)^{\frac{1}{2}} * F_m$$

Equation 165

Where:

v_{Adj}	=	*Specific volume of the adjacent space*
v_{Refrig}	=	*Specific volume of the refrigerated space*
r_{Adj}	=	*Air temperature density of the adjacent space*
r_{Refrig}	=	*Air temperature density of the refrigerated space*
F_m	=	*Density factor*
q	=	*Refrigeration load for fully established flow*
$Height$	=	*Doorway height (see Table 185)*
$Width$	=	*Doorway width (see Table 185)*

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:

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

Equation 166

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

Equation 167

Where:

$Q_{baseline}$	=	*Baseline total infiltration load*
$Q_{retrofit}$	=	*Total infiltration load, post-retrofit*
m	=	*Time the door is open per day (see Table 185)*
D_F	=	*Doorway flow factor (see Table 185)*
$E_{baseline}$	=	*Baseline assumed effectiveness against infiltration, 0*
$E_{retrofit}$	=	*Assumed effectiveness against infiltration post-retrofit (see Table 185)*

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

$$kW_{baseline} = \frac{Q_{baseline}}{EER * 1000}$$

Equation 168

$$kW_{retrofit} = \frac{Q_{retrofit}}{EER * 1000}$$

Equation 169

$$kWh_{baseline} = kW_{baseline} * EFLH$$

Equation 170

$$kWh_{retrofit} = kW_{retrofit} * EFLH$$

Equation 171

Where:

$kW_{baseline}$	=	*Baseline demand consumption of the compressor*
$kW_{retrofit}$	=	*Demand consumption of the compressor, post-retrofit*
$kWh_{baseline}$	=	*Baseline energy consumption of the compressor*
$kWh_{retrofit}$	=	*Energy consumption of the compressor, post-retrofit*
EER	=	*EER per facility type (see Table 185), which are averaged or weighted across suction-group types (see Table 186)*
FLH	=	*Assumed full-load hours per facility type (see Table 185)*

The difference between the baseline and retrofit demand/energy calculations yields whole-door energy savings, which are divided by the area of the doorway to yield per-square foot savings:

$$\Delta kW = kW_{baseline} - kW_{retrofit}$$

Equation 172

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

Equation 173

$$kW_{Savings} = \frac{\Delta kW}{Height * Width}$$

Equation 174

$$kWh_{Savings} = \frac{\Delta kWh}{Height * Width}$$

Equation 175

Where:

ΔkW = *Whole-door demand savings*

ΔkWh = *Whole-door energy savings*

$kW_{Savings}$ = *Per-square foot demand savings*

$kWh_{Savings}$ = *Per-square-foot energy savings*

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 185. 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 186:

Table 185. Assumed Independent Variables[365]

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	N/A
Refrigeration box temperature		39	8	39	5	37	5	28	N/A
Relative humidity of adjacent surroundings	Rh	0.55	0.55	0.55	0.55	0.55	0.55	0.3	N/A
Relative humidity of refrigeration box		0.65	0.4	0.4	0.6	0.5	0.45	0.86	N/A
Height	$Height$	7	7	7	7	7	7	12	N/A
Width	$Weight$	3	3	3	3	3	3	10	N/A
Doorway flow factor	D_F	0.51	0.51	0.51	0.51	0.625	0.625	0.8	N/A
Effectiveness against infiltration – post-retrofit	$E_{retrofit}$	0.8	0.81	0.79	0.83	0.88	0.88	0.89	N/A
Time door is open per day	m	45	38	38	9	132	102	494	N/A
Full-load-hours (FLH) of operation	FLH	5,509	5,509	6,887	6,887	6,482	6,482	2,525	N/A
EER[366]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	N/A

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

[366] EER is not an independent variable but is rather dependent on Table 186. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 186. Default EER by System Configuration[367]

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 187. Energy Consumption and Demand for Coolers and Freezers for Deemed Openings

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

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

Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are shown below in Table 188.

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

Table 188. Deemed Energy and Demand Savings for Freezers and Coolers

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
$kW_{savings}$ $per\ sq.ft.$	0.004	0.021	0.003	0.005	0.018	0.076	0.061	N/A
$kWh_{savings}$ $per\ sq.ft.$	22.50	114.01	23.58	33.15	119.88	494.32	153.36	N/A

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-StripCrtn.[368]

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

[368] 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

- DEER 2014 EUL update

Document Revision History

Table 189. Nonresidential Strip Curtains for Walk-In Refrigerated Storage 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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.

High-Efficiency Condition

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

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 per door*[369]

For low temperature:

kW_{ASH} = *0.191 per door*[370]

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

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

Equation 176

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

Equation 177

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system,[371] the cooling load contribution from door heaters can be given by:

$$Q_{ASH}(ton-hrs) = 0.35 \times kW_{ASH} \times \frac{3{,}412 \frac{Btu}{hr}}{12{,}000 \frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 178

[369] 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.

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

[371] *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.[372]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 190.

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

Equation 179[373]

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	=	*0.87*
SCT	=	$T_{DB} + 15$

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

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

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

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

Equation 180[374]

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.4886737934442*
f	=	*-0.248051519588758*
g	=	*-7.57495453950879 x* 10^{-6}
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*0.87*
SCT	=	T_{DB} *+ 10*

Table 190. Coefficients by Climate Zone

Climate zone	T_{DB}[375]	SCT_{MT}	SCT_{LT}	EER_{MT}	EER_{LT}
Zone 1: Amarillo	98.6	113.6	108.6	6.18	4.74
Zone 2: Dallas	101.4	116.4	111.4	5.91	4.56
Zone 3: Houston	97.5	112.5	107.5	6.29	4.86
Zone 4: Corpus Christi	96.8	111.8	106.8	6.36	4.91
Zone 5: El Paso	101.1	116.1	111.1	5.94	4.58

Where:

T_{DB}	=	*Dry-bulb temperature*

[374] Ibid.

[375] 2017 ASHRAE Handbook: Fundamentals, 0.4% summer design dry-bulb temperatures. http://ashrae-meteo.info/v2.0/.

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 181

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

Equation 182

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 183

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

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

Equation 184

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:

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

Equation 185

Table 191. Deemed Energy and Demand Savings Values by Climate Zone and Refrigeration Temperature

Climate zone	Medium temperature		Low temperature	
	Annual energy savings (kWh/door)	Peak demand savings (kW/door)	Annual energy savings (kWh/door)	Peak demand savings (kW/door)
Zone 1: Amarillo	1,139	0.130	2,092	0.239
Zone 2: Dallas	1,148	0.131	2,111	0.241
Zone 3: Houston	1,136	0.130	2,084	0.238
Zone 4: Corpus Christi	1,134	0.129	2,080	0.237
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.[376]

Program Tracking Data and Evaluation Requirements

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

- 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

- DEER 2014 EUL update

Document Revision History

Table 192. Nonresidential Zero-Energy Doors for Refrigerated Cases 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
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 revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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

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.[377] An average baseline gasket efficacy[378] of 90 percent is assumed for this measure.

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

[378] 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.[379,380] 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 193 below.

Table 193. Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)[381]

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[382] 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[383] 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.

[379] Southern California Edison (SCE). WPSCNRRN0013—Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases and Solid Doors of Reach-in Coolers and Freezers. 2007.

[380] 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.

[381] Ibid., Table 5-3.

[382] The SCE ex-ante savings as reported in the PG&E report were 10.2 and 21.7 kWh/linear foot for coolers and freezers respectively.
Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. Table 5-3.
http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.
Modeled savings as reported in the SEC report for climate zone 4 were approximately 6 and 15 kWh/linear foot for coolers and freezers respectively.

[383] 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. Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Coolers)

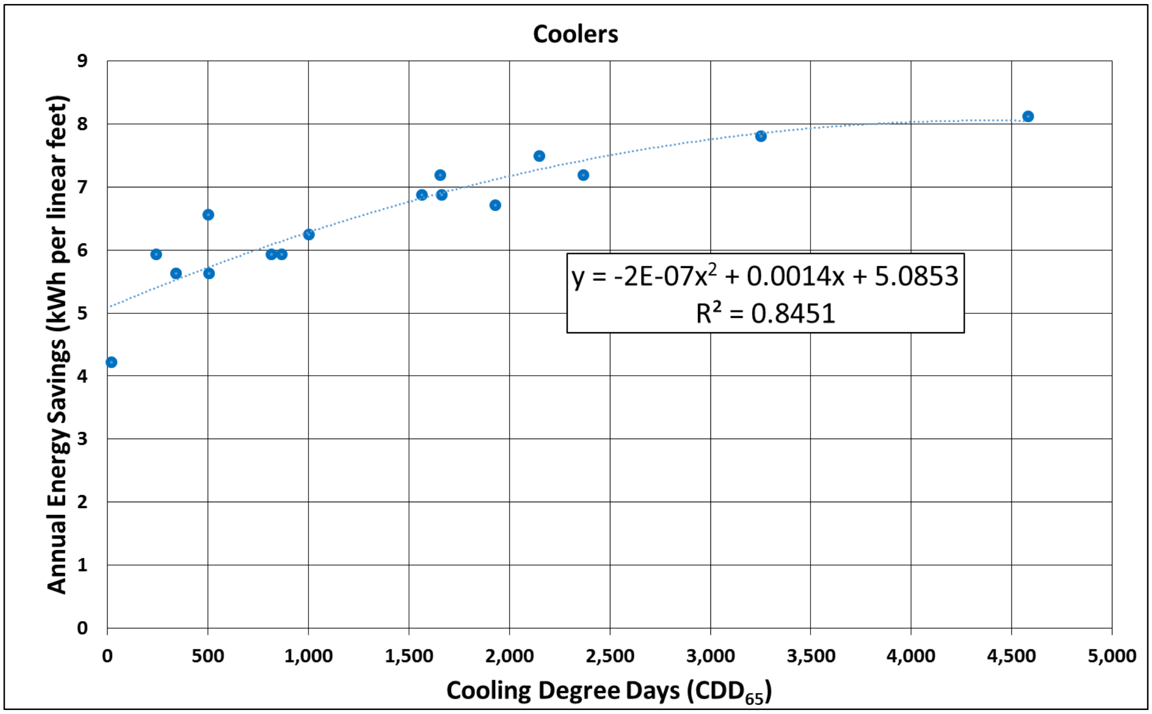
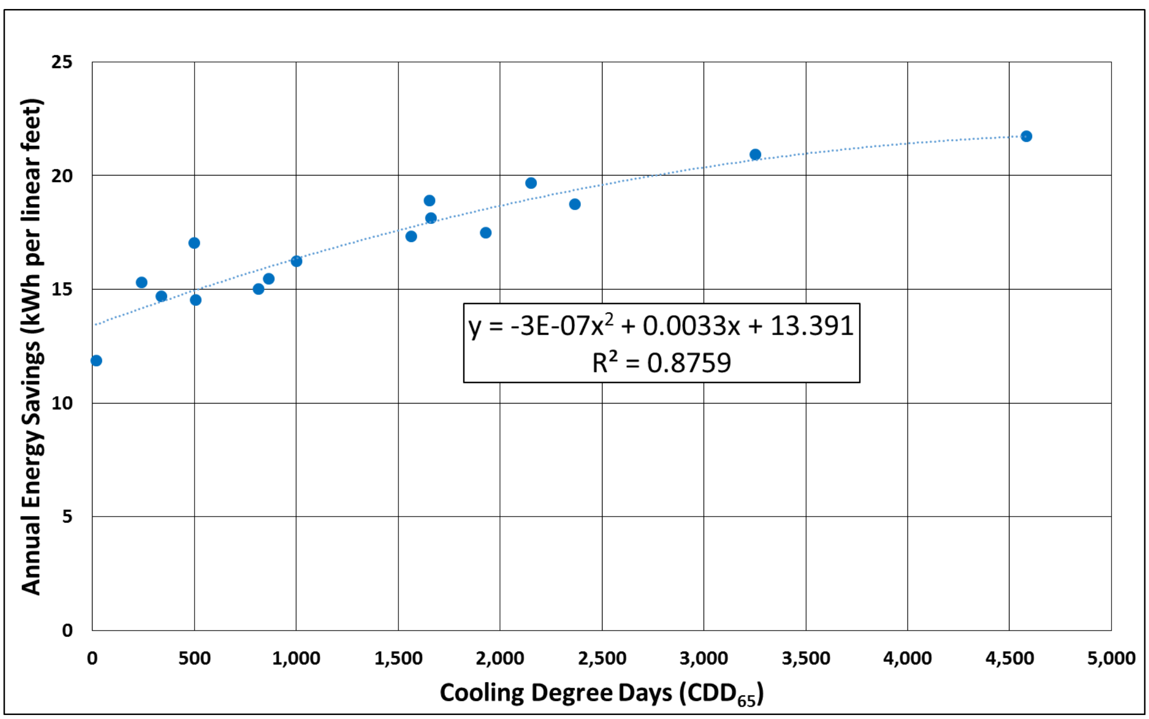


Figure 4. Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Freezers)



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 193 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 194 below.

Table 194. Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)

Refrigerator type	CA CZ1-CZ16 average savings (kWh/ft)	CA average savings normalized to TX by CDD (kWh/ft)	TX vs. CA energy savings	Average CDD adjustment factor	PG&E baseline 90% efficacy (kWh/ft)	TX baseline 90% efficacy (kWh/ft)
Cooler	6.5	7.4	113%	115%	3	3.5
Freezer	17.1	20.0	117%		23	26.5

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8,760 hours).

Savings Algorithms and Input Variables

The energy and demand algorithms and associated input variables are listed below:

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

Equation 186

$$Demand\ Savings\ [kW] = \frac{kWh_{Savings}}{8760} \times L$$

Equation 187

Where:

ΔkWh/ft = *Annual energy savings per linear foot of gasket (see Table 195)*

L = *Total gasket length (ft.)*

Deemed Energy and Demand Savings Tables

Table 195. Deemed Energy and Demand Savings per Linear Foot of Installed Door Gasket

Refrigerator type	ΔkW/ft	ΔkWh/ft
Walk-in or reach-in cooler	0.0004	3.5
Walk-in or reach-in freezer	0.0030	26.5

Claimed Peak Demand Savings

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8,760 hours).

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 3 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDrGask.[384]

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

- TMY3 Hourly Weather Data by Climate Zone[385]

[384] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[385] http://texasefficiency.com/index.php/regulatory-filings/deemed-savings

Document Revision History

Table 196. Nonresidential Door Gaskets for Walk-In and Reach-In Coolers and Freezers 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 revisions.
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.

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).[386] 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.

[386] 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

$$\text{kWh savings} = \frac{w \times h^{1.5} \times energy\ factor}{COP \ \times 3{,}412}$$

Equation 188

$$\text{energy factor} = hours \ \times 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E$$

Equation 189

$$\text{kW savings} = \frac{w \times h^{1.5} \times demand\ factor}{COP \ \times 3{,}412}$$

Equation 190

$$\text{demand factor} = 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E$$

Equation 191

Where:

w	=	*Width of the door opening (ft.)*
h	=	*Height of the door opening (ft.)*
$energy\ factor$	=	*The outcome of Equation 189 based on climate zone and cold storage application, see Table 197 and Table 198*
$demand\ factor$	=	*The outcome of Equation 191 based on climate zone and cold storage application, see Table 199, Table 200, and Table 201*
$hours$	=	*Operating hours, 3,798*[387]
3,790	=	*Constant*[388]

[387] Operating hours taken from TRM Volume 3, Table 8, hours for refrigerated warehouse.
[388] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

$\frac{q_s}{A}$ = *Sensible heat load of infiltration air per square foot of door opening, ton/ft², see Table 202*

R_s = *Sensible heat ratio of the infiltration air heat gain, see Table 203*

ΔD_t = *Change in percent of time the doorway is open, 0.33*[389]

D_f = *Doorway flow factor, varies based on temperature delta between cold room and infiltration air, 0.8 for delta T ≥ 20°F, 1.1 for delta T < 20°F*[390]

ΔE = *Change in door effectiveness, 0.2*[391]

COP = *Coefficient of performance, assume 2.8 COP*[392]

$3{,}412$ = *Conversion factors*

Table 197. High-Speed Doors—Energy Factors for Door to Unconditioned Area

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

Table 198. High-Speed Doors—Energy Factors for Door to Conditioned Area

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

Table 199. High-Speed Doors—Summer and Winter Demand Factors for Door to Conditioned Area

Cold room temperature	All temperatures
All climate zones	1.0

389 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.

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

391 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.

392 Air cooled chiller efficiency from IECC 2009.

Table 200. High-Speed Doors—Summer Demand Factors for Door to Unconditioned Area

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

Table 201. High-Speed Doors—Winter Demand Factors for Door to Unconditioned Area

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

Table 202. High-Speed Doors—$\frac{q_s}{A}$, Sensible Heat Load of Infiltration Air[393]

Cold room temperature	Applicable climate zones							
	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

393 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.

Table 203. High-Speed Doors—R_s, Sensible Heat Ratio of Infiltration Air[394]

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

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 191 implies Equation 188 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.

[394] 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.

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
- 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

Not applicable.

Document Revision History

Table 204. Nonresidential High-Speed Doors for Cold Storage Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/20221	TRM v9.0 update. General reference checks and text edits.

2.6 NONRESIDENTIAL: WATER HEATING

2.6.1 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

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

Equation 192

$$Pump\ Demand\ Savings\ [kW] = Annual\ Pump\ Energy\ Savings\ \times PLS$$

Equation 193

Where:

kW_{pump} = *The demand used by the circulation pump, obtained from the project site; if unknown, assume 0.075 kW*

$Pump_{\%On\_base}$ = *Baseline pump operation as percentage of time, 100%*

$Pump_{\%On\_eff}$ = *Efficient pump operation as percentage of time, 7%*[395]

Hours = *Hours per year = 8,760*

PLS = *Probability-weighted peak load share, Table 205*

Table 205. Central DHW Controls—Probability Weighted Peak Load Share[396]

Building type	Commercial		Lodging[397]	
Climate zone	Summer peak	Winter peak	Summer peak	Winter peak
Zone 1	0.00016	0.00011	0.00012	0.00015
Zone 2	0.00017	0.00011	0.00012	0.00014
Zone 3	0.00016	0.00011	0.00012	0.00015

395 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.

396 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.

397 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[397]	
Climate zone	Summer peak	Winter peak	Summer peak	Winter peak
Zone 4	0.00016	0.00011	0.00012	0.00015
Zone 5	0.00018	0.00011	0.00012	0.00014

Thermal Distribution Savings Algorithm

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

Equation 194

$$Thermal\ Demand\ Savings\ [kW] = Annual\ Thermal\ Energy\ Savings\ \times PLS$$

Equation 195

Where:

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

$kWh_{reference}$ = *Annual kWh energy savings from reference study, see Table 206.*

HDD Adjustment = *Climate adjustment for Texas heating degree days, see Table 207.*

PLS = *Probability-weighted peak load share, see Table 205*

Table 206. Central DHW Controls—Reference kWh by Water Heater and Building Type[398]

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

Table 207. Central DHW Controls—HDD Adjustment Factors[399]

Climate zone	HDD adjustment
Zone 1	1.9
Zone 2	1.1
Zone 3	0.7
Zone 4	0.5
Zone 5	1.1

398 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.

399 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 208 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 208. Central DHW Controls—Annual kWh Circulation Pump 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 209 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 209. Central DHW Controls—Annual kWh Thermal Distribution Savings per Dwelling Unit

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

Deemed Summer and Winter Demand Savings Tables

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

Table 210. Central DHW Controls—Peak Demand kW Circulation Pump Savings

Pump size	Climate zone	Commercial		Lodging	
		Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
≤ 50	Zone 1	0.065	0.045	0.049	0.061
	Zone 2	0.069	0.045	0.049	0.057
	Zone 3	0.065	0.045	0.049	0.061
	Zone 4	0.065	0.045	0.049	0.061
	Zone 5	0.073	0.045	0.049	0.057

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

Table 211. Central DHW Controls—Peak Demand kW Thermal 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
Zone 1	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Zone 2	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Zone 3	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Zone 4	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Zone 5	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-Timeclock.[400]

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
- 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

- DEER 2014 EUL update.

Document Revision History

Table 212. Nonresidential 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.

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

2.6.2 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)[401] 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.

[401] A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{OCC}{n_{SH}}$$

Equation 196

Where:

SHFR	=	*Showerhead flow rate, gallons per minute (gpm) (see Table 213)*
BW	=	*Behavioral waste, minutes per shower (see Table 213)*
n_S	=	*Number of showers per occupied room per day (see Table 213)*
365	=	*Constant to convert days to years (see Table 213)*
OCC	=	*Occupancy rate (see Table 213)*
n_{SH}	=	*Number of showerheads per room (see Table 213)*

Applying the formula to the values used for Texas from Table 213 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM): 2.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}838\ gal$$

$$Showerhead\ (2.0\ GPM): 2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}471\ gal$$

$$Showerhead\ (1.75\ GPM): 1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}287\ gal$$

$$Showerhead\ (1.5\ GPM): 1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1{,}103\ gal$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 213.

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

Equation 197

Where:

HW% = *Hot water percentage (see Table 213)*

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

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

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

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

Table 213. 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)[402]				1.742
Showers/occupied room/day[403]				1.756
Occupancy rate[404]				65.9%
Showerheads/room[405]				1.0
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water[406]				80-85%, or 82.5% on average
Hot water saved/year (gal)	1,516	1,213	1,062	910

[402] 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.

[403] 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.

[404] 2001-2019 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 years (2015-2019).

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

[406] 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.

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times 3{,}412}$$

Equation 198

Where:

ρ	=	*Water density, 8.33 lbs/gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
V	=	*Gallons of hot water saved per year per showerhead (see Table 213)*
$T_{SetPoint}$	=	*Water heater setpoint: 120°F* [407]
T_{Supply}	=	*Average supply water temperature (see Table 214)*
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.*[408]
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3{,}412 \times 365} \times CF$$

Equation 199

[407] 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.

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

Where:

$T_{SupplySeasonal}$	=	*Seasonal supply water temperature (see Table 214)*
CF	=	*Peak coincidence factor (see Table 215)*

Table 214. Showerhead TSRVs—Water Mains Temperatures

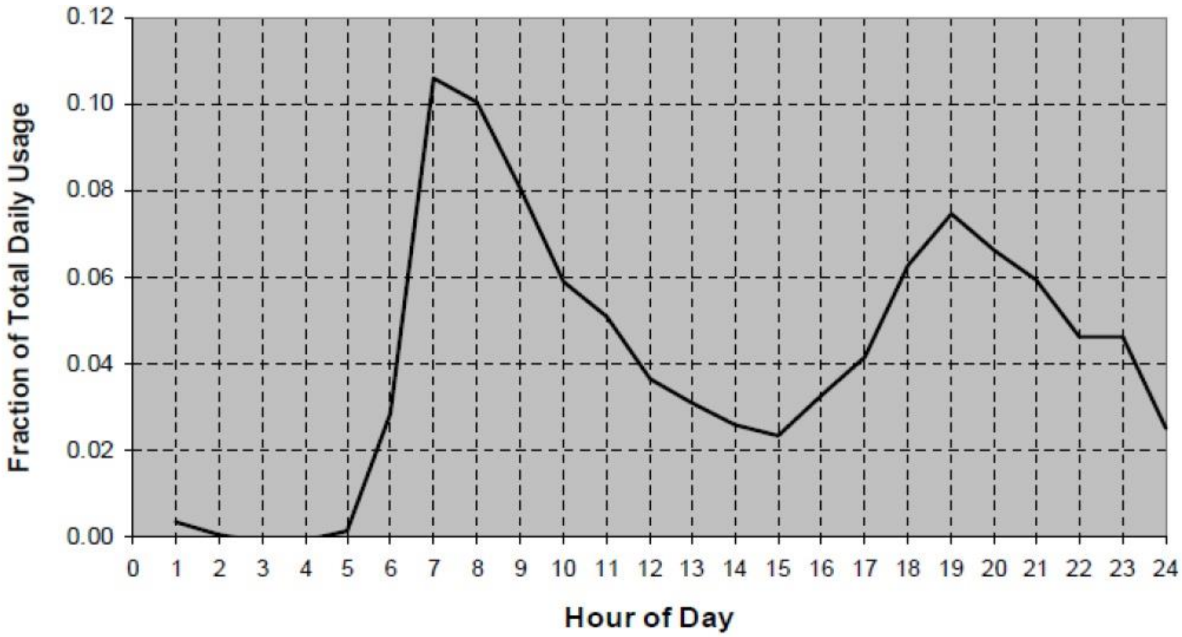
Climate zone	Water mains temperature (°F)[409]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 215. 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

[409] Based on typical meteorological year (TMY) dataset for TMY3: https://nsrdb.nrel.gov/about/tmy.html.

Figure 5. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[410]



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.

[410] 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.[411] This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[412]

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
- 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

Document Revision History

Table 216. Nonresidential Showerhead Temperature Sensitive Restrictor Valves 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.

[411] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[412] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.

2.6.3 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)[413] 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.

[413] A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a commercial lodging shower arm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage.

Part 1: To determine baseline gallons of behavioral waste per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = \%WUE_{SH} \times SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{OCC}{n_{SH}}$$

Equation 200

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

Equation 201

Where:

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 217)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 217)*

SHFR = *Showerhead flow rate, gallons per minute (gpm) (see Table 217)*

TSFR = *Tub spout flow rate, gallons per minute (gpm) (see Table 217)*

BW = *Behavioral waste, minutes per shower (see Table 217)*

n_S = *Number of showers per occupied room per day (see Table 217)*

365 = *Constant to convert days to years (see Table 217)*

OCC = *Occupancy rate (see Table 217)*

n_{SH} = *Number of showerheads per room (see Table 217)*

Applying the formula to the values from Table 217 returns the following values:

$$Showerhead\ (1.5\ GPM): 0.6 \times \left(1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 662$$

$$Showerhead\ (1.75\ GPM): 0.6 \times \left(1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 772$$

$$Showerhead\ (2.0\ GPM): 0.6 \times \left(2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 882$$

$$Showerhead\ (2.5\ GPM): 0.6 \times \left(2.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 1{,}103$$

$$Tub\ Spout\ (5.0\ GPM): 0.4 \times \left(5.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0}\right) = 1{,}471$$

Part 2: To determine baseline gallons of diverter leakage per year, the following formula was used:

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{OCC}{n_{SH}}$$

Equation 202

Where:

DLR = *Diverter leakage rate (gpm) (see Table 217)*

t_S = *Shower time (min/shower) (see Table 217)*

Applying the formula to the values used for Texas from Table 217 returns the following values:

$$Diverter\ (0.8\ GPM): 0.8 \times 7.8 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 2{,}634$$

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percentage of hot water from Table 217.

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

Equation 203

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 217)*
$HW\%_{D}$	=	*Diverter hot-water percentage (see Table 217)*

Applying the formula to the values from Table 217 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 217. 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			N/A
Tub-spout flow rate (gpm)[414]	N/A	5.0		N/A
Percentage of warm-up events[415]	60%	40%		N/A
Average behavioral waste (minutes per shower)[416]		1.742		N/A
Average diverter leakage-rate (gpm)[417]		N/A	0.80	N/A
Average shower time (minutes)[418]		N/A	7.8	N/A
Showers/occupied room/day[419]				1.756
Occupancy rate[420]				65.9%
Showerheads/room[421]				1.0

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

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

416 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.

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

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

419 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.

420 2001-2019 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 years (2015-2019).

421 Assuming industry standard for standard one-bathroom rooms.

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
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[422]	80-85%, or 82.5% average		73.7%	N/A
Gallons of hot water saved per year (1.5 gpm)	N/A			3,700
Gallons of hot water saved per year (1.75 gpm)	N/A			3,791
Gallons of hot water saved per year (2.0 gpm)	N/A			3,882
Gallons of hot water saved per year (2.5 gpm)	N/A			4,064

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times 3{,}412}$$

Equation 204

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

V = *Gallons of hot water saved per year per showerhead (see Table 217)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [423]

[422] 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.

[423] 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.

T_{Supply}	=	*Average supply water temperature (see Table 218)*
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*[424]
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3{,}412 \times 365} \times CF$$

Equation 205

Where:

$T_{SupplySeasonal}$	=	*Seasonal-supply water temperature (see Table 218)*
CF	=	*Peak coincidence factor (see Table 219)*

Table 218. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature (°F)[425]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	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

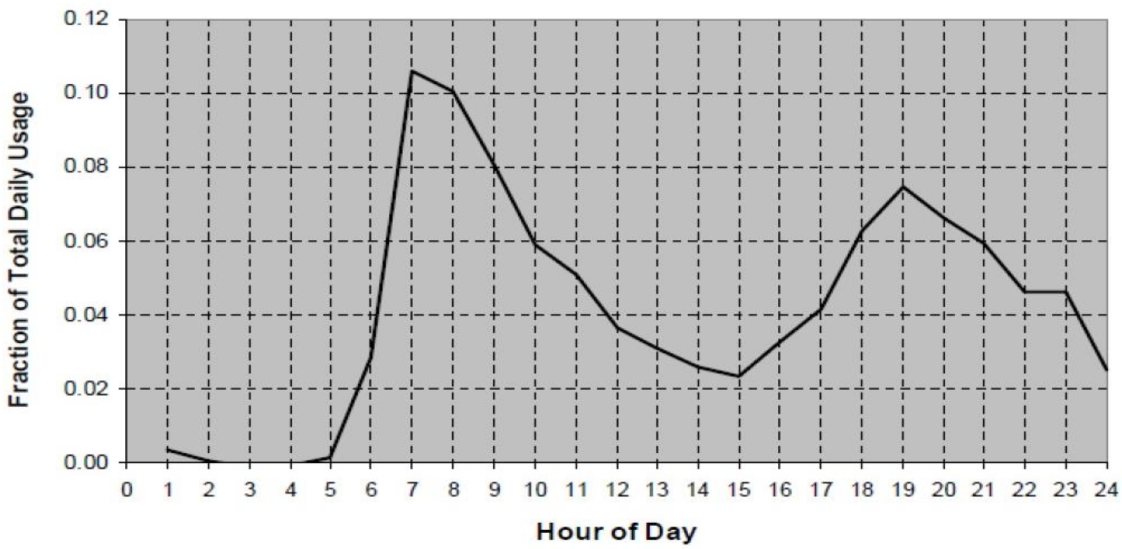
[424] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

[425] Based on typical meteorological year (TMY) dataset for TMY3: https://nsrdb.nrel.gov/about/tmy.html.

Table 219. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors

Climate zones	Summer	Winter
Zone 1: Amarillo	0.039	0.073
Zone 2: Dallas	0.035	0.075
Zone 3: Houston	0.038	0.080
Zone 4: Corpus Christi	0.038	0.068
Zone 5: El Paso	0.028	0.069

Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[426]



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.

[426] 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.[427]

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
- 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

Document Revision History

Table 220. Nonresidential Tub Sprout and Showerhead Temperature Sensitive Restrictor Valves 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.

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

2.7 NONRESIDENTIAL: MISCELLANEOUS

2.7.1 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.[428]

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 221. Vending Machine Controls—Refrigerated Cold Drink Unit Deemed Savings[429]

Climate zone	kWh savings	Summer kW savings[430]	Winter kW savings
Zone 1: Amarillo	1,612	0.023	0.060
Zone 2: Dallas		0.021	0.063
Zone 3: Houston		0.022	0.060
Zone 4: Corpus Christi		0.022	0.064
Zone 5: El Paso		0.015	0.068

428 Appliance Standards for Refrigerated Beverage Vending Machines. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

429 Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

430 Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56. https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper.pdf.

Table 222. Vending Machine Controls—Refrigerated Reach-In Unit Deemed Savings[431]

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Zone 1: Amarillo	1,086	0.026	0.069
Zone 2: Dallas		0.024	0.073
Zone 3: Houston		0.026	0.068
Zone 4: Corpus Christi		0.026	0.074
Zone 5: El Paso		0.017	0.078

Table 223. Vending Machine Controls—Non-Refrigerated Snack Unit Deemed Savings[432]

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Zone 1: Amarillo	387	0.005	0.013
Zone 2: Dallas		0.004	0.013
Zone 3: Houston		0.005	0.013
Zone 4: Corpus Christi		0.005	0.014
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.[433]

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

[431] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.
[432] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.
[433] 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.
- PUCT Docket 36779—Provides EUL for Vending Machine Controls.

Relevant Standards and Reference Sources

- 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://aceee.org/files/proceedings/2002/data/papers/SS02_Panel10_Paper05.pdf.
- DEER 2014 EUL update.

Document Revision History

Table 224. Nonresidential Vending Machine 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

2.7.2 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.[434]

Eligibility Criteria

To be eligible for HVAC savings, controls must be capable of either a 5ºF or 10ºF 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.

[434] 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[435] 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.[436]

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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[435] 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.

[436] A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 225. Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Climate zone[437]	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo (Panhandle)	0.059	267	0.075	380	0.059	341	0.075	441
Dallas (North)	0.076	315	0.091	443	0.076	365	0.091	485
Houston (South)	0.082	324	0.097	461	0.082	351	0.097	484
McAllen (Valley)	0.086	354	0.103	500	0.086	369	0.103	513
El Paso (West)	0.063	251	0.078	379	0.063	283	0.078	406
10-degree setup/setback offset								
Amarillo (Panhandle)	0.111	486	0.126	598	0.111	627	0.126	726
Dallas (North)	0.146	559	0.161	686	0.146	640	0.161	761
Houston (South)	0.151	559	0.166	695	0.151	602	0.166	735
McAllen (Valley)	0.163	617	0.179	761	0.163	650	0.179	792
El Paso (West)	0.118	432	0.133	561	0.118	482	0.133	607

Table 226. Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Climate zone	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo (Panhandle)	0.053	232	0.072	439	0.053	303	0.072	530
Dallas (North)	0.073	258	0.093	452	0.073	303	0.093	505
Houston (South)	0.074	242	0.094	430	0.074	260	0.094	450
McAllen (Valley)	0.081	260	0.102	451	0.081	267	0.102	459
El Paso (West)	0.056	178	0.075	360	0.056	196	0.075	380
10-degree setup/setback offset								
Amarillo (Panhandle)	0.102	426	0.121	568	0.102	557	0.121	684
Dallas (North)	0.134	452	0.154	617	0.134	517	0.154	676
Houston (South)	0.136	423	0.156	599	0.136	446	0.156	621
McAllen (Valley)	0.149	467	0.169	652	0.149	483	0.169	667
El Paso (West)	0.106	312	0.126	479	0.106	338	0.126	501

437 Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo (Panhandle) was "Panhandle", Dallas-Ft Worth (North) was "North", Houston (South) was "South Central", El Paso (West) was "Big Bend", and McAllen (Valley) was "Rio Grande Valley".

Table 227. Deemed Energy and Demand Savings for Dormitories per Room, by Region

Climate zone	Heat pump				Electric heat			
	HVA only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo (Panhandle)	0.034	136	0.061	319	0.034	152	0.061	316
Dallas (North)	0.048	214	0.076	425	0.048	223	0.076	428
Houston (South)	0.051	242	0.078	461	0.051	244	0.078	462
McAllen (Valley)	0.053	265	0.081	492	0.053	266	0.081	492
El Paso (West)	0.031	110	0.059	327	0.031	110	0.059	326
10-degree setup/setback offset								
Amarillo (Panhandle)	0.073	261	0.084	404	0.073	289	0.084	417
Dallas (North)	0.078	293	0.105	505	0.078	304	0.105	511
Houston (South)	0.081	326	0.108	543	0.081	328	0.108	545
McAllen (Valley)	0.088	368	0.114	591	0.088	370	0.114	593
El Paso (West)	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[438]. 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
- HVAC system and equipment type
- Heating type (heat pump, electric resistance)
- Temperature offset category (5 or 10° F)

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[438] 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.

- 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

- ASHRAE Standard 90.1-1999
- Measure Life Study. Prepared for The Massachusetts Joint Utilities by ERS. November 17, 2005.
- Codes and Standards Enhancement Initiative (CASE): Guest Room Occupancy Controls, 2013 California Building Energy Efficiency Standards. October 2011.

Document Revision History

Table 228. Nonresidential Lodging Guest Room Occupancy Sensor Controls 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revisions.

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"[439] 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[440] 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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[439] 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.

[440] 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*[441] (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,*[442] 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.[443]

Savings Algorithms and Inputs

The energy and demand algorithms and associated input variables are listed below:

$$Energy\ Savings\ [kWh] = kW_{avg} * (TimeClock\%On - POC\%On) * 8760$$

Equation 206

$$Demand\ Savings\ [kW] = \frac{EnergySavings}{8760}$$

Equation 207[444]

The inputs for the energy and peak coincident demand savings are listed below:

$$kW_{avg} = HP \times 0.746 \times \frac{\frac{LF}{ME}}{SME}$$

Equation 208

[441] 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).
[442] *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.
[443] The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.
[444] 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 209[445]

Where:

kW_{avg}	=	*The demand used by each rod pump*
HP	=	*Rated pump-motor horsepower*
0.746	=	*Conversion factor from hp to kW*
LF	=	*Motor load factor—ratio of average demand to maximum demand, see Table 229*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 230*
SME	=	*Mechanical efficiency of sucker-rod pump, see Table 229*
TimeClock%On	=	*Stipulated-baseline timeclock setting, see Table 229*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956, derived from SPE 16363* [446]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

Deemed Energy and Demand Savings Tables

Table 229. Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/deemed values
LF (Load factor)	25%[447]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[448]
Timeclock%On	65%[449]

[445] 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 ($Run_{contstant}$ + $Run_{coefficient}$ * VolumetricEfficiency%) with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25 percent).

[446] 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).

[447] *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.

[448] Engineering estimate for standard gearbox efficiency.

[449] A TimeClock%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.

Table 230. NEMA Premium Efficiency Motor Efficiencies[450]

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%

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 207.

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.[451]

[450] 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.

[451] 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.

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 timeclock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times[452]

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 42551—Provides energy and demand savings calculations and EUL

Relevant Standards and Reference Sources

- 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).
- 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I]
- 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.
- Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011.

[452] 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 231. Nonresidential 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable speed pool pump.

Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa[453].

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.[454] 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.

Baseline Condition

The baseline condition is a 1 to 3 horsepower (hp) standard efficiency single-speed pool pump.

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[453] These pump products are ineligible for ENERGY STAR® v3.0 certification: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%203.0%20Pool%20Pumps%20Specification.pdf

[454] 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. U.S. DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf.

High-Efficiency Condition

The high-efficiency condition is a 1 to 3 hp ENERGY STAR® certified variable speed pool pump.

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.[455]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

Equation 210

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:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours \times days}{EF_{conv} \times 1000}$$

Equation 211

$$kWh_{ES} = \frac{gal \times turn_{day} \times days}{EF_{ES} \times 1000}$$

Equation 212

455 The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

Where:

hours	=	*Conventional single-speed pump daily operating hours (see Table 232)*
days	=	*Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*
PFR_{conv}	=	*Conventional single-speed pump flow rate [gal/min] (see Table 232)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (see Table 232)*
gal	=	*The volume of the pool in gallons (see Table 233)*
$turn_{day}$	=	*Turnovers per day, number of times the volume of the pool is run through the pump per day (see Table 207)*
EF_{ES}	=	*ENERGY STAR®-weighted energy factor [gal/W·hr] (see Table 207)*
60	=	*Constant to convert between minutes and hours*
1,000	=	*Constant to convert from kilowatts to watts*

Table 232. Conventional Pool Pumps Assumptions[456]

New rated pump HP	Hours limited hours[457]	Hours, 24/7 Operation	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 ≤ 3			101.6667	1.9987

456 Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

457 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.

Table 233. ENERGY STAR® Pool Pumps Assumptions[458]

New rated pump HP	Turnovers/day limited hours	Turnovers/day 24/7 Operation	Gallons	EF_{ES} (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 ≤ 3	2.6	5.2	28,000	7.1

Demand Savings Algorithms

$$kW_{Savings} = \frac{kWh_{conv} - kWh_{ES}}{hours} \times \frac{DF}{days}$$

Equation 213

Where:

hours = *Conventional single-speed pump daily operating hours (see Table 232)*

days = *Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*

DF = *Demand factor from Table 234*

Table 234. Demand Factors[459]

Operation	Summer DF	Winter DF
24/7 operation	1.0	1.0
Seasonal/limited hours	1.0	0.5

[458] ENERGY STAR® turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.
[459] Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

Deemed Energy and Demand Savings Tables

Table 235. ENERGY STAR® Variable Speed Pool Pump Energy Savings[460]

New rated pump HP	Year-round operation: 24/7 operation kWh savings	Year-round operation: Limited hours kWh savings	Seasonal operation (7 months) 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 ≤ 3	19,250	9,625	5,612

Table 236. ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings

New rated 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 ≤ 3	2.198	1.281

Table 237. ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings

New rated 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 ≤ 3	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.

[460] 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.

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/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

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.[461]

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
    - 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

- The applicable version of the ENERGY STAR® specifications and requirements for pool pumps

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

Document Revision History

Table 238. Nonresidential ENERGY STAR® 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 revisions.
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.

2.7.5 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[462], and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.[463]

[462] ENERGY STAR® Low Carbon IT Calculator available for download at: https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep.

[463] 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.[464]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$kWh_{savings} = \frac{W_{active}\left(hrs_{active_{pre}} - hrs_{active_{post}}\right) + W_{sleep}\left(hrs_{sleep_{pre}} - hrs_{sleep_{post}}\right) + W_{off}\left(hrs_{off_{pre}} - hrs_{off_{post}}\right)}{1{,}000}$$

Equation 214

$$Summer\ kW_{savings} = \left(W_{active} - W_{sleep}\right) \times CF_{inactive}$$

Equation 215

$$Winter\ kW_{savings} = 0$$

Equation 216

Where:

W_{active}	=	*Total wattage of the equipment, including computer and monitor, in active/idle mode (see Table 239)*
$hrs_{active_{pre}}$	=	*Annual number of hours the computer is in active/idle mode before computer management software is installed (see Table 240)*
$hrs_{active_{post}}$	=	*Annual number of hours the computer is in active/idle mode after computer management software is installed (see Table 240)*
W_{sleep}	=	*Total wattage of the equipment, including computer and monitor, in sleep mode (see Table 239)*
$hrs_{sleep_{pre}}$	=	*Annual number of hours the computer is in sleep mode before computer management software is installed (see Table 240)*

[464] Based on 2015 custom project metering from El Paso Electric.

$hrs_{sleep_{post}}$	=	*Annual number of hours the computer is in sleep mode after computer management software is installed (see Table 240)*
W_{off}	=	*Total wattage of the equipment, including computer and monitor, in off mode (see Table 239)*
$hrs_{off_{pre}}$	=	*Annual number of hours the computer is in off mode before computer management software is installed (see Table 240)*
$hrs_{off_{post}}$	=	*Annual number of hours the computer is in off mode after computer management software is installed (see Table 240)*
1,000	=	*Conversion factor: 1 kW / 1,000 W*
CF	=	*Coincidence factor (see Table 241)*

Table 239. Computer Power Management—Equipment Wattages[465]

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional monitor[466]	18.3	0.30	0.30
Conventional computer	48.11	2.31	0.96
Conventional notebook (including display)	14.82	1.21	0.61
ENERGY STAR® monitor	15.0	0.26	0.26
ENERGY STAR® computer	27.11	1.80	0.81
ENERGY STAR® notebook (including display)	8.61	0.89	0.46

Table 240. Computer Power Management—Operating Hours[467]

Building activity type	$hrs_{active_{pre}}$	$hrs_{active_{post}}$	$hrs_{sleep_{pre}}$	$hrs_{sleep_{post}}$	$hrs_{off_{pre}}$	$hrs_{off_{post}}$
Typical office (8 hours/day, 5 days/week, 22 non-workdays/year)	4,650	1,175	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

465 Equipment wattages taken from the ENERGY STAR® Office Equipment Calculator, updated October 2016. Available for download at https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

466 Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR® Office Equipment Calculator.

467 Hours taken from assumptions in the ENERGY STAR® calculator. $Hours_{pre}$ assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night. $Hours_{post}$ assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.

Table 241. Computer Power Management—Coincidence Factors, All Activity Types

Climate zone	Summer CF		Winter CF	
	Active	Inactive	Active	Inactive
1	0.65	0.35	0.11	0.89
2	0.62	0.38	0.12	0.88
3	0.66	0.34	0.12	0.88
4	0.62	0.38	0.14	0.86
5	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 239, Table 240, and Table 241. The following tables provide these deemed values.

Table 242. Computer Power Management—Deemed Energy Savings Values, All Climate Zones

Equipment	Office or school kWh
Conventional LCD monitor	62.6
Conventional computer	161.4
Conventional notebook	48.2
ENERGY STAR® monitor	51.3
ENERGY STAR® computer	89.5
ENERGY STAR® notebook	27.5

Table 243. Computer Power Management—Deemed Demand Savings Values, Office, or School

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	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	0.007	0	0.006	0	0.007	0	0.004	0
Conventional computer	0.016	0	0.017	0	0.015	0	0.017	0	0.011	0
Conventional notebook	0.005	0	0.005	0	0.005	0	0.005	0	0.003	0
ENERGY STAR® monitor	0.005	0	0.006	0	0.005	0	0.006	0	0.004	0

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)
ENERGY STAR® computer	0.009	0	0.010	0	0.009	0	0.010	0	0.006	0
ENERGY STAR® notebook	0.003	0	0.003	0	0.003	0	0.003	0	0.002	0

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.[468]

Program Tracking Data and Evaluation Requirements

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

- Equipment type
  - Conventional or ENERGY STAR®
  - Monitor, computer, or notebook
- Application type (office, school)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

[468] 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.

Document Revision History

Table 244. Nonresidential Computer Power Management 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. 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.

2.7.6 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 249. 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).[469]

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

[469] 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.

Energy Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

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

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

Under these legislative changes, 200-500 hp and subtype II motor baselines will be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct)[470] (see Table 248) and are thus no longer equivalent to pre-1992/pre-EPAct defaults.

Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct)[471], as listed in Table 250.

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 248.

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.

[470] 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.

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Actual motor operating hours are expected to be used to calculate savings. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 245 or Table 246 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 217

Demand Savings Algorithms

HVAC Applications:

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

Equation 218

Industrial Applications[472]:

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

Equation 219

Where:

hp	=	*Nameplate horsepower data of the motor*
0.746	=	*hp-to-kWh conversion Factor (kW/hp)*[473]
LF	=	*Estimated load factor (if unknown, see Table 245 or Table 246)*

[472] Assumes three-shift operating schedule

[473] 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 248)*[474]
η_{post}	=	*Efficiency of the newly installed motor [%]*
Hrs	=	*Estimated annual operating hours (if unknown, see Table 245 or Table 246)*
CF	=	*Coincidence factor (see Table 245)*
$kWh_{savings,ROB}$	=	*Total energy savings for a new construction or ROB project*
$kW_{savings,ROB}$	=	*Total demand savings for a new construction or ROB project*

Table 245. Premium Efficiency Motors—HVAC Assumptions by Building Type

Building type	Load factor[475]	CF[476]	HVAC fan hours[477]
Hospital	0.75	1.00	8,760
Large office (>30k SqFt)			4,424
Small office (≤30k SqFt)			4,006
K-12 school			4,173
College			4,590
Retail			5,548
Restaurant (fast-food)			6,716
Restaurant (sit-down)			5,256

[474] In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 247.
[475] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
[476] 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
[477] Factors are equivalent to Table 85 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 246. Premium Efficiency Motors—Industrial Assumptions by Building Type

Industrial processing	Load factor[478]	Hours[479]					
		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 247. Rewound Motor Efficiency Reduction Factors[480]

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

Table 248. Premium Efficiency Motors—New Construction and Replace-on-Burnout Baseline Efficiencies by Motor Size (%)[469,473]

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

[478] 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

[479] 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

[480] U.S. 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: $\eta_{baseline, ROB}$			Closed motors: $\eta_{baseline, ROB}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
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
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	N/A	95.8	95.8	N/A	96.2	95.8
450	N/A	96.2	96.2	N/A	96.2	95.8
500	N/A	96.2	96.22	N/A	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 249); 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 249. Remaining Useful Life (RUL) of Replaced Motor[481]

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[482]	0.0
9	5.9		

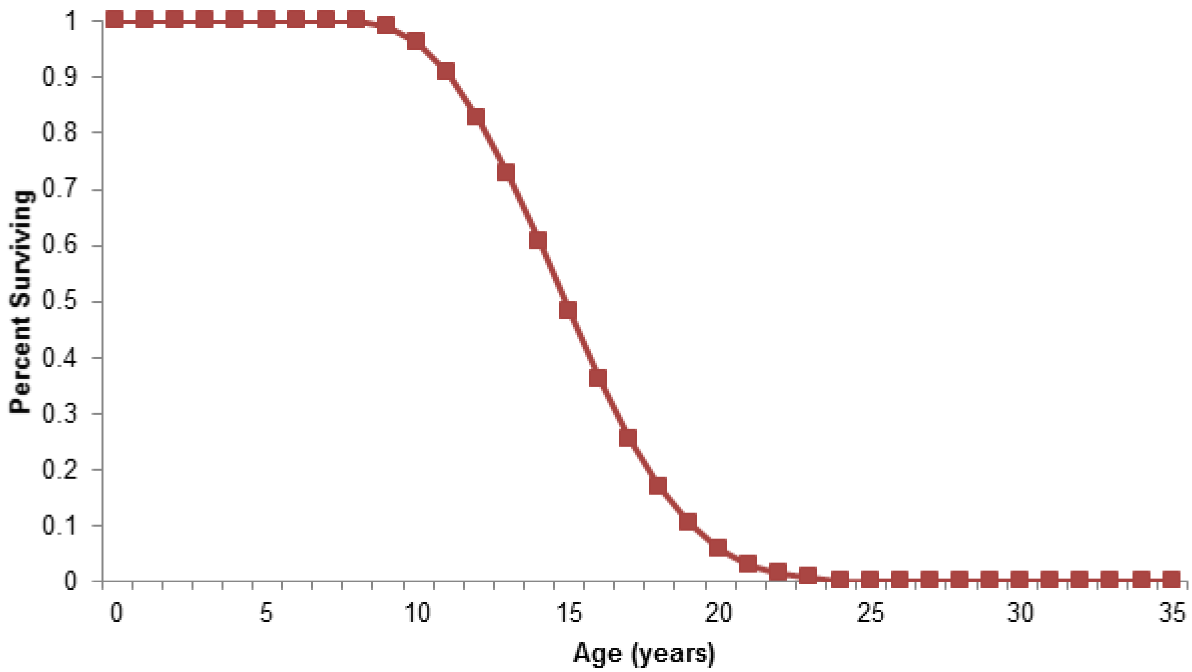
Derivation of RULs

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.

[481] 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.

[482] 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. Survival Function for Premium Efficiency Motors[483]



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 220

[483] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project.

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

Equation 221

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 222

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 223

Industrial Applications

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8{,}760\ hours}$$

Equation 224

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 225

Industrial Applications

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8{,}760\ hours}$$

Equation 226

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 227

Where:

$\eta_{baseline,ER}$ = *Assumed original motor efficiency for remaining EUL time period (Table 250 or Table 251)*[484]

$kWh_{savings,RUL}$ = *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 250. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size (%)[471]

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

[484] Ibid.

hp	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
40	93.0	93.0	91.7	93.0	93.0	91.7
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	N/A	95.4	95.4	N/A	95.4	95.4
450	N/A	95.8	95.8	N/A	95.4	95.4
500	N/A	95.8	95.8	N/A	95.8	95.4

Table 251. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)[485]

hp	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
	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	N/A	95.4	95.4	N/A	95.4	95.4
450	N/A	95.8	95.8	N/A	95.4	95.4
500	N/A	95.8	95.8	N/A	95.8	95.4

[485] Federal Standards for Electric Motors, Table 4,

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 15 years.[486]

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:

- Number of units installed
- 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

[486] 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

Relevant Standards and Reference Sources

- Federal Energy Policy Act of 1992 (EPAct)
    - Defaults prior to EPAct 1992 from the DOE's *MotorMaster+* database (circa 1992)
- 2007 Energy Independence and Security Act (EISA)
- The applicable version of the Technical Support Document for electric motors

Document Revision History

Table 252. Nonresidential Premium Efficiency Motors Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Replace-on-burnout and Early Retirement clarifications.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.

2.7.7 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 an ENERGY STAR® compliant Level 2 EVSE.

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

$$ENERGY\ STAR\ Idle\ Consumption\ [kWh] = \frac{(hrs_{plug} \times W_{plug} + hrs_{unplug\_C} \times W_{unplug}) \times days_C + hrs_{unplug\_NC} \times W_{unplug} \times days_{NC}}{1000}$$

Equation 228

$$Baseline\ Idle\ Consumption\ [kWh] = \frac{ENERGY\ STAR\ Idle\ Consumption}{0.6}$$

Equation 229

$$Annual\ Energy\ Savings\ [kWh] = Baseline\ Idle\ Consumption - ENERGY\ STAR\ Idle\ Consumption$$

Equation 230

$$Demand\ Savings\ [kW] = \frac{Annual\ Energy\ Savings\ (kWh)}{hrs_{unplug\_C} \times days_C + hrs_{unplug\_NC} \times days_{NC}} \times PDPF$$

Equation 231

Where:

hrs_{plug} = *Hours per day the vehicle is plugged into the EVSE and not charging, 2.8 hrs*[487]

W_{plug} = *Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging, 6.9 W*[488]

hrs_{unplug_C} = *Hours per day the vehicle is not plugged into the EVSE on a charging day, 19.0 hrs*[489]

[487] 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.

[488] Average Idle Mode Input Power from ENERGY STAR® certified EVSE product list as of July 13, 2020.

[489] 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.

hrs_{unplug_NC}	=	*Hours per day the vehicle is not plugged into the EVSE on a non-charge day, 24 hrs*
W_{unplug}	=	*Wattage of the EVSE when the vehicle is not plugged into the EVSE, 3.3 W*[490]
$days_C$	=	*Number of charging days per year, 204 days*[491]
$days_{NC}$	=	*Number of non-charging days per year, 161 days*
1000	=	*Constant to convert from W to kW*
0.6	=	*Efficiency adjustment factor*[492]
PDPF	=	*Peak demand probability factor (see Table 253)*

Table 253. EVSE Peak Demand Probability Factors[493]

Location type	Public		Workplace		Fleet	
Climate zone	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF
Zone 1: Amarillo	0.46526	0.46032	0.87484	0.75271	0.27206	0.44421
Zone 2: Dallas	0.45808	0.47380	0.86213	0.75558	0.22867	0.42040
Zone 3: Houston	0.46134	0.42544	0.87173	0.68222	0.26507	0.34306
Zone 4: Corpus Christi	0.46892	0.49816	0.87553	0.77324	0.25862	0.50077
Zone 5: El Paso	0.42680	0.51324	0.80969	0.92091	0.15042	0.57715

Deemed Energy and Demand Savings Tables

Table 254 presents the deemed annual energy savings per EVSE.

Table 254. EVSE Annual Energy Savings

Annual energy savings (kWh) (all location types)
19.7

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490 Average No Vehicle Mode Input Power from ENERGY STAR® certified EVSE product list.

491 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 x 0.56 = 204.

492 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.

493 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.

Table 255 presents the deemed summer and winter peak kW savings per EVSE.

Table 255. EVSE Peak Demand Savings

Location type	Public		Workplace		Fleet	
Climate zone	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
Zone 1: Amarillo	0.0012	0.0012	0.0022	0.0019	0.0008	0.0012
Zone 2: Dallas	0.0012	0.0012	0.0022	0.0019	0.0006	0.0012
Zone 3: Houston	0.0012	0.0011	0.0022	0.0017	0.0007	0.0010
Zone 4: Corpus Christi	0.0012	0.0013	0.0022	0.0020	0.0007	0.0014
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.[494]

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:

- Quantity
- Climate zone
- Location Type (public, workplace, or fleet) [495]
- EVSE manufacturer and model number

[494] 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.

[495] Refer to Eligibility Criteria section for location type definitions.

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for electric vehicle supply equipment.

Document Revision History

Table 256. Nonresidential Electric Vehicle Supply Equipment 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.

2.7.8 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. 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[496]:

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

Equation 232

Where:

%GPM	=	*Percentage flow rate (see Table 257)*
i	=	*Each hour of the year*

Table 257. VFD for Water Pumping—Water Demand Profile[497]

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

[496] 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.

[497] 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.

Hour ending	Percentage flow rate
21	0.745
22	0.608
23	0.529
24	0.294

VFD Technology[498]:

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

Equation 233

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 234

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

Equation 235

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 the pump typical design point*
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	=	*HP to kW conversion factor*
η	=	*Motor efficiency of a standard efficiency motor (see Table 258)*

[498] 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).

Table 258. Motor Efficiencies[499]

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

Hourly and Peak Demand Savings Calculations

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

Equation 236

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

Equation 237

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*

[499] 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.

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:

$$Annual\ kWh = \sum_{i=1}^{8760} (kW_i)$$

Equation 238

Where:

8760 = *Total number of hours in a year*

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

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

Equation 239

Deemed Energy and Demand Savings Tables

Table 255 presents the deemed summer and winter peak kW savings per EVSE.

Table 259. Water Pump VFD Savings per Motor HP

Climate zone	Annual kWh savings per motor HP	Winter peak demand kW savings per motor HP
Zone 1: Amarillo	1,389	0.097
Zone 2: Dallas		0.069
Zone 3: Houston		0.067
Zone 4: Corpus Christi		0.138
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.[500]

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

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
- Climate zone
- Motor horsepower

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

Document Revision History

Table 260. Nonresidential Water Pumping VFD Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

2.7.9 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

$$Annual\ Energy\ Savings\ (kWh) = \Delta Water\ (gallons)/1{,}000{,}000 \times E_{water\ supply}$$

Equation 240

$$\Delta Water = \frac{S_L\ (lb/hr)}{8.33\ (lbs/gal)} \times Hours \times L$$

Equation 241

$$S_L = 24.24 \times P_{ia} \times D^2 \times A \times FF$$

Equation 242

$$Peak\ Demand\ Savings\ (kW) = \frac{Annual\ Energy\ Savings\ (kWh)}{Hours} \times DF$$

Equation 243

Where:

$E_{water\ supply}$	=	*Water supply energy factor: 2,300 kWh/million gallons*
S_L	=	*Average steam loss per trap (lb/hr) (see Table 261)*
Hours	=	*Annual hours when steam system is operational, equal to heating degree days by climate zone (see Table 262)*
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 261*
24.24	=	*Constant lb/(hr-psia-in2)*
P_{ia}	=	*Average steam trap inlet pressure, absolute (psia),* $P_{ig} + P_{atm}$
P_{ig}	=	*Average steam trap inlet pressure, gauge (psig) (see Table 261)*
P_{atm}	=	*Atmospheric pressure, 14.7 psia*

D	=	*Diameter of orifice (inches), use actual if possible, or defaults in Table 261*
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*
DF	=	*Demand factor, assume value of 1 for industrial and process steam applications; for commercial heating applications, see Table 32 through Table 36 in Section 2.2.2; for commercial dry cleaners, use DF for stand-alone retail*

Table 261. Steam Traps—Default Inputs[501]

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, S_L (lb/hr/trap)	Hours	L
Commercial dry cleaners	82.8	0.125	100%	18.5	2,425	0.27
Industrial or process low pressure < 15 psig	-	-		6.9	8,282	0.16
Industrial or process medium pressure > 15 and < 30 psig	16	0.1875	50%	6.5	8,282	0.16
Industrial or process medium pressure > 30 and < 75 psig	47	0.2500		23.4	8,282	0.16
Industrial or process high pressure > 75 and < 125 psig	101			43.8	8,282	0.16
Industrial or process high pressure > 125 and < 175 psig	146			60.9	8,282	0.16
Industrial or process high pressure > 175 and < 250 psig	202			82.1	8,282	0.16
Industrial or process high pressure > 250 and < 300 psig	263			105.2	8,282	0.16
Commercial heating LPS	-	-	100%	6.9	Table 262	0.27

501 Default inputs for the steam trap measure are sourced from the Illinois TRM version 9.0, measure 4.4.16 Steam Trap Replacement or Repair. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf

Table 262. Steam Trap—Hours

Climate zone	Hours (HDD) [502]
1	4,565
2	2,567
3	1,686
4	1,129
5	2,677

Deemed Energy and Demand Savings Tables

Table 263. Steam Trap—Annual 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 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

[502] 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 264. Steam Trap—Peak Demand Savings, Without Audit

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	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 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	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Food service	Full-service restaurant	2.21E-04	2.57E-04	2.26E-04	1.80E-04	1.44E-04
		24-hour full-service	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	2.47E-04	3.09E-04	2.57E-04	1.75E-04	1.34E-04
	Healthcare	Hospital	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient healthcare	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 stand-alone 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

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Service	Service	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	1.39E-04	1.44E-04	9.77E-05	4.12E-05	2.06E-05

Table 265. Steam Trap—Peak Demand Savings, With Audit

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	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 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

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Food sales	Convenience	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	8.19E-04	9.53E-04	8.38E-04	6.67E-04	5.33E-04
		24-hour full-service	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	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	Hospital	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient healthcare	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	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Service	Service	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.[503]

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 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

None

Document Revision History

Table 266. Nonresidential Steam Trap Repair and Replacement Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

[503] EULs for the steam trap measure are sourced from the Illinois TRM version 9.0, measure 4.4.16 Steam Trap Replacement or Repair. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf.

2.7.10 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

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 244

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[504]
n	=	*Motor efficiency, actual or default to value in Table 267*
hours	=	*Operating hours per year, actual*
EI	=	*Efficiency increase, 1.0% per gear mesh*[505]

Table 267. Motor Efficiencies[506]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936
30	0.941
40	0.941
50	0.945

[504] 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.

[505] Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf. Accessed August 2021.

[506] 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.

Motor horsepower	Full load efficiency
60	0.950
75	0.950
100	0.954

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.[507]

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

None

[507] 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.

Document Revision History

Table 268. Nonresidential Hydraulic Gear Lubricants Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

2.7.11 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

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 245

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[508]
n	=	*Motor efficiency, actual or default to value in Table 269*
hours	=	*Operating hours per year, actual*
EI	=	*Efficiency increase, 3.2%*[509]

Table 269. Motor Efficiencies[510]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936

508 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.

509 Focus on Energy Lubricant Study, https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study.

510 Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nomincal 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.

Motor horsepower	Full load efficiency
30	0.941
40	0.941
50	0.945
60	0.950
75	0.950
100	0.954

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.[511]

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.

[511] 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

Relevant Standards and Reference Sources

None

Document Revision History

Table 270. Nonresidential Hydraulic Oils Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

APPENDIX A: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

The following appendix describes the method to calculate savings for any dual baseline measure, including all early retirement measures. This supersedes the previous Measure Life Savings found in PUCT Dockets 40083 and 40885 and is revised to clarify the understanding of the measure life calculations and reduce any misrepresentation of net present value (NPV) of early retirement projects.

Option 1 provides reduced savings claimed over the full EUL. Option 2 provides higher savings claimed over a reduced EUL. The lifetime savings are the same for both options 1 and 2. Option 1 calculations were originally provided in Docket [43681].

<u>Option 1—Weighting Savings and Holding Measure Life Constant</u>

Step 1: Determine the measure life for first-tier (FT) and second-tier (ST) components of the calculated savings:

$$First\ Tier\ (FT)\ Period = ML_{FT} = RUL$$

Equation 246

$$Second\ Tier\ (ST)\ Period = ML_{ST} = EUL - RUL$$

Equation 247

Where:

RUL	=	*The useful life corresponding with the first tier-savings; for early retirement projects, RUL is the remaining useful life determined from lookup tables based on the age of the replaced unit (or default age when actual age is unknown)*
EUL	=	*The useful life corresponding with the second-tier savings; for early retirement projects, EUL is the estimated useful life as specified in applicable measure from Texas TRM (or approved petition)*

Step 2: Calculate the FT demand and energy savings and the ST demand and energy savings:

$$\Delta kW_{FT} = kW_{retired} - kW_{installed}$$

Equation 248

$$\Delta kW_{ST} = kW_{baseline} - kW_{installed}$$

Equation 249

$$\Delta kWh_{FT} = kWh_{retired} - kWh_{installed}$$

Equation 250

$$\Delta kWh_{ST} = kWh_{baseline} - kWh_{installed}$$

Equation 251

Where:

ΔkW_{FT}	=	*First-tier demand savings*
ΔkW_{ST}	=	*Second-tier demand savings*
$kW_{retired}$	=	*Demand of the first-tier baseline system, usually the retired system*[512]
$kW_{baseline}$	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[513]
$kW_{installed}$	=	*Demand of the replacement system*[514]
ΔkWh_{FT}	=	*First-tier energy savings*
ΔkWh_{ST}	=	*Second-tier energy savings*
$kWh_{retired}$	=	*Energy usage of the first-tier baseline system, usually the retired system*[512]
$kWh_{baseline}$	=	*Energy usage of the second-tier baseline system, usually the baseline ROB system*[513]
$kWh_{installed}$	=	*Energy usage of the replacement system*[514]

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 252

$$NPV_{ST,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ST}}\right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kW_{ST}$$

Equation 253

$$NPV_{FT,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{FT}}\right\} \times \Delta kWh_{FT}$$

Equation 254

512 Retired system refers to the existing equipment that was in use before the retrofit has occurred.
513 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).
514 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 255

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* [515]
d	=	*Discount rate weighted average cost of capital (per utility)* [515]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [515]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [515]
ML_{FT}	=	*First-tier measure life (calculated in Equation 246)*
ML_{ST}	=	*Second-tier measure life (calculated in Equation 247)*

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total,kW} = NPV_{FT,kW} + NPV_{ST,kW}$$

Equation 256

$$NPV_{Total,kWh} = NPV_{FT,kWh} + NPV_{ST,kWh}$$

Equation 257

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*

[515] 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 258

$$NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}$$

Equation 259

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:

$$Weighted\ kW = \frac{NPV_{Total\ kW}}{NPV_{EUL,kW}}$$
$$= \frac{\left[\left(1 - \left(\frac{1+e}{1+d}\right)^{RUL}\right) \times (kW_{retired} - kW_{installed})\right] + \left[\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kW_{baseline} - kW_{installed})\right]}{\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL}\right)}$$

Equation 260

$$Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPV_{EUL,kWh}}$$
$$= \frac{\left[\left(1 - \left(\frac{1+e}{1+d}\right)^{RUL}\right) \times (kWh_{retired} - kWh_{installed})\right] + \left[\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times (kWh_{baseline} - kWh_{installed})\right]}{\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL}\right)}$$

Equation 261

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 256*

$NPV_{Total,\ kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 257*
$NPV_{EUL,\ kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 258*
$NPV_{EUL,\ kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 259*

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 262

$$EUL_{kWh} = \frac{ln\left[\frac{NPV_{Total,kWh} \times (d-e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1+e)}\right]}{ln\left[\frac{(1+e)}{(1+d)}\right]}$$

Equation 263

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.