Public Utility Commission of Texas

Texas Technical Reference Manual

Version 7.0

Volume 3: Nonresidential Measures

Program Year 2020

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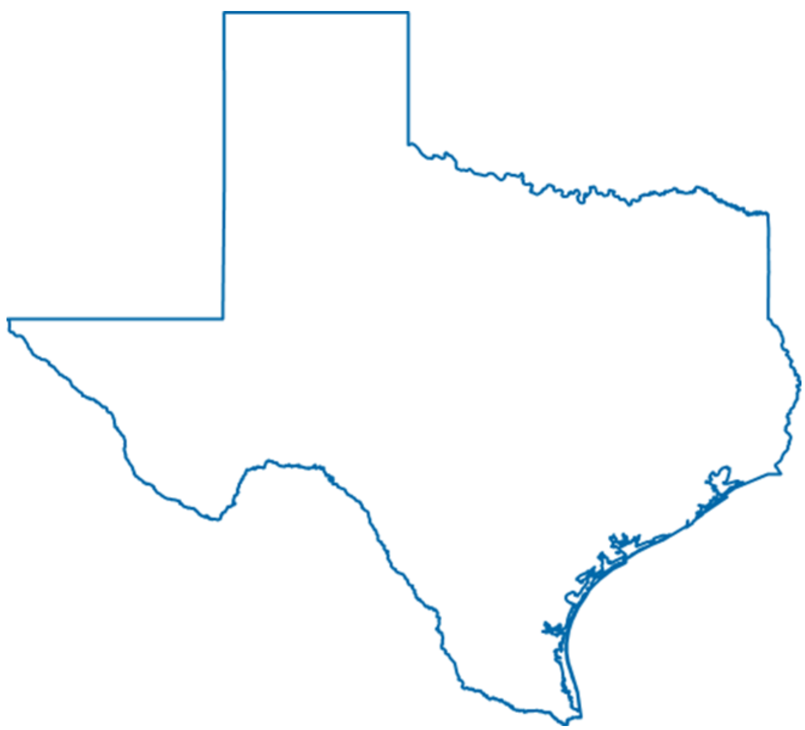

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Acknowledgments

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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 Associates (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	7.0 Update
Lighting	Lighting: Lamps and Fixtures	--	--	X	X	X	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 a partial summer session). Revised Outdoor: Athletic Field and Court factors. Added Midstream lighting guidance, assumptions, and calculations. Program tracking requirements updated.
	Lighting Controls	--	--	X	X	X	Program tracking requirements updated.
	LED Traffic Signals	--	--	X	X	X	TRM v7.0 origin.
HVAC	AC Tune-up	--	--	X	--	X	No revisions.
	Package and Split-System (AC and Heat Pumps)	--	--	X	X	X	Program tracking requirements updated.
	Chillers	--	--	X	X	X	Program tracking requirements updated.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
HVAC	Package Terminal Units and Room Air Conditioners (AC and Heat Pumps)	--	--	X	X	X	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.
	Variable Frequency Drives	--	X	X	--	--	Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
	Condenser Air Evaporative Pre-cooling	--	--	X	--	X	No revisions.
	Computer Room Air Conditioners	--	--	X	X	--	TRM v7.0 origin.
	High-volume Low-speed Fans	--	--	X	--	--	TRM v7.0 origin.
Building Envelope	ENERGY STAR® Roofs	X	--	X	X	--	Minor error updates to Savings Factor Table for greater than and less than symbols.
	Window Treatments	X	--	X	X	--	No revisions.
	Entrance and Exit Door Air Infiltration	--	X	X	--	--	Minor text revisions.
Food Service	ENERGY STAR® Combination Ovens Measure Overview	--	X	X	--	--	Program tracking requirements updated.
	ENERGY STAR® Electric Convection Ovens	--	X	X	--	--	Corrected convection oven definitions. Program tracking requirements updated.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
Food Service	ENERGY STAR® Commercial Dishwashers	--	X	X	--	--	Program tracking requirements updated.
	ENERGY STAR® Commercial Electric Hot Food Holding Cabinets	--	X	X	--	--	Program tracking requirements updated.
	ENERGY STAR® Kitchen Electric Fryers	--	X	X	--	--	Savings and efficiencies revised for EnergyStar® 3.0 specifications. Program tracking requirements updated.
	Pre-rinse Spray Valves	--	X	X	--	--	No revisions.
	ENERGY STAR® Electric Steam Cookers	--	X	X	--	--	Program tracking requirements updated.
	Demand Controlled Kitchen Ventilation	--	X	X	--	--	TRM v7.0 origin.
	Commercial Ice Makers	--	X	X	--	--	TRM v7.0 origin.
Refrigeration	Door Heater Controls	--	X	X	--	--	No revisions.
	ECM Evaporator Fan Motors	--	--	X	--	--	No revisions.
	Electronic Defrost Control	--	--	X	--	--	No revisions.
	Evaporator Fan Controls	--	--	X	--	--	No revisions.
	Night Covers for Open Refrigerated Cases	--	X	X	--	--	No revisions.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
Refrigeration	High-efficiency Solid and Glass Door Reach-in Cases	--	--	X	--	--	No revisions.
	Strip Curtains for Walk-in Cooler/ Freezer	--	X	--	--	--	No revisions.
	Zero Energy Glass Doors	--	X	X	--	--	No revisions.
	Door Gaskets for Walk-in and Reach-in Coolers and Freezers	--	X	X	--	--	No revisions.
Miscellaneous	Vending Machine Controllers	--	X	X	--	--	No revisions.
	Lodging Guest Room Occupancy Sensor Control	--	X	--	--	--	No revisions.
	Pump-Off Controller	--	X	X	--	--	No revisions.
	ENERGY STAR® Pool Pumps	--	X	X	--	--	Added ineligible products list. Program tracking requirements updated.
	Computer Power Management	--	X	X	--	--	TRM v7.0 origin.
	Premium Efficiency Motors	--	--	X	--	--	TRM v7.0 origin.
	Central DHW Controls	--	X	X	--	--	TRM v7.0 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 (RET) and new construction (NC)

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 (see Fixture Codes tab in the latest version of the *Lighting Survey Form*[2]*).* The *Lighting Survey Form (LSF)* is one example of a calculator that is used to determine energy and demand savings. Pre- and post-retrofit lighting inventories are

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

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

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 *Lighting Survey Form* calculator is available publicly 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. 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 L^{70} rated life (hours) verified through some combination of the following references: *DesignLights Consortium™ (DLC)*, *ENERGY STAR®*, DOE LED Lighting Facts,[4] or independent lab testing[5] (e.g., LM-79, LM-80, TM-21, ISTMT). Rated life for LED fixtures should be greater than or equal to 50,000 hours[6] and greater than or equal to 10,000 hours[7] for integrated-ballast LED lamps.

[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] As of December 16, 2016, LED, Lighting Facts no longer lists replacement lamps, but luminaires and retrofit kits continue to be listed.

[5] DLC test lab requirements: https://www.designlights.org/content/QPL/ProductSubmit/LabTesting.

[6] Equivalent to the L^{70} 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.

[7] Equivalent to the rated life requirement for all lamps as specified in the ENERGY STAR® lamps specification v2.1.

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:[8]

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

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https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

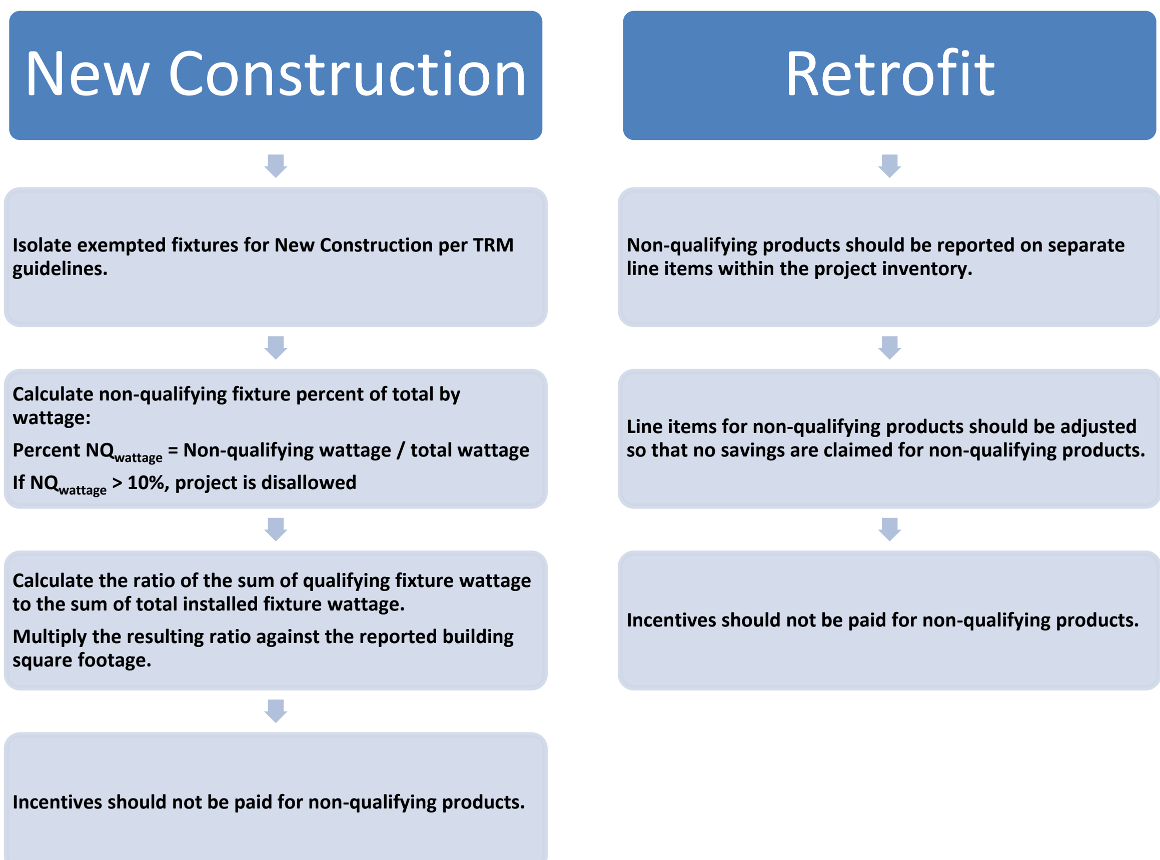
[8] IECC 2015, Section C405.4.1.

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

Non-qualifying LEDs. This section provides guidance to assess and calculate nonresidential lighting project savings that include non-qualifying LEDs.

Figure 1 summarizes the recommended protocol for lighting system projects with non-qualifying LEDs when square footage cannot be isolated. Additional explanations and criteria for use follow.

Figure 1: 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)
- If $NQ_{wattage}$ >10 %, project is declined and not allowed in program
- If $NQ_{wattage}$ <10 %, project is approved and continue to step 2 or step 3 as applicable to project type

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

- List all non-qualifying LEDs in the calculator but exclude from the lighting power density calculation.
- 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.

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. Fixture wattages used for the savings calculations are determined from the Table of Standard Fixture Wattages.

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 list, 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) 60/75W	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) 95/110W	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

T12 Length	Lamp Count	Revised Lamp Wattage	Revised System Wattage
	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."[9] 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[10]

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

Acceptable efficient fixture types are specified in the Table of Standard Fixture Wattages. In addition, some technologies such as LEDs must meet the additional requirements specified under Eligibility Criteria.

[9] "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.

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

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,[11] and high-performance T8 lamps that are on the T8 Replacement Lamp products list developed by the Consortium for Energy Efficiency (CEE) as published on its website.

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

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. The savings are calculated in separate methods for retrofit projects and new construction projects, and both are described below.

Retrofit[12,13]

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

Equation 1

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

Equation 2

New Construction

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

Equation 3

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[11] 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.

[12] 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.

[13] 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.

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

Equation 4

Where:

kW_{pre}	=	Total kW of existing measure(s) (Approved baseline fixture code wattage from deemed savings tool divided by 1000)
$kW_{installed}$	=	Total kW of retrofit measure(s) (Verified installed fixture code wattage from deemed savings tool divided by 1000) [14]

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 applications (see Table 12)

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

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

Existing construction: standard fixture wattage table. One example of a Table of Standard Fixture Wattages can be found in the Fixture Codes tab of the latest version of the *Lighting Survey*

[14] 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.

Form maintained on the Texas Energy Efficiency website.[15] 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 Frontier'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.

[15] Frontier Associates *Lighting Survey Form*, *Fixture Codes* tab: http://texasefficiency.com/index.php/regulatory-filings/lighting.

Table 4: New Construction LPDs for Interior Space Types by Building Type[16]

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[17]

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

[16] IECC 2015 Table C405.4.2(1) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.5.1.
[17] 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)[18]	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)[19]	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[20]	--	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 or 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	LED Lumen Range
250	< 15,000
400	15,000-24,999
1,000	25,000-49,999
2,000	≥ 50,000

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)[21] building types but have been modified for Texas. Refer to Volume 1, Appendix B for a description of the Texas peak demand

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[18] 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.

[19] Ibid.

[20] 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.

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

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.

Table 7: Commercial Lighting Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[22]
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

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

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[22]
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		
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
	2 Shift (70-120 hr/week)		
	3 Shift (>120 hr/week)		

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[22]
			13) Plastics and Rubber Products 14) Primary Metals 15) Printing and Related Support 16) Textile Mills 17) Transportation Equipment 18) Wood Products
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
Office	Large Office Medium Office Small 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
Parking	Parking Garage	Buildings used for parking applications.	No sub-categories collected.

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[22]
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[22]
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	6,209
Agriculture: Non-24 Hour Grow Lighting	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[23]	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

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

Building Type	Operating Hours
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[24]	767
Outdoor: Billboard[25]	3,470
Outdoor: Dusk-to-Dawn[26]	3,996
Outdoor: Less than Dusk-to-Dawn[27]	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

[24] "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.
[25] Ibid.
[26] This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule.
[27] This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

Table 9: Summer Peak Coincidence Factors by Building Type

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[28]	0.42	0.39	0.90	0.90	0.57
Education: K-12 without Summer Session	0.39	0.39	0.90	0.87	0.40
Food Sales: Non-24 Hour Supermarket or Convenience Store	0.90	0.90	0.90	0.90	0.90
Food 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

[28] 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
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
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

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[29]	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than Dusk-to-Dawn[30]	0.67	0.71	0.61	0.75	1.00
Parking Garage	1.00	1.00	1.00	1.00	1.00

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

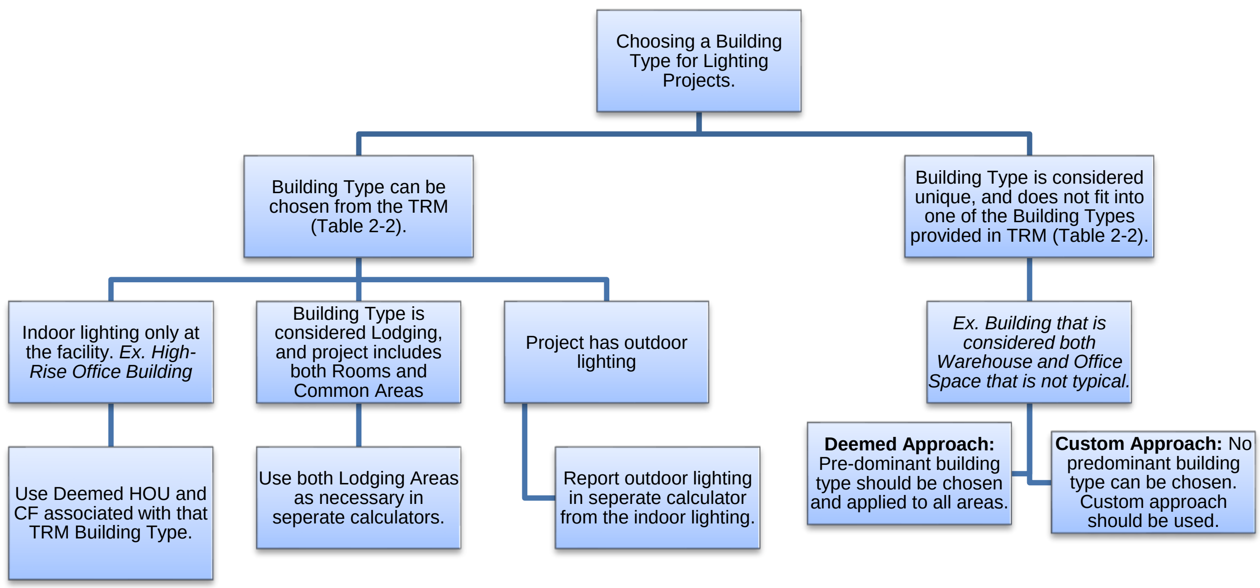
Lighting Calculator Building Type

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.[31]

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. 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.[32] 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 of these building types for a single project.

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

[31] *Annual Statewide Portfolio Report for Program Year 2013 – Volume I*. Prepared for the Public Utility Commission of Texas. October 6, 2014.
[32] More information on how these values were created can be found in PUCT Docket #39146.

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. 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[33]

Space Conditioning Type	Energy Interactive HVAC Factor	Demand Interactive HVAC Factor
Refrigerated Air	1.05	1.10
Evaporative Cooling[34]	1.02	1.04
Med. 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

Midstream Lighting

This section provides guidance on calculating and allocating savings at the sector-level for midstream lighting programs. The assumptions below are to be used for midstream lighting programs' claimed savings starting with PY2020.

An increased number of utilities are offering or planning to offer 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.

Midstream Program Assumptions

For 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[35] and 2014 MECS[36] as well as lamp density and lamp type distribution survey data from the DOE 2015 U.S. Lighting Market Characterization (LMC)[37].

[33] PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).
[34] 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.
[35] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[36] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[37] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

Table 12: Midstream Assumptions by Lamp Type[38]

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
Pin-based Lamp	3,744	0.67	0.67	0.72	0.72	0.68	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	3,996	0.67	0.71	0.61	0.75	1.00	1.00

Additionally, baseline wattage for directional/reflector lamps should be calculated[39] as follows:

$$W_{base} = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1{,}479(BA) - 12.02(D \times BA) + 14.69(BA^2) - 16{,}720 \times \ln(CBCP)}$$

Equation 5

Where:

D	=	*Bulb diameter (e.g., 16 for PAR16, MR16, or MRX16)*
BA	=	*Beam angle (from ENERGY STAR® certification[40])*
$CBCP$	=	*Center beam candle power (from ENERGY STAR® certification[41])*

Note: Round DOWN to nearest wattage from the table below:

[38] 2012 CBECS and 2014 MECS.
[39] ENERGY STAR® Lamp Center Beam Intensity Benchmark Tool. Revised September 2016. https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd.
[40] ENERGY STAR® Light Bulbs Product Finder: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[41] Ibid.

Table 13: Permitted Baseline Wattage by Reflector Lamp Type and Diameter[42,43]

Reflector Type	D	Permitted Wattage
MR16	16	20, 35, 40, 45, 50, 60, 75
MRX16	16	50
PAR16	16	40, 45, 50, 60, 75
PAR20	20	50, 75
PAR30S	30	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250
PAR30L	30	20, 30, 35, 37, 40, 42, 45, 50, 65, 75
PAR38	38	20, 35, 40, 45, 50, 60, 75

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) values are defined for specific lighting types by the Texas petition process, and are maintained on the Texas Energy Efficiency website and are listed below:[44]

- Halogen Lamps: 1.5 years
- High-intensity Discharge Lamps: 15.5 years
- Integrated-ballast CCFL Lamps: 4.5 years
- Integrated-ballast CFL Lamps: 2.5 years
- Integral LED Lamps: 9 years[45]
- LED Fixtures: 15 years
- LED Corn Cob Lamps: 15 years

[42] ENERGY STAR® Lamp Center Beam Intensity Benchmark Tool. Revised September 2016. https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd.
[43] ENERGY STAR® Light Bulbs Qualified Product Listing. Accessed 7/23/2019. https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[44] PUCT Docket 36779.
[45] PUCT Docket 38023.

- LED Tubes: 15 years
- Modular CFL and CCFL Fixtures: 16 years
- T8 and T5 Linear Fluorescents: 15.5 years.

Program Tracking Data and Evaluation Requirements

The following 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
- 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 or exterior space square footage
- **For new construction only:** verify if SECO compliance certification forms were filed[46]
- 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
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage
- Post-retrofit lamp specifications sheets: Post retrofit lamp product qualification information from DLC, ENERGY STAR®, DOE LED Lighting Facts, or independent lab testing
- Post-retrofit ballast type
- Post-retrofit lighting controls

[46] 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 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 Table 14).
- **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 midstream only:** Qualified product list

Lighting Measure Groups to be Used for Measure Summary Reports

The lighting measure groups below 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. These lighting groups are consistent with the EULs defined for lighting technologies and will ensure that the correct, approved EUL can be associated with reported lighting savings.

Table 14: Lighting Measure Groups to be Used for Reporting Savings[47]

TRM Standard Measure Groups
T8/T5 Linear Fluorescent
Integrated-Ballast CCFL lamps
Integrated-Ballast CFL lamps
Modular CFL and CCFL fixtures
Light Emitting Diode (LED)
LED Corn Cob Lamps
LED Tubes
Integral LED lamp
High-intensity Discharge (HID)
Halogen

[47] A “Lighting Controls” lighting measure group is also used in the tracking data summary, but it is only used to report savings for *rebated, eligible* lighting controls. The savings for lighting systems with non-eligible lighting controls should use the relevant lamp type lighting measure group.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Describes Effective Useful Life (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[48])
- DOE's LED Lighting Facts showcases LED products for general illumination from manufacturers who commit to testing products and reporting performance results. https://energy.gov/eere/ssl/solid-state-lighting and http://www.lightingfacts.com/. Accessed 08/21/2017.
- ENERGY STAR® requirements for Commercial LED Lighting. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG. Accessed 08/21/2017.
- Design Lights Consortium. www.designlights.org. Accessed 08/21/2017.
- Consortium for Energy Efficiency. Commercial Lighting Qualifying Products List (for 4-foot lamps). http://library.cee1.org/content/Commercial-lighting-qualifying-products-lists Accessed 02/09/2016.
- National Electrical Manufacturers Association. NEMA Premium Electronic Ballast Program. https://www.nema.org/Technical/Pages/NEMA-Premium.aspx Accessed 08/21/2017.
- U.S. Lighting Market Characterization report, September 2002, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lmc_vol1_final.pdf. Accessed 09/19/2013.
- 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. Accessed 09/19/2013.
- COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules updated 07/25/2016.

[48] 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 15: 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.

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 (RET), new construction (NC)

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 16.

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).

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 6

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

Equation 7

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 17*
PAF	=	*Lighting control Power Adjustment Factor, see Table 17*
CF	=	*Coincidence factor by building type, see Table 9 or Table 10*
HVACenergy	=	*Energy Interactive HVAC factor by building type, see Table 11*
HVACdemand	=	*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 17. 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 16: 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
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 17: Lighting Controls Energy and Power Adjustment Factors[49]

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[50]	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[51]	0.47	0.47

[49] 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.

Deemed Energy and Demand Savings Tables

This section is not applicable.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for lighting controls is provided by the 2007 GDS Associates Report.[52]

- Occupancy Sensor: 10 years
- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 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 NC
- Conditioned Space Type: cooling equipment type, refrigerated space temperature range, heating fuel type (specified per control)
- Location of Controlled Lighting: interior or exterior (specified per control)

[50] 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.

[51] 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/.

[52] 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.

- Baseline Lighting Control Type Code
- Installed Lighting Control Type Code[53]
- Lighting Control Mount Type: wall, ceiling, integrated fixture, etc.
- Lighting Control Specification Sheets
- Controlled Fixture Configuration
- 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 Effective Useful Life.

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.[54])

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[53] 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.

[54] 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 18: 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 v2.1 update. No revisions.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Equation 6 and Equation 7 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.

2.1.3 Light Emitting Diode (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 (RET)

Program Delivery Type(s): 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 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[55], 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[56] 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

[55] 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.
[56] 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.

be compliant with the current federal standard except for yellow "ball" or "arrow" fixtures where there is no federal standard.

Table 19: Federal Standard Maximum Wattages[57] and Nominal Wattages[58]

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 8

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

Equation 9

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 20*

CF = *Coincidence factor from Table 20*

57 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.

58 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 20: Incandescent and LED Traffic Signal Savings Assumptions[59]

Fixture Type	Incand. Wattage	LED Wattage	AOH	CF[60]
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

[59] 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.
[60] 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 21: 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, Appendix B: Peak Demand Reduction Documentation 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 22: Incandescent and LED Traffic Signal EULs by Fixture Type[61]

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	

[61] 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 following 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
- **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

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 23: LED Traffic Signals Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

2.2 NONRESIDENTIAL: HVAC

2.2.1 Air Conditioner or Heat Pump Tune-ups Measure Overview

TRM Measure ID: NR-HV-TU

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 32 through Table 38

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 and heat pumps of any configuration as long as everything on the checklist below can be completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions in the understanding that such measures restore operating efficiencies, on average, 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 (i.e., 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[62]

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

[62] Based on ENERGY STAR® HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

- 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
- 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 10

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

Equation 11

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 24.*
$HSPF_{pre}$	=	*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 24.*

Table 24: Default EER and HSPF per Size Category[63]

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

[63] 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 converted from COP x 3.412.

[64] Code specified HSPF from federal standard effective January 23, 2006, through January 1, 2015.

[65] 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.[66]

Heating energy savings are only applicable to heat pumps.

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

Equation 12

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

Equation 13

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

Equation 14

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 24 [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 24 [Btuh/W]*
$HSPF_{post}$	=	*Heating efficiency of the equipment after the tune-up [Btuh/W]*

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

Equation 15

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

Equation 16

Where:

$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone [hours]. See Table 34 through Table 38 in Section 2.2.2.*

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

Demand Savings Algorithms

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

Where:

DF_C	=	*Cooling Demand factor. See Table 34 through Table 38 in Section 2.2.2.*
DF_H	=	*Heating Demand factor. See Table 34 through Table 38 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is 5 years.[67]

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is 3 years ,[68] and the estimated useful life of refrigerant charge adjustment is 10 years.[69] The other parts of the tune-up checklist

[67] 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.

[68] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx.

[69] Ibid.

are not listed in DEER, therefore 5 years, as referenced by the Measure Life Report, is used as the best representation of the entire tune-up.

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

This section is not applicable.

Document Revision History

Table 25: 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.

2.2.2 Split System/Single 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 32 through Table 38

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout (ROB), early retirement (ER), and new construction (NC)

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)
- 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 HVAC Chillers measure.

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 climate zone is determined from the county-to-climate-zone mapping table.

- The building falls into one of the categories listed in Table 34 through Table 38. Building type descriptions and examples are provided in Table 32 and Table 33.
- 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.
- 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 related to efficiency and system capacity for early retirement and replace-on-burnout/new construction are as follows:

Early Retirement

Early retirement 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 26 through Table 30 according to the capacity, system type, and age (based on year of manufacture) of the replaced system.[70] When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in Table 26 through Table 30 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 an age of 17 years.[71] 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.

Regarding the ER baseline efficiency tables, PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via ER programs and included a category for 1990-1991. 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 1990-1991. This practice is reflected in the ER baseline efficiency tables, by showing the Year Installed as "≤ 1991" rather than 1990–1991.

[70] 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.

[71] 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 26 through Table 30 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. 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 26: ER Baseline Full-load Efficiency for ACs

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER][72]	Package System < 5.4 tons [EER][73]	All Systems 5.4 to < 11.3 tons [EER][74]	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]
≤ 1991	9.2	9.0	8.9	8.0	8.0	7.8
1992–2001	9.2	9.0	8.9	8.3	8.3	8.0
2002–2005	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

[72] 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

[73] Ibid.

[74] 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.

Table 27: ER Baseline Part-load Efficiency for ACs[75]

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][76]	All Systems 11.3 to < 20 tons [IEER]	All Systems 20 to < 63.3 tons [IEER]	All Systems ≥ 63.3 tons [IEER][55]
≤ 1991	10.0	9.7	9.1	8.2	8.1	7.9
1992–2001	10.0	9.7	9.1	8.5	8.4	8.1
2002–2005	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

Table 28: ER Baseline Full-load Cooling Efficiency for HPs

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][58]	All Systems 20 to < 63.3 tons [EER][58]	All Systems ≥ 63.3 tons [EER][58]
≤ 1991	9.2	9.0	8.9	8.0	8.0	7.8
1992–2001	9.2	9.0	8.9	8.3	8.3	8.5
2002–2005	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

75 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.

76 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.

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 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.

Table 29: ER Baseline Part-load Cooling Efficiency for HPs[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][60]	All Systems 20 to < 63.3 tons [IEER][60]	All Systems ≥ 63.3 tons [IEER][60]
≤ 1991	10.0	9.7	9.1	8.2	8.1	7.9
1992–2001	10.0	9.7	9.1	8.5	8.4	8.6
2002–2005	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

Table 30: 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]
≤ 1998	6.8	6.6	3.0	3.0
1999–2000	6.8	6.6	3.0	2.9
2001–2005	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

[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 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.

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

Table 31: Baseline Efficiency Levels for ROB and NC Air Conditioners and Heat Pumps[82]

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source[83]
Air Conditioner	< 5.4	All	11.2 EER[84] 13.0 SEER (split) 11.8 EER[85] 14.0 SEER (packaged)	DOE Standards/ IECC 2015
	5.4 to < 11.3	None or Electric Resistance	11.2 EER 12.8 IEER	
		All Other	11.0 EER 12.6 IEER	
	11.3 to < 20	None or Electric Resistance	11.0 EER 12.4 IEER	
		All Other	10.8 EER 12.2 IEER	
	20 to < 63.3	None or Electric Resistance	10.0 EER 11.6 IEER	
		All Other	9.8 EER 11.4 IEER	
	≥ 63.3	None or Electric Resistance	9.7 EER 11.2 IEER	IECC 2015
		All Other	9.5 EER 11.0 IEER	

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

83 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.

84 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.

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

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source[83]
Heat Pump (cooling)[86]	< 5.4	Heat Pump	11.8 EER[87] 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)[88]	< 5.4	Heat Pump	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

Package and split-systems must exceed the minimum efficiencies specified in Table 31.

For reference, both ENERGY STAR® and the Consortium for Energy Efficiency (CEE) offer suggested guidelines for high-efficiency equipment. 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

The high-efficiency retrofits must meet the following criteria:[89]

- 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

[86] 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”.
[87] There is no code specified EER for this size category. The code specified SEER value 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.
[88] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.
[89] From PUCT Docket #41070.

for the total combination of systems are within ± 20%. 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

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

Equation 17

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

Equation 18

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

Equation 19

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

Equation 20

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

Equation 21

Where:

$Cap_{C/H,pre}$ = *Rated equipment cooling/heating capacity of the existing 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 31) [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 31) [COP]*

Note: Use EER for kW savings calculations and SEER/IEER and COP for kWh savings calculations. The COP expressed for units ≥ 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

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

Equation 22

DF = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 34 through Table 38)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 34 through Table 38)*

Early Retirement Savings

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

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 32 and Table 33. These building types are derived from the EIA CBECS study.[90]

The DF and EFLH values for packaged and split AC and HP units are presented in Table 34 through Table 38. 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.

[90] 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.*

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

Table 32: Commercial HVAC Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[91]
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

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

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[91]
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[91]
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.

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[91]
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 33: Commercial HVAC Floor Area and Floor Assumptions by Building Type[92]

Building Type	Principal Building Activity	Average Floor Area (ft^2)	Average # of Floors
Data Center	Data Center	Not specified	Not specified
Education	College/University	Not specified	Not specified
	Primary School	73,960	1

[92] 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, last accessed 10/20/2015.

Building Type	Principal Building Activity	Average Floor Area (ft²)	Average # of Floors
	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
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 34: DF and EFLH Values for Amarillo (Climate Zone 1)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump[93]			
		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	--	--

[93] 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[93]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
	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
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 35: DF and EFLH Values for Dallas (Climate Zone 2)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump[94]			
		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

[94] 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[94]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
	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
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 36: DF and EFLH Values for Houston (Climate Zone 3)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump[95]			
		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	--	--
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

[95] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Table 37: DF and EFLH Values for Corpus Christi (Climate Zone 4)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump[96]			
		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
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

[96] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Table 38: DF and EFLH Values for El Paso (Climate Zone 5)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump[97]			
		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	--	--
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

[97] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the “Other” building type for heating energy/demand savings.

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation 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 split and packaged air conditioners and heat pumps is 15 years.[98]

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. As previously noted, for ER units of unknown age, a default value of 17 years should be used. 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.

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

Table 39: Remaining Useful Life Early Retirement Systems[99]

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[100]	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
- Climate zone
- Baseline equipment type
- Baseline equipment rated cooling and heating capacity
- Baseline number of units
- **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)

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

[100] 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.

- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed number of units
- Installed cooling and heating efficiency ratings
- Installed make and model
- Installed unit AHRI certificate
- **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 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 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. 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://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

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 early retirement 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 early retirement 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.
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 early retirement 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.

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 (ROB), early retirement (ER), and new construction (NC)

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:[101]

- 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 climate zone is determined from the county-to-climate-zone mapping table.[102]
- The building falls into one of the categories listed in Table 54 through Table 58. Building type descriptions and examples are provided in Table 32 and Table 33.
- 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.

Baseline Condition

Early Retirement

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

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is

[101] 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

[102] The TRM climate zone/regions and county-level assignments were created and are currently maintained by Frontier for the Electric Utilities Marketing Managers of Texas (EUMMOT).

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 of manufacture) of the replaced system.[103] 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 21 years for non-centrifugal chillers and 26 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.

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,[104] coinciding with the IECC 2009 and IECC 2015 code increases.

Code-specified efficiencies in effect prior to 2002 were given in COP and have been converted to EER and kW/ton in the tables below using EER = COP x 3.412 and kW/ton = 3.516 ÷ COP. Values in the "≤ 2001" row of the following tables have been converted and are expressed in italics.

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.

<u>ER Baseline: Air-cooled Chillers</u>

Table 41: ER Baseline Full-load Efficiency of All Path A Air-cooled Chillers[105]

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

[103] 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.
[104] IECC 2015 not enforced in Texas until program year 2018.
[105] 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[106]

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

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

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

[106] Ibid.

ER Baseline: Centrifugal Water-cooled Chillers

Table 45: ER Baseline Full-load Efficiency of Centrifugal Path A Water-cooled Chillers[107]

Year Installed (Replaced System)	< 75 tons [kW/ton]	≥ 75 to 150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 400 tons [kW/ton]	≥ 400 to < 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	*0.925*	*0.925*	*0.837*	*0.748*	*0.748*	*0.748*
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.634	0.634	0.634	0.576	0.576	0.570
≥ 2018	0.610	0.610	0.610	0.560	0.560	0.560

Table 46: ER Baseline Full-load Efficiency of Centrifugal Path B Water-cooled Chillers[108]

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

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

107 Ibid.
108 Ibid.

Table 48: ER Baseline Part-load Efficiency (IPLV) of Centrifugal Path B Water-cooled Chillers

Year Installed (Replaced System)	< 75 tons [kW/ton]	≥ 75 to 150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 400 tons [kW/ton]	≥ 400 to < 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*	*0.733*
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.450	0.450	0.450	0.400	0.400	0.400
≥ 2018	0.440	0.440	0.400	0.390	0.380	0.380

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

Table 49: ER Baseline Full-load Efficiency of Screw/Scroll/Recip. Path A Water-cooled Chillers[109]

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[110]

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

[109] Ibid.
[110] Ibid.

Table 51: ER Baseline Part-load Efficiency (IPLV) of Screw/Scroll/Recip. Path A Water-cooled Chillers

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

Table 52: ER Baseline Part-load Efficiency (IPLV) of Screw/Scroll/Recip. Path B Water-cooled Chillers

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.[111] 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.

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

Table 53: Baseline Efficiencies for ROB and NC Air-cooled and Water-cooled Chillers[112]

System Type [Efficiency Units]		Efficiency Type	Capacity [Tons]	Path A		Path B	
				Full-load	IPLV	Full-load	IPLV
Air-cooled Chiller		EER	< 150	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
			≥ 150	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water-cooled Chiller	Screw/ Scroll/ Recip.	kW/ton	< 75	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
			≥ 75 and < 150	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
			≥ 150 and < 300	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
			≥ 300 and < 600	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
			≥ 600	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
	Centrifugal		< 150	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
			≥ 150 and < 300	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.400
			≥ 300 and < 400	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
			≥ 400	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380

High-efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 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:[113]

- 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%. 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.

[112] IECC 2015 Table C403.2.3(7).
[113] From PUCT Docket #41070.

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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 23

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

Equation 24

Where:

$Cap_{C,pre}$ = *Rated equipment cooling capacity of the existing 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 25. [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 25. [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 25

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[114]

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 26

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

Equation 27

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 28

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

Equation 29

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.

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

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

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 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[115]			
		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
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

[115] 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.

Table 55: DF and EFLH for Dallas (Climate Zone 2)

Building Type	Principal Building Activity	Chiller[116]			
		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[117]			
		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
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

[116] Ibid.
[117] Ibid.

Table 57: DF and EFLH for Corpus Christi (Climate Zone 4)

Building Type	Principal Building Activity	Chiller[118]			
		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[119]			
		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
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

[118] Ibid.
[119] Ibid.

Measure Life and Lifetime Savings

Effective Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years[120]
- Centrifugal chillers: 25 years.[121]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 59. As previously noted, for ER units of unknown age, a default value of 21 years for non-centrifugal chillers and 26 years for centrifugal chillers should be used. 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 59: Remaining Useful Life of Early Retirement Systems[122]

Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)	Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)
1	18.7	23.9	17	5.0	8.7
2	17.7	22.9	18	4.5	8.1
3	16.7	21.9	19	4.0	7.5
4	15.7	20.9	20	3.6	7.1
5	14.7	19.9	21	3.0	6.6
6	13.7	18.9	22	2.0	6.3
7	12.7	17.9	23	1.0	5.9
8	11.8	16.9	24[123]	0.0	5.6

120 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.

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

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

123 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.

Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)
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

Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)
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[124]	N/A	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, conversion
- Building type
- Climate zone
- Baseline equipment type (compressor/condenser type)
- Baseline equipment rated capacity
- Baseline number of units
- **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 equipment type (compressor/condenser type)
- Installed path (Path A or Path B)
- Installed equipment rated capacity

[124] Ibid.

- Installed number of units
- Installed efficiency rating
- Installed make and model
- Installed unit AHRI certificate
- **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 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 60: 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.

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 64 through Table 68

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout (ROB), early retirement (ER), and new construction (NC)

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 climate zone is determined from the county-to-climate-zone mapping table [125]
- 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.

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 of manufacture) of the replaced system.[126] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 61, 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 17 years.[127] 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.

[125] The TRM climate zone/regions and county-level assignments were created and are currently maintained by Frontier for the Electric Utilities Marketing Managers of Texas (EUMMOT).

[126] 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.

[127] 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.

Table 61: ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units[128]

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	$12.5 - (0.213 \times \text{Cap}/1000)$		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	--
	7,000-15,000	$12.3 - (0.213 \times \text{Cap}/1000)$	$3.2 - (0.026 \times \text{Cap}/1000)$	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 62 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 62: Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units[129,130]

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*	--

[128] 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.
[129] IECC 2015 Table C403.2.3(3).
[130] 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 63 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b).

Table 63: Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units[131]

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

[131] 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 62 and Table 63.

The high-efficiency retrofits must also 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%. 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-ctandard 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

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

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

Where:

$Cap_{C/H,pre}$ = *Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [BTUH]; 1 ton = 12,000 Btuh*

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

$Cap_{C/H,post}$ = *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 61 through Table 63)*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 61 and Table 62)*[133]

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h])—(Must exceed minimum federal standards found in Table 62 and Table 63)* [134]

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 62)*

DF = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 34 through Table 38)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours], see Table 64 through Table 68.*

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.

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Deemed Energy and Demand Savings Tables

Table 64 through Table 68 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.

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

Table 64: 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

Table 65: 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
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

Table 66: 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

Table 67: 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

Table 68: 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
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

Measure Life and Lifetime Savings

Effective Useful Life (EUL)

The EUL of PTAC/PTHP units is 15 years, as specified in DEER 2014. The EUL of RAC units is 11 years based on current DOE Final Rule standards for residential room air conditioners.[135]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 69.

As previously noted, for ER units of unknown age, a default value of 17 years should be used. 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.

[135] The updates were made in Federal Register, 76 FR 22582-22584, but the reference to the EUL is found here: http://www.regulations.gov/contentStreamer?objectId=0900006480c34c55&disposition=attachment&contentType=pdf. Accessed 04/02/2014. This value is listed as 10.5 years and has been rounded up to 11.

Table 69: Remaining Useful Life of ER PTAC/PTHP Systems[136]

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[137]	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.

- Equipment type: PTAC, PTHP, or RAC
- Equipment configuration category: Standard/non-standard or room AC
- Decision/action type: ROB, NC, or ER
- Building type
- Climate zone
- Baseline equipment rated cooling and heating capacities
- Baseline number of units
- Baseline cooling and heating efficiency rating
- Baseline make and model
- **For ER Only**: Baseline age and method of determination (e.g., nameplate, blueprints, Customer reported, not available)

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

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

- **For ER only**: Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Installed equipment type
- Installed equipment rated capacity
- Installed number of units
- Installed efficiency rating
- Installed make and model
- Installed unit AHRI certificate
- **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

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. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45

- Code of Federal Regulations. Title 10. Part 430—Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
- 2015 International Energy Conservation Code. Table C403.2.3(3).

Document Revision History

Table 70: 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).
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.

2.2.5 HVAC Variable Frequency Drive (VFD) Measure Overview

TRM Measure ID: NR-HV-VF

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 74 through Table 80

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET)

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 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 90.1-2004, 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 34

Where:

$t_{db,i}$	=	*The hourly dry bulb temperature (DBT) using TMY3 data*
m	=	*The slope of the relationship between DBT and CFM, see Table 71*
b	=	*The intercept of the relationship between DSBT and CFM, see Table 71*

The minimum flow rate is set to 60% cfm based on common design practice.[138] 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.[139]

[138] 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%.

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

Table 71: AHU Supply Fan VFD %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 35

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 72*

b = *The intercept of the relationship between DSBT and GPM, see Table 72*

The minimum flow rate is set to 10% GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[140] 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.[141]

[140] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.
[141] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 72: Chilled Water Pump VFD %CFM 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 36

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 73*

b = *The intercept of the relationship between DSBT and GPM, see Table 73*

The minimum flow rate is set to 10% GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[142] 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.[143]

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

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

Table 73: Hot Water Pump VFD %CFM 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[144] for the applicable baseline and the new VFD technology:

Baseline Technologies

For AHU supply fan: [145]

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

Equation 37

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

Equation 38

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

Equation 39

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.

144 https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225. Please note, the CFM^2 coefficients in Equation 36 and Equation 37 have the wrong sign in the reference document.

145 Ibid.

For chilled and hot water pumps[146]:

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

Equation 40

VFD Technology

For AHU supply fan:

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

Equation 41

For chilled and hot water pumps[147]:

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

Equation 42

Step 3 - Calculate kW_{full} using the hp from the motor nameplate, LF (75%), and the applicable motor efficiency from ASHRAE 2004, Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B 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 43

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

Equation 44

Where:

$\%power_i$	=	*Percentage of full load 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)*[148]
kW_{full}	=	*Fan motor power demand operating at the fan design 100% CFM or pump design 100% 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% at the fan or pump design 100% per DEER*

[146] 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.

[147] 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).

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

		2005
η	=	*Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013*
0.746	=	*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 45

Where:

schedule	=	*1 when building is occupied, 0.2 when building is unoccupied, see Table 74*

Table 74: Yearly Motor Operation Hours by Building Type[149]

Building Type	Weekday Schedule	Weekend Schedule	Annual Building Occupied Hours	Annual Motor Operation Hours[150]
Hospitals and Healthcare	24 hr	24 hr	8,760	8,760
Office—Large	8am–8pm	8am–10am	3,340	4,424
Office—Small	8am–6pm	8am–10am	2,818	4,006
Education—K-12	7am–5pm	8am–12pm	3,026	4,173
Education—College and University	8am–8pm	8am–12pm	3,548	4,590
Retail	9am–10pm	9am–10pm	4,745	5,548
Restaurants—Fast Food	6am–11pm	6am–11pm	6,205	6,716
Restaurants—Sit Down	11am–11pm	11am–11pm	4,380	5,256

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 46

149 The building hours of operation were noted in PUCT Docket 40668 to have been referenced from Commercial Building Energy Consumption Survey (CBECS) 2003. The specific analysis/report could not be confirmed.

150 Motor operation hours are building occupied hours plus 20 percent of unoccupied hours.

Where:

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

Total Peak Demand Saved Calculation, including interactive effects (this applies only to AHU supply fans):

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

Equation 47

Where:

$Cooling_{EER}$ = *Air conditioner full-load cooling efficiency, assumed at 11.2, based on ASHRAE Standard 90.1–2004 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 48

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 49

Deemed Energy and Demand Savings Tables

Table 75: 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 and Healthcare	1,160	1,101	1,071	1,046	1,121
Office—Large	569	536	515	499	545
Office—Small	514	484	464	449	493
Education—K-12	539	508	484	469	517
Education—College and University	590	555	533	517	565
Retail	710	668	645	629	680
Restaurants—Fast Food	872	823	796	776	838
Restaurants—Sit Down	674	635	617	603	646
Summer kW Savings (kW per Motor HP)					
All Building Types	0.041	0.032	0.038	0.061	0.041

Table 76: 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 and Healthcare	1,824	1,672	1,597	1,533	1,722
Office—Large	881	801	754	716	822
Office—Small	797	724	678	643	743
Education—K-12	837	761	709	673	782
Education—College and University	914	830	780	741	852
Retail	1,098	998	944	904	1,024
Restaurants- Fast Food	1,358	1,238	1,172	1,122	1,272
Restaurants—Sit Down	1,044	949	906	870	974
Summer kW Savings (kW per Motor HP)					
All Building Types	0.047	0.037	0.047	0.067	0.047

Table 77: 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 and Healthcare	388	345	324	307	359
Office—Large	185	163	151	141	169
Office—Small	167	148	135	126	153
Education—K-12	176	156	142	132	161
Education—College and University	192	169	156	145	175
Retail	230	203	189	178	210
Restaurants- Fast Food	286	253	236	222	262
Restaurants—Sit Down	219	194	182	172	200
Summer kW Savings (kW per Motor HP)					
All Building Types	0.009	0.009	0.01	0.011	0.01

Table 78: 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 and Healthcare	3,300	3,035	2,904	2,792	3,124
Office—Large	1,595	1,453	1,368	1,299	1,490
Office—Small	1,442	1,313	1,228	1,165	1,348
Education—K-12	1,514	1,380	1,285	1,219	1,418
Education—College and University	1,654	1,505	1,414	1,344	1,545
Retail	1,988	1,809	1,712	1,640	1,857
Restaurants—Fast Food	2,458	2,245	2,128	2,040	2,307
Restaurants—Sit Down	1,889	1,720	1,644	1,579	1,765
Summer kW Savings (kW per Motor HP)					
All Building Types	0.049	0.037	0.061	0.086	0.051

Table 79: Chilled Water Pump Savings per Motor HP

Building Type	Climate Zone				
	1	2	3	4	5
Energy Savings (kWh per Motor HP)					
Hospitals and Healthcare	777	1,154	1,337	1,479	1,049
Office—Large	455	621	699	758	590
Office—Small	411	560	633	683	533
Education—K-12	422	577	655	710	549
Education—College and University	475	644	727	788	613
Retail	576	780	888	958	738
Restaurants—Fast Food	662	924	1,057	1,152	868
Restaurants—Sit Down	540	736	837	908	690
Summer kW Savings (kW per Motor HP)					
All Building Types	0.046	0.029	0.035	0.087	0.049

Table 80: Hot Water Pump Savings per Motor HP

Building Type	Climate Zone				
	1	2	3	4	5
Energy Savings (kWh per Motor HP)					
Hospitals and Healthcare	1,304	912	723	597	1,044
Office—Large	600	417	323	257	468
Office—Small	541	378	286	228	421
Education—K-12	572	399	301	239	448
Education—College and University	620	431	332	264	487
Retail	746	510	397	321	593
Restaurants—Fast Food	940	649	510	413	745
Restaurants—Sit Down	710	487	386	314	566
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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this VFD measure is 15 years per both the PUCT-approved Texas EUL filing (Docket No. 36779) and DEER 2014 (EUL ID—HVAC-VSD-fan).

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 90.1-2004: Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors.
- 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). Accessed at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.
- 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. Accessed 12/12/2014.

Document Revision History

Table 81: 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 41.
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.

2.2.6 Condenser Air Evaporative Pre-cooling Measure Overview

TRM Measure ID: NR-HV-EP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 83 through Table 87

Fuels Affected: Electricity

Decision/Action Type: Retrofit and new construction (NC)

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 control 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 82 contains values that can be used as a reference for evaluating evaporative effectiveness.

Table 82: Average Weather during Peak Conditions[151]

Weather 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

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

Equation 50

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

Equation 51

[151] Extracted from weather data from building models that were used to create summer peak period value used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Where:

Cap_C	=	*Rated equipment cooling capacity of the existing equipment at AHRI standard conditions [Btuh or ton]*
η_C	=	*Cooling efficiency of existing equipment [Btu/W-h, or kW/ton]*
$EFLH_{reduction}$	=	*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 83 through Table 87.*
DRF	=	*Demand reduction factor. The average peak hour energy reduction divided by the rated full loaded demand. See Table 83 through Table 87.*

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 rather than kW/ton, a conversion to kW/ton needs to be performed using the following conversion:

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

Equation 52

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 32. These building types are derived from the EIA CBECS study.[152]

The DRF and $EFLH_{reduction}$ values for packaged and split AC are presented in Table 83 through Table 87. 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.

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

Deemed savings are estimated using building simulation models, which estimate the hourly impacts of installing an evaporative pre-cooling system (i.e., modeling the difference between base and change case). The base models are the same models used to derive values for the other commercial HVAC sections of the TRM. Adjustments are made for the evaporative pre-cooling measure by updating all existing HVAC equipment to operate with evaporative pre-cooling when the outside temperature is above 70°F.

Table 83: 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
Service	Service	0.21	104	-	-
Warehouse	Warehouse	0.12	34	-	-
Other	Other	0.08	34	0.10	45

Table 84: 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 85: 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 86: 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 87: 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL for Evaporative Pre-cooling System is 15 years. This matches the minimum EUL of the HVAC equipment where the system is to be installed.

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 make and model
- Installed number of units
- Installed evaporative pre-cooling system make and model
- Installed evaporative pre-cooling system evaporative effectiveness
- **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.

Document Revision History

Table 88: 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.

2.2.7 Computer Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-CR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 90 and Table 91

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout (ROB), early retirement (ER), and new construction (NC)

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 climate zone is determined from the county-to-climate-zone mapping table
- 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.

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 89. 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 89: Baseline Efficiency Levels for ROB and NC CRACs[153]

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% propylene glycol)	< 65,000	2.50 / 2.39	
	≥ 65,000 and < 240,000	2.15 / 2.04	
	≥ 240,000	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	< 65,000	2.45 / 2.34	
	≥ 65,000 and < 240,000	2.10 / 1.99	
	≥ 240,000	2.05 / 1.94	

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

High-efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 31.

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 53

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

Equation 54

Where:

$Cap_{C,pre}$ = *Rated equipment cooling capacity of the existing 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*

$\eta_{baseline,C}$ = *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 31) [SCOP]*

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

DF = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 34)*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, building* *type, and equipment type [hours] (Table 34)*

<u>Early Retirement Savings</u>

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. A description of the building types that are eligible to use this measure is presented in Table 90. These building types are derived from the EIA CBECS study.[154]

The DF and EFLH values for CRAC units are presented in Table 91. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

Table 90: Commercial CRAC Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[155]
Data Center	Data Center	Buildings used to house computer systems and associated components.	1) Data Center

Table 91: 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

[154] 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.*

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

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation 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.[156]

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 equipment type
- Baseline equipment rated cooling and heating capacity
- Baseline number of units
- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed number of units
- Installed cooling and heating efficiency ratings
- Installed make and model

[156] 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.

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. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/77.

Document Revision History

Table 92: Computer Room Air Conditioners Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

2.2.8 High-volume Low-speed (HVLS) 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, replace-on-burnout, or 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.[157] 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 55

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

Equation 56

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*

[157] 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 and from MacroAir Fans White Paper.

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)*

<u>Retrofit (Early Retirement)</u>

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 57

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.

<u>Replace-on-Burnout/New Construction</u>

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.[158]

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

Equation 58

[158] 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.

Hours of Operation

Table 93 provides the hours to be used in calculating energy savings for HVLS fan installation by climate zone.

Table 93: Hours of Circulating Fan Operation by Barn Type[159]

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

Demand savings shall be claimed according to the Summer Demand Savings estimated using Equation 56, above. While there is a strong case for winter operation of HVLS fans in reverse for circulating warm air trapped below the roof back to the ground, this operation is not currently considered and as such there are no winter demand savings developed for this measure.

A coincidence factor of 1.0 should be used to calculate the summer demand savings for this measure, as the criteria for whether fans will be operating or not are always met during peak hours[160] as defined in Section 4 of Volume 1 of this TRM.

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 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.

[159] 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).

[160] For example, fans are turned on in dairy applications when the Temperature Humidity Index (THI) exceeds 68. The THI exceeds 68 in all the peak hours in the TMY files for all the Texas TRM Climate Zones as presented in Tables 4-5 through 4-9 of Volume 1 of this TRM.

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
- HVLS fan(s): rated HP
- HVLS fan(s): rated CFM
- HVLS fan(s): count
- **For early retirement only:** replaced fans: count
- **For early retirement only:** replaced fans: diameter
- **For early retirement only:** replaced fans: rated HP
- **For early retirement only:** replaced fans: rated CFM
- **For early retirement only:** replaced fans: 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 94: High-volume Low-speed Fans Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

2.3 NONRESIDENTIAL: BUILDING ENVELOPE

2.3.1 ENERGY STAR® 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 (RET)

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section presents the deemed savings methodology for the installation of an ENERGY STAR® certified roof. The installation of an ENERGY STAR® roof decreases the roofing heat transfer coefficient and reduces the solar heat transmitted to the building space. During hours when cooling is required in the building, this measure decreases the cooling energy use. During hours when heating is required in the building, this measure may increase or decrease the heating energy use depending on the project.

Eligibility Criteria

Measures installed through utility programs must be a roof that meets ENERGY STAR® specifications. 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 or less[161]
- An initial solar reflectance of greater than or equal to 65 percent
- 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

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

- 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[162]

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.[163]

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.

Table 95. Assumed Cooling and Heating Efficiencies (COP)

Year of Construction; Applicable Code	RTU	Heat Pump Cooling	Heat Pump 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

[162] ENERGY STAR® Certified Roofs. http://www.energystar.gov/productfinder/product/certified-roof-products/. Accessed 08/15/2016.
[163] Lawrence Berkeley National Lab Cool Roofing Material Database. https://heatisland.lbl.gov/resources/cool-roofing-materials-database. Accessed 08/2018.

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.

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 97 through Table 101. 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 59

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

Equation 60

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

Equation 61

Where:

Roof Area	=	*Total area of ENERGY STAR® roof in square feet*
ESF	=	*Energy Savings Factor from Table 97 through Table 101 by building type, pre/post insulation levels, and heating/cooling system.*
PSDF	=	*Peak Summer Demand Factor from Table 97 through Table 101 by building type, pre/post insulation levels, and heating/cooling system.*
PWDF	=	*Peak Winter Demand Savings Factor from Table 97 through Table 101 by building type, pre/post insulation levels, and heating/cooling system.*

If the insulation levels are unknown, use the mapping in Table 96 to estimate the R-value based on the year of construction.

Table 96. Estimated R-value based on Year of Construction

Year of Construction	Estimated R-value[164]
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

Table 97. Roof Savings Factor 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

[164] 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 98. Roof Savings Factor 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 99. Roof Savings Factor 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 100. Roof Savings Factor 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 101. Roof Savings Factor 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

Estimated Useful Life is 15 years for cool roofs, as discussed in PUCT Docket Nos. 36779 and 41070. The DEER 2014 update also provides a 15-year life for cool roofs (EUL ID—BldgEnv-CoolRoof).

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county location
- Roofing square foot (conditioned area)
- Existing roofing amount of construction, if possible
- Existing roofing amount of slope
- Existing roof insulation R-value, or year of building construction
- New roof insulation R-Value, if adding insulation
- ENERGY STAR® roofing initial solar reflectance
- ENERGY STAR® roofing solar reflectance after three years
- ENERGY STAR® roofing rated life
- Copy of ENERGY STAR® certification
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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/. Accessed 08/10/2018.
- IECC 2000 Table 802.2(17), 2009 Table 502.2(1), and 2015 Table C402.1.4
- DEER 2014 EUL update.

Document Revision History

Table 102: 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.
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.

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 (RET)

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 film 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. Demand and energy savings result in demand and energy use of cooling equipment.

Eligibility Criteria

This measure is applicable for treatment of single-paned windows in south or west facing orientations (as specified in Table 103 that do not have existing solar films or solar screens, are not shaded by exterior awnings or overhangs, and are in buildings that are mechanically cooled (DX or chilled water).

Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatment. Interior and exterior shading (as specified in Table 104) is acceptable but should be considered in the savings calculation.

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

$$Demand\ Savings_o\ [kW] = \frac{A_{film,o} \times SHGF_o \times (SC_{pre,o} - SC_{post,o})}{3413 \times COP}$$

Equation 62

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

Equation 63

$$Energy\ Savings_o\ [kWh] = \frac{A_{film,o} \times SHG_o \times (SC_{pre,o} - SC_{post,o})}{3413 \times COP}$$

Equation 64

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

Equation 65

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 [ft²]*
$SHGF_o$	=	*Peak solar heat gain factor for orientation of interest [Btu/hr-ft²-year]. See Table 103.*
SHG_o	=	*Solar heat gain for orientation of interest [Btu/ft2-year]. See Table 103.*
SCpre	=	*Shading coefficient for existing glass/interior-shading device. See Table 104.*
SCpost	=	*Shading coefficient for new film/interior-shading device, from manufacturer specs*
COP	=	*Cooling equipment COP based on Table 105 or actual COP equipment, whichever is greater*
3413	=	*Conversion factor [Btu/kW]*

Table 103: Solar Heat Gain Factors[165]

Orientation	Solar Heat Gain (SHG) [Btu/ft²-year]	Peak Hour Solar Heat Gain (SHGF) [Btu/hr-ft²-year]				
		Zone 1[166]	Zone 2	Zone 3	Zone 4	Zone 5
South-East	158,844	25	25	25	25	34
South-South-East	134,794	26	26	26	26	38
South	120,839	33	33	44	44	57
South-South-West	134,794	87	87	106	111	102
South-West	158,844	152	152	164	173	143
West-South-West	169,696	192	192	196	207	163
West	163,006	204	204	198	211	158
West-North-West	139,615	185	185	170	183	131
North-West	107,161	139	139	117	126	89

Table 104: Recommended Shading Coefficient (SC) for Different Pre-existing Shade Types

Shading Type	Shading Coefficient	Source[167]
None	0.95	Table 29: Based on ¼" clear single-pane glass
Roller Shade	0.81	Table 25: Based on clear glass, dark opacity
Venetian Blinds	0.74	Table 25: Based on clear glass, medium-color blinds
Louvered Exterior Shades	0.59	Table 24: Based on Profile Angle ≤ 10⁰, Group 4
Draperies—Open Weave	0.65	Table 29: Based on ¼" clear single-pane glass, Option D
Draperies—Closed Weave	0.53	Table 29: Based on ¼" clear single-pane glass, Option F/G

[165] 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.

[166] 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.

[167] Table numbers and shading coefficients provided are from 1997 ASHRAE Fundamentals Handbook, Chapter 29.

Table 105: Recommended COP for Different HVAC System Types

HVAC Type	COP	Source[168]
Air Conditioners and Heat Pumps	3.02	Table 6.2.1A: Air Conditioner, ≥19 kW and <40 kW
Air-cooled Chillers	3.1	Table 6.2.1C: Air Cooled Chiller without Condenser <528kW
Water-cooled Chiller	5.0	Table 6.2.1C: Water-cooled Centrifugal Chiller <528 kW
Room Air Conditioner	2.84	Table 6.2.1D: Room A/C with Louvered Sides, < 2.3 kW
PTAC/PTHP	3.66	Table 6.2.1D: PTAC (new construction), 2.3 kW

Measure Life and Lifetime Savings

Estimated Useful Life is 10 years for solar screens, as discussed in PUCT Docket Nos. 36779 and 41070. The DEER 2014 update also provides an EUL of 10 years for this measure (EUL ID—GlazDayIt-WinFilm).

Program Tracking Data and Evaluation Requirements

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

- Existing window shading coefficients
- Existing window interior shading type
- Description of existing window presence of exterior shading from other buildings or obstacles
- Window film or solar screen shading coefficient
- Eligible window treatment application area by orientation (e.g., S, SSW, SW)
- Cooling equipment type
- Cooling equipment rated efficiency

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for reflective window films and sunscreens.

Relevant Standards and Reference Sources

- 1997 ASHRAE Fundamentals, Chapter 29, Table 17.

[168] Table numbers and COP provided are from ASHRAE 90.1-1999.

- ASHRAE Standard 90.1-1999
- DEER 2014 EUL update

Document Revision History

Table 106: Nonresidential Window Treatment 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 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.

2.3.3 Entrance and Exit Door Air Infiltration

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 (RET)

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. A space with interior vestibule doors is 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).[169] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,[170] 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 66

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 67

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

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

[170] 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 68

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 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 69

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

Equation 70

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

Equation 71

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

Equation 72

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 73

Where:

T_{design}	=	*Daytime and nighttime design temperature (°F, see Table 108)*
$T_{avg\ outside\ ambient}$	=	*Average outside ambient temperature, specified by month (°F, see Table 107)*

Table 107: Average Monthly Ambient Temperatures (°F)[171]

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 108: Daytime and Nighttime Design Temperatures

Temperature Description	T_{design} (°F)
Daytime Cooling Design Temperature	74
Daytime Heating Design Temperature	72
Nighttime Cooling Design Temperature[172]	78
Nighttime Heating Design Temperature[173]	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 74

[171] TMY3 climate data.
[172] Assuming 4-degree setback.
[173] 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 75

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

Equation 76

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 77

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

Equation 78

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

Equation 79

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 80

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 81

Where:

CFM_{pre}	=	*Calculated pre-retrofit air infiltration (cubic feet per minute)*
$CFM_{reduction}$	=	*59%*[174]
1.08	=	*Sensible heat equation conversion*[175]
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 (inches). 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 109: 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	2.23	4.50	8.94	13.43
Zone 2: Dallas	4.59	9.27	18.41	27.63
Zone 3: Houston	3.54	7.17	14.22	21.34
Zone 4: Corpus Christi	5.88	11.86	23.56	35.37
Zone 5: El Paso	3.30	6.69	13.27	19.92

[174] 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).

[175] 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

Table 110: 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	119.13	240.28	477.32	716.53
Zone 2: Dallas	57.53	116.26	230.76	346.40
Zone 3: Houston	31.98	64.78	128.46	192.84
Zone 4: Corpus Christi	26.80	54.14	107.47	161.33
Zone 5: El Paso	53.63	108.51	215.28	323.17

Table 111: 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	36.10	72.81	144.64	217.13
Zone 2: Dallas	17.43	35.23	69.93	104.97
Zone 3: Houston	9.69	19.63	38.93	58.44
Zone 4: Corpus Christi	8.12	16.40	32.57	48.89
Zone 5: El Paso	16.25	32.88	65.24	97.93

Table 112: 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	0.0062	0.0124	0.0247	0.0371
Zone 2: Dallas	0.0052	0.0106	0.0211	0.0316
Zone 3: Houston	0.0051	0.0102	0.0203	0.0305
Zone 4: Corpus Christi	0.0048	0.0097	0.0193	0.0289
Zone 5: El Paso	0.0048	0.0098	0.0194	0.0291

Table 113: 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	0.0315	0.0636	0.1263	0.1896
Zone 2: Dallas	0.0485	0.0974	0.1939	0.2911
Zone 3: Houston	0.0248	0.0500	0.0993	0.1490
Zone 4: Corpus Christi	0.0224	0.0451	0.0896	0.1346
Zone 5: El Paso	0.0117	0.0238	0.0471	0.0708

Table 114: 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	0.0162	0.0326	0.0647	0.0971
Zone 2: Dallas	0.0209	0.0420	0.0835	0.1254
Zone 3: Houston	0.0120	0.0243	0.0482	0.0724
Zone 4: Corpus Christi	0.0102	0.0206	0.0409	0.0615
Zone 5: El Paso	0.0058	0.0117	0.0232	0.0348

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL for this measure is 11 years, according to the California Database of Energy Efficiency Resources (DEER 2014).[176] This measure life is consistent with the residential air infiltration measure in the Texas TRM.

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Existing gap width
- Installed measure (weather stripping or door sweep)
- Linear feet 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.

[176] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Relevant Standards and Reference Sources

- Not applicable.

Document Revision History

Table 115: 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.

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, replace-on-burnout, or new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section presents the deemed savings methodology for the installation of high efficiency 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 meet ENERGY STAR® qualifications, with half-size and full-size ovens as defined by ENERGY STAR® and a pan capacity ≥ 5 and ≤ 20.[177]

- 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.

[177] ENERGY STAR® Program Requirements for Commercial Ovens. https://www.energystar.gov/sites/default/files/specs//private/Commercial%20Ovens%20Program%20Requirements%20V2%201.pdf. Accessed 01/26/2015.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[178]

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

Baseline Condition

Eligible baseline condition for Retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20.

High-efficiency Condition

The high-efficiency combination ovens must be ENERGY STAR® rated. To do so, they meet the following minimum energy efficiency and idle energy rate requirements, as shown in Table 116 below.

Table 116: Cooking Energy Efficiency and Idle Energy Rate Requirements[179]

Operation	Idle Rate (kW)	Cooking Energy Efficiency (%)
Steam Mode	≤ 0.133P + 0.6400	≥ 55
Convection Mode	≤ 0.080P + 0.4989	≥ 76

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The calculation for these deemed values are calculated based on the following algorithms:

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

Equation 82

[178] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

[179] 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

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

Equation 83

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

Equation 84

$$kWh_{post} = kWh_{conv} + kWh_{st}$$

Equation 85

kWh_{conv} and kWh_{st} are each calculated the same for both the base (baseline) and post (ENERGY STAR®) cases, as shown in Equation 84 and Equation 85, except they require their respective *η (Cooking Efficiencies),* E_{Idle} *(Idle Energy Rates) and* C_{cap} *(Production Capacity)* relative to Convection and Steam Modes as seen in Table 117*.*

$$kWh = \left(\left(W_{food} \times \frac{E_{food} \times 50\%}{\eta_{\text{cooking}}} \right) + E_{idle} \times \left(\left(t_{hours} - \frac{W_{food}}{C_{cap}} \right) \times 50\% \right) \right) \times \frac{t_{days}}{1000}$$

Equation 86

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{post}	=	*Post annual energy consumption [kWh]*
t_{days}	=	*Facility operating days per year*
t_{hours}	=	*Equipment operating hours per day*
CF	=	*Peak coincidence factor*
W_{food}	=	*Pounds of food cooked per day [lb/day]*
E_{food}	=	*ASTM energy to food [Wh/lb]. (Differs for Convection-Mode and Steam-Mode®. See Table 117)*
E_{Idle}	=	*Idle energy rate [W]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 117*
$\eta cooking$	=	*Cooking energy efficiency [%]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 117)*
CCap	=	*Production capacity per pan [lb/hr]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 117)*
1000	=	*Wh to kWh conversion*

Table 117: Deemed Variables for Energy and Demand Savings Calculations

Parameter	Convection-mode		Steam-mode	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
kWh_{base}	See Table 116			
kWh_{post}				
W_{food}	200			
T_{hours}	12			
T_{days}	365			
N_{pans}	10			
CF[180]	0.92			
E_{food}	73.2		30.8	
$\eta_{cooking}$	72%	76%	49%	55%
E_{idleB}	1,320	1,299	5,260	1,970
C_{cap}	79	119	126	177

Deemed Energy and Demand Savings Tables

The energy and demand savings of High-efficiency Combination Ovens in Table 118 are calculated in the Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment using the default parameters shown above in Table 117.

Table 118: Deemed Energy and Demand Savings Values[181]

kWh_{base}	kWh_{post}	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
18,282	11,914	6,368	1.338

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years, consistent with the ENERGY STAR® calculator and with the DEER 2014 EUL update (EUL ID—Cook-ElecCombOven).

180 California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed 07/12.2012, http://capabilities.itron.com/CeusWeb/Chart.aspx.

181 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. Accessed 01/27/2015.

Program Tracking Data and Evaluation Requirements

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

- High efficiency manufacturer make and model
- High efficiency heavy load cooking efficiency
- High efficiency equipment idle rate
- Oven size
- Copy of ENERGY STAR® certification
- 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 119: 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.

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, replace-on-burnout, or 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 (early retirement), replacement, or new installation of a full-size or half-size high efficiency electric convection oven. 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 off energy rates of the oven, cooking efficiencies, operating hours, production capacities, and building type. Average energy and demand consumption has been calculated based on these default values to create a stipulated savings value. The energy and demand savings are determined on a per-oven basis.

Eligibility Criteria

Eligible units must meet ENERGY STAR® qualifications, with half-size and full-size electric ovens as defined by ENERGY STAR®[182]

- 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 but not a full-size sheet pan.
- Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[183]

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[182] ENERGY STAR® Program Requirements for Commercial Ovens.https://www.energystar.gov/sites/default/files/specs/private/Commercial_Ovens_Program_Requirements_V2_1.pdf. Accessed 01/26/2015.

[183] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

- Convection ovens eligible for rebate do not include ovens that have the ability to heat the cooking cavity with saturated or superheated steam.

Baseline Condition

Eligible baseline condition for retrofit situations is an electric convection oven.

High-efficiency Condition

The high-efficiency convection ovens must be ENERGY STAR® rated and therefore, must meet the following minimum energy efficiency and idle energy rate requirements, as shown in Table 120 below:

Table 120: Convection Oven Cooking Energy Efficiency and Idle Energy Requirements

Oven Capacity	Idle Rate (W)	Cooking Energy Efficiency (%)
Full-Size	≤ 1,600	≥ 71
Half-Size	≤ 1,000	≥ 71

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

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

$$Energy\ [kWh] = (E_{base} - E_{HE}) \times \frac{days}{1000}$$

Equation 87

$$Peak\ Demand\ [kW] = \frac{(E_{base} - E_{HE})}{T_{on}} \times \frac{CF}{1000}$$

Equation 88

$$E_{base} = \frac{LB \times E_{Food}}{EFF_{base}} + \left[IDLE_{base} \times \left(T_{on} - \frac{LB}{PC_{base}}\right)\right]$$

Equation 89

$$E_{HE} = \frac{LB \times E_{Food}}{EFF_{HE}} + \left[IDLE_{HE} \times \left(T_{on} - \frac{LB}{PC_{HE}}\right)\right]$$

Equation 90

Where:

E_{base} = *Baseline daily energy consumption (kWh/day)*

E_{HE}	=	*High efficiency daily energy consumption (kWh/day)*
LB	=	*Pounds of food cooked per day [lb/day]*
Days	=	*Number of operating days per year [days/yr]*
CF	=	*Coincidence Factor*
Efood	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
EFF_{base}	=	*Baseline heavy load cooking energy efficiency [%]*
EFF_{HE}	=	*High efficiency heavy load cooking energy efficiency [%]*
$IDLE_{base}$	=	*Baseline idle energy rate [kW]*
$IDLE_{HE}$	=	*High efficiency idle energy rate [kW]*
T_{on}	=	*Operating hours per day [hrs./day]*
PC_{base}	=	*Baseline production capacity [lbs./hr]*
PC_{HE}	=	*High efficiency production capacity [lbs/hr]*

Table 121: Deemed Variables for Energy and Demand Savings Calculations[184]

Variable	Full-Size	Half-Size
LB[186]	100	
Days	365	
CF[185]	0.92	
E_{food}[186]	73.2	
EFF_{base}[186]	65%	68%
EFF_{HE}[186]	71%	
$IDLE_{base}$[186]	2,000	1,030
$IDLE_{HE}$[186]	1,600	1,000
T_{on}	12	
PC_{base}[186]	90	45
PC_{HE}[186]	90	50

[184] The FSTC "Electric Combination Oven Life-Cycle Cost Calculator" was used to determine the annual energy consumption of both baseline and energy efficient electric combination ovens. The FSTC calculator uses oven performance parameters based on ASTM Standard Test Method F2861. The FSTC calculator default values assume equipment is operating 12 hours a day, 365 days a year. To account for variations in operation of different facility kitchens, calculator inputs for equipment operating hours and annual days of operation were assumed based on the facility types shown in Table 70.

[185] California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed 07/12/2012, http://capabilities.itron.com/CeusWeb/Chart.asnx.

[186] Default values in ENERGY STAR® calculator for Full Size Ovens.

Deemed Energy and Demand Savings Tables

The energy and demand savings of high efficiency convection ovens are deemed values based on an assumed capacity for the average convection oven installed. The following tables provide these deemed values.

Table 122: Deemed Energy and Demand Savings Values

Oven Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
Full-Size	1,937	0.410
Half-Size	192	0.040

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years, consistent with ENERGY STAR® research and with the DEER 2014 EUL update (EUL ID—Cook-ElecConvOven).

Program Tracking Data and Evaluation Requirements

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

- High efficiency equipment manufacturer and model number
- High efficiency equipment heavy load cooking efficiency
- High efficiency equipment idle rate
- Oven size
- Copy of ENERGY STAR® certification
- 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. Accessed 01/22/2015.

- ENERGY STAR® list of Qualified Commercial Ovens. https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results. Accessed 01/22/2015.
- DEER 2014 EUL update.

Document Revision History

Table 123: 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.

2.4.3 ENERGY STAR® Commercial 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, replace-on-burnout, and 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 an ENERGY STAR® commercial dishwasher. Commercial dishwashers that have earned the ENERGY STAR® label are, on average, 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

The dishwasher must be ENERGY STAR® certified and fall under one of the following categories, and are described in Table 124:

- Under counter dishwasher
- Stationary rack, single tank, door type dishwasher
- Single tank conveyor dishwasher
- 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.[187]

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.

Table 124: Nonresidential ENERGY STAR® Commercial Dishwashers Descriptions

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

[187] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

Baseline Condition

Baseline equipment is either a low-temperature[188] or high temperature[189] machine as defined by Table 124, 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 meet or exceed the ENERGY STAR® v2.0 specification. High-temperature equipment sanitizes using hot water and requires a booster heater. Booster heaters must be electric. Low-temperature equipment uses chemical sanitization and does not require a booster heater. The high-efficiency dishwasher is required to have the maximum idle energy rate and water consumption as shown in Table 125 below.

Table 125: High-efficiency Requirements for Commercial Dishwashers[190]

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	≤ 0.50	≤ 1.19	≤ 0.50	≤ 0.86
Stationary Single Tank Door	≤ 0.60	≤ 1.18	≤ 0.70	≤ 0.89
Single Tank Conveyor	≤ 1.50	≤ 0.79	≤ 1.50	≤ 0.70
Multiple Tank Conveyor	≤ 2.00	≤ 0.54	≤ 2.25	≤ 0.54
Pot, Pan, and Utensil	< 1.00	≤0.58[191]	≤ 1.20	≤ 0.58[191]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The calculation for these deemed values are calculated based on the following algorithms:

[188] Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.
[189] High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.
[190] Table 125 values are provided in ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers, Version 2.0. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers. Accessed 11/13/19.
[191] Water Consumption for pot, pan and utensil is specified in gallons per square foot rather than gallons per rack.

$$Energy\ Savings\ [kWh] = (V_{waterB} - V_{waterP}) \times \left(\frac{\Delta T_{DHW} + \Delta T_{boost}}{\eta_{DHW}}\right) \times \rho_{water} \times C_p \times \frac{1\ W}{3413\ kBtuh} + (Idle_{base} - Idle_{post}) \times \left(t_{days} \times t_{hours} - t_{days} \times N_{racks} \times \frac{WashTime}{60}\right)$$

Equation 91

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

Equation 92

$$V_{waterB} = t_{days} \times N_{racks} \times V_{galrackB}$$

Equation 93

$$V_{waterP} = t_{days} \times N_{racks} \times V_{galrackP}$$

Equation 94

Where:

V_{waterB}	=	*Baseline volume of water consumed per year [gallons]*
V_{waterP}	=	*Post measure volume of water consumed per year [gallons]*
t_{days}	=	*Facility operating days per year [days]*
t_{hours}	=	*Equipment operating hours per day [hours]*
N_{racks}	=	*Number of racks washed per days*
CF	=	*Peak coincidence factor*
$V_{galrackB}$	=	*Gallons of water used per rack of dishes washed for conventional dishwashers [gallons]*
$V_{galrackP}$	=	*Gallons of water used per rack of dishes washed for ENERGY STAR® dishwashers [gallons]*
ρ_{water}	=	*Density of water [lbs/gallon]*
C_p	=	*Specific heat of water [Btu/lb ºF]*
ΔT_{DHW}	=	*Inlet water temperature increase for building water heater [ºF]*
η_{DHW}	=	*Building electric water heater and booster heater efficiency [%]*
ΔT_{boost}	=	*Inlet water temperature for booster water heater [ºF]*
$IDLE_{base}$	=	*Baseline Idle Energy Rate [kW]*
$IDLE_{post}$	=	*High Efficiency Idle Energy Rate [kW]*
$WashTime$	=	*Wash time per Rack*

Table 126: Deemed Variables for Energy and Demand Savings Calculations

Inputs	Under Counter	Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
t_{days}[192]	365				
t_{hours}[5]	18				
CF[193]	0.97				
ρ_{water}	8.208 [lbs/gallon]				
C_p	1.0 [Btu/lb ºF]				
ΔT_{DHW}[4]	Gas Hot Water Heaters: 0ºF Electric Hot Water Heaters: 70 ºF				
η_{DHW}	98%				
ΔT_{boost}	Gas Booster Heaters: 0 ºF Electric Booster Heaters: 40 ºF				
η_{boost}	98%				
Low-temperature Units					
N_{racks}	75	280	400	600	Not applicable.
$V_{galrackB}$	1.73	2.10	1.31	1.04	Not applicable.
$V_{galrackP}$	1.19	1.18	0.79	0.54	Not applicable.
$IDLE_{base}$	0.50	0.60	1.60	2.00	Not applicable.
$IDLE_{post}$	0.50	0.60	1.50	2.00	Not applicable.
WashTime	2.0	1.5	0.3	0.3	Not applicable.
High-temperature Units					
N_{racks}	75	280	400	600	280
$V_{galrackB}$	1.09	1.29	0.87	0.97	0.70
$V_{galrackP}$	0.86	0.89	0.70	0.54	0.58
$IDLE_{base}$	0.76	0.87	1.93	2.59	1.20

[192] ENERGY STAR®. "Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment." Accessed 12/16/2013.

[193] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Chart.aspx. Accessed 07/12/12.

Inputs	Under Counter	Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
$IDLE_{post}$	0.50	0.70	1.50	2.25	1.20
WashTime	2.0	1.0	0.3	0.2	3.0

Deemed Energy and Demand Savings Tables

The energy and demand savings of high-efficiency dishwashers are deemed values based on an assumed capacity for the average convection oven installed. The following tables provide these deemed values.

Table 127: Deemed Energy and Peak Demand Savings Values by Dishwasher

Facility Description	Under Counter		Door Type		Single Tank Conveyor		Multi-tank Conveyor		Pot, Pan, and Utensil	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Low Temp./ Electric Hot Water Heater	2,540	0.375	16,153	2.385	13,626	2.012	18,811	2.777	NA	NA
High Temp./ Electric Hot Water Heater with Electric Booster Heater	3,171	0.468	11,863	1.751	9,212	1.360	27,408	4.046	3,311	0.489
High Temp./ Gas Hot Water Heater with Electric Booster Heater	2,089	0.308	4,840	0.715	4,948	0.730	11,230	1.658	1,204	0.178

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 11 years, consistent with ENERGY STAR® research.

Program Tracking Data and Evaluation Requirements

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

- Baseline and post-retrofit dishwasher machine type
- Post-retrofit make and model number
- Energy source for primary water heater
- Energy source for booster water heater
- Copy of ENERGY STAR® certification

- 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. Accessed 01/30//2015.
- 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. Accessed 01/30//2015.
- ENERGY STAR® v2.0 Calculator (Commercial Kitchen Equipment Savings Calculator). http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx. Accessed 01/27/2015.

Document Revision History

Table 128: Nonresidential ENERGY STAR® Commercial Dishwashers Revision History

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

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, replace-on-burnout, or new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section covers the energy and demand savings resulting in the installation of ENERGY STAR® qualified hot food holding cabinets. Models that meet these ENERGY STAR® specifications incorporate better insulation, 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 with 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

Hot food holding cabinets must be ENERGY STAR® certified.[194] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[195]

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

- Dual function equipment
- Heated transparent merchandising cabinets

[194] A list of ENERGY STAR® qualified products can be found on the ENERGY STAR® website: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets. Accessed 11/13/19.

[195] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

- Drawer warmers

Baseline Condition

Eligible baseline equipment is a half-size, three-quarter size, or full-size hot food holding cabinet with a maximum idle energy rate of < 40 watts/ft³ for all equipment sizes.

High-efficiency Condition

Eligible equipment is set by ENERGY STAR® and based on the cabinet's interior volume. Table 129 summarizes idle energy rates per ENERGY STAR® v2.0:

Table 129: Maximum Idle Energy Rate Requirements ENERGY STAR® Qualification[196]

Product Category	Product Interior Volume [ft³]	Idle Energy Rate [W]
Half Size	0 < V < 13	≤ 21.5 V
Three-Quarter Size	13 ≤ V ≤ 28	≤ 2.0 V + 254.0
Full Size	28 ≤ V	≤ 3.8 V + 203.5

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

The calculation for these deemed values are calculated based on the following algorithms:

$$Energy\ Saving\ [kWh] = (E_{IdleB} - E_{IdleP}) \times \frac{1}{1000} \times t_{hrs} \times t_{days}$$

Equation 95

$$Peak\ Demand\ [kW] = (E_{IdleB} - E_{IdleP}) \times \frac{1}{1000} \times CF$$

Equation 96

Where:

E_{IdleB} = *Baseline idle energy rate [W] (See Table 130)*

E_{IdleP} = *Idle energy rate after installation [W] (See Table 130)*

V = *Product Interior Volume [ft³]*

t_{hrs} = *Equipment operating hours per day [hrs]*

t_{days} = *Facility operating days per year*

[196] V = Interior Volume = Interior Height x Interior Width x Interior Depth

CF = *Peak coincidence factor*

Table 130: Equipment Operating Hours per Day and Operating Days per Year

Input Variable	Half-size	Three-quarter Size	Full-size
Product Interior Volume [ft^3]	12	20	30
Baseline Equipment Idle Energy Rate [E_{IdleB}]	480	800	1,200
Efficient Equipment Idle Energy Rate [E_{IdleP}]	258	294	318
Operating Hours per Day [t_{hours}]	15		
Facility Operating Days per Year [t_{days}]	365		
Peak Coincidence Factor[197] [CF]	0.92		

Deemed Energy and Demand Savings Tables

The energy and demand savings of electric hot food holding cabinets are deemed values. The following tables provide these deemed values.

Table 131: Deemed Energy and Demand Savings Values by HFHC Size

Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
Half	1,215	0.204
Three-Quarter	2,770	0.466
Full	4,832	0.812

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years per the PUCT approved Texas EUL filing (Docket No. 36779) and is consistent with ENERGY STAR®'s research[198] and the DEER 2014 EUL update (EUL ID—Cook-Hold Cab)

[197] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Chart.aspx. Accessed 07/12/12.

[198] ENERGY STAR® measure life based on Food Service Technology Center (FSTC) research on available models, 2009. ENERGY STAR®. "Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment." https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx. Accessed 11/13/19.

Program Tracking Data and Evaluation Requirements

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

- Baseline equipment interior cabinet volume
- Baseline equipment idle energy rate
- Post-retrofit equipment interior cabinet volume
- Post-retrofit equipment size (half, three-quarters, full)
- Copy of ENERGY STAR® certification
- 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. Accessed 01/21/2015.
- DEER 2014 EUL update.

Document Revision History

Table 132: 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.

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, replace-on-burnout, or new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section presents the deemed savings methodology for the installation of an ENERGY STAR® Electric Fryer. Fryers that have earned the ENERGY STAR® rating 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 ENERGY STAR® qualifications, either counter-top or floor type designs, with standard-size and large vat fryers as defined by ENERGY STAR.®[199]

- 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 foodservice operations, healthcare, hospitality, and supermarkets.[200]

[199] ENERGY STAR® Program Requirements Product Specifications for Electric Fryers. Eligibility Criteria Version 2.0. https://www.energystar.gov/sites/default/files/specs/private/Commercial_Fryers_Program_Requirements.pdf. Accessed 11/13/19.

[200] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

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

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

Baseline Condition

Baseline fryers can be existing or new electric standard-size fryers ≥ 12 inches < 18 inches wide or large vat fryers > 18 inches and < 24 inches wide that do not meet ENERGY STAR® product criteria.

High-efficiency Condition

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 ENERGY STAR® requirements listed below in Table 133.

Table 133: High-efficiency Requirements for Electric Fryers

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

The calculation for these deemed values are calculated based on the following algorithms:

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

Equation 97

$$Peak\ Demand\ [kW] = \frac{kWh_{base} - kWh_{post}}{t_{OpHrs} \times t_{days}} \times CF$$

Equation 98

$$kWh_{base} = \left(W_{food} \times \frac{E_{food}}{\eta_{cookingB}} + E_{idleB} \times \left(t_{OpHours} - \frac{W_{food}}{C_{CapB}}\right)\right) \times \frac{t_{days}}{1000}$$

Equation 99

$$kWh_{post} = \left(W_{food} \times \frac{E_{food}}{\eta_{cookingP}} + E_{idleP} \times \left(t_{OpHours} - \frac{W_{food}}{C_{CapP}}\right)\right) \times \frac{t_{days}}{1000}$$

Equation 100

Where:

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

kWh_{post} = *Post annual energy consumption [kWh]*

W_{food} = *Pounds of food cooked per day [lb/day]*

E_{food} = *ASTM energy to food [Wh/lb]*

$\eta_{cookingP}$ = *Post measure cooking energy efficiency [%]*

$\eta_{cookingB}$ = *Baseline cooking energy efficiency [%]*

E_{IdleP} = *Post measure idle energy rate [W]*

E_{IdleB} = *Baseline idle energy rate [W]*

C_{CapP} = *Post measure production capacity per pan [lb/hr]*

C_{CapB} = *Baseline production capacity per pan [lb/hr]*

t_{Days} = *Facility operating days per year [days/yr]*

t_{OpHrs} = *Average daily operating hours per day [hr]*

η_{PC} = *Percent of rated production capacity [%]*

CF = *Peak coincidence factor*

Table 134: Deemed Variables for Energy and Demand Savings Calculations[201]

Parameter	Standard-sized Vat		Large Vat	
	Baseline	Post Retrofit	Baseline	Post Retrofit
kWh_{base}	See Table 135			
kWh_{post}				
W_{food}	150			
t_{OpHrs}	16		12	
t_{days}	365			
CF[202]	0.92			
E_{food}	167			
$\eta_{cooking}$	75%	83%	70%	80%
E_{idle}	1,050	800	1,350	1,110
C_{Cap}	65	70	100	110

Deemed Energy and Demand Savings Tables

The energy and demand savings of Electric Fryers are deemed values. Table 135 provides these deemed values.

Table 135: Deemed Energy and Demand Savings Values by Fryer Type

Fryer Type	kWh_{base}	kWh_{post}	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
Standard	17,439	15,062	2,376	0.374
Large Vat	18,236	15,738	2,497	0.525

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years per the PUCT approved Texas EUL filing (Docket No. 36779) and by the DEER 2014 EUL update (EUL ID—Cook-ElecFryer).

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201 Deemed input values come from ENERGY STAR® Commercial Kitchen Equipment Calculator. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx. Accessed 09/26/2019.

202 California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Chart.aspx. Accessed 07/12/12,

Program Tracking Data and Evaluation Requirements

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

- Manufacturer and model number
- High-efficiency unit heavy load cooking efficiency
- High-efficiency unit equipment idle rate
- Fryer width
- Copy of ENERGY STAR® certification
- 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. Accessed 11/13/2019.
- DEER 2014 EUL update.

Document Revision History

Table 136: 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 EnergyStar® 3.0 specifications. Program tracking requirements updated.

2.4.6 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 138

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 to save 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. Installation of pre-rinse spray valves reduces energy consumption associated with heating the water.

Eligibility Criteria

Pre-rinse spray valves must have a maximum flow rate no greater than 1.25 GPM. Units must be used for commercial food preparation only.

Baseline Condition

Eligible baseline equipment is a pre-rinse sprayer using 1.60 GPM.[203]

High-efficiency Condition

Eligible equipment is a pre-rinse sprayer using 1.25 GPM or less. The sprayer should be capable of the same cleaning ability as the old sprayer.[204]

[203] Federal standards, based on EPACT 2005 and ASTM F2324 test conditions require a base line of 1.6 GPM.

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The calculation for these deemed values are calculated based on the following algorithms:

$$Energy\ [kWh]\ = (F_B \times U_B - F_P \times U_P) \times \frac{Days}{Year} \times (T_H - T_C) \times C_H \times \frac{C_E}{Eff_E}$$

Equation 101

$$Peak\ Demand\ [kW] = P \times (F_B \times U_B - F_P \times U_P) \times (T_H - T_C) \times C_H \times \frac{C_E}{Eff_E}$$

Equation 102

Where:

F_B	=	*Average baseline flow rate of sprayer (GPM)*
F_P	=	*Average post measure flow rate of sprayer (GPM)*
U_B	=	*Baseline water usage duration*
U_P	=	*Post-retrofit water usage duration*
T_H	=	*Average mixed hot water (after spray valve) temperature (ºF)*
T_C	=	*Average supply (cold) water temperature (ºF)*
Days	=	*Annual facility operating days for the applications*
C_H	=	*Unit conversion: 8.33 BTU/(Gallons-ºF)*
C_E	=	*Unit conversion: 1 BTU = 0.00029308 kWh (1/3412)*
Eff_E	=	*Efficiency of electric water heater*
P	=	*Hourly peak demand as percent of daily demand*

Table 137: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
F_B	1.6[203]
F_P	1.25[203,204]
$U_B = U_P$	Fast Food Restaurant: 45 min/day/unit[205] Casual Dining Restaurant: 105 min/day/unit[205] Institutional: 210 min/day/unit[205] Dormitory: 210 min/day/unit[205] K-12 School: 105 min/day/unit[206]
T_H	120[207]
T_C	69[208]
Days[209]	Fast Food Restaurant: 360 Casual Dining Restaurant: 360 Institutional: 360 Dormitory: 270 K-12 School: 193
C_H	8.33
C_E	0.00029
Eff_E	1.0
P[210]	Fast Food Restaurant: 6.81% Casual Dining Restaurant: 17.36% Institutional: 5.85% Dormitory: 17.36% K-12 School: 11.35%

[205] CEE Commercial Kitchens Initiative Program Guidance on pre-rinse valves.

[206] Assuming that institutions (e.g., prisons, university dining halls, hospitals, nursing homes) are serving three meals a day, prorate schools by 1.5hrs to 3hrs (assuming schools serve breakfast to half of the students and lunch to all), yielding 105 minutes per day.

[207] According to ASTM F2324-03 Cleanability Test, the optimal operating conditions are at 120°F. This test consists of cleaning a plate of dried tomato sauce in less than 21 seconds with 120 ± 4°F water at a specified distance from the plate. This test is performed at 60 ± 2 psi of flowing water pressure.

[208] FEMP Performance Requirements for Federal Purchases of Pre-rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-rinse Spray Valves. Average calculated input water temperature for five Texas climate zone cities.

[209] 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.

[210] ASHRAE Handbook 2011. HVAC Applications. Chapter 50 - Service Water Heating American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The Hourly Flow Profiles given in Figure 24 on page 50.19, were reviewed and A-85 118 analyzed. The Hourly Peak Demand as a percent of the daily flow was estimated by knowing the total daily flow, the hourly flow, and the peak demand period window in Arkansas.

Deemed Energy and Demand Savings Tables

The energy and demand savings of pre-rinse sprayers are deemed values. The following table provides these deemed values.

Table 138: Deemed Energy and Demand Savings Values by Building Type

Pre-rinse Spray Valve Electric Savings	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
Fast Food	706	0.134
Casual Dining	1,647	0.794
Institutional	3,295	0.535
Dormitory	2,471	1.589
School	883	0.519

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 5 years.[203,208] This is consistent with PUCT Docket No. 36779.

Program Tracking Data and Evaluation Requirements

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

- Baseline Equipment flow-rate
- Retrofit Equipment flow-rate
- Building Type

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Attachment A: https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF. Accessed 09/09/2013.
- PUCT Docket 36779—Provides EUL for pre-rinse sprayers

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 139: 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.

2.4.7 ENERGY STAR® Electric Steam Cookers Measure Overview

TRM Measure ID: NR-FS-SC

Market Sector: Commercial

Measure Category: Cooking Equipment

Applicable Building Types: See Eligibility Criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, replace-on-burnout, or 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® electric steam cookers. Steam cookers are available in 3, 4, 5, 6 pan, and larger capacities. ENERGY STAR® qualified units 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 Steam Cookers can have a 3, 4, 5, or 6 pan capacity. A list of eligible equipment is found on the ENERGY STAR® list of qualified equipment.[211] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets[212]

Baseline Condition

Eligible baseline conditions for retrofit situations are electric steam cookers that are not ENERGY STAR® certified.

High-efficiency Condition

The high-efficiency electric steam cookers are assumed to be ENERGY STAR® certified and have the characteristics shown in Table 140.

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[211] ENERGY STAR® Qualified Commercial Steam Cookers. List Posted on May 15, 2012. http://www.energystar.gov/ia/products/prod_lists/Steamers_prod_list.pdf. Accessed 09/09/2013.

[212] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

Table 140: ENERGY STAR® Energy Efficiency and Idle Rate Requirements for Electric Steam Cookers[213]

Pan Capacity	Cooking Energy Efficiency [%]	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 103

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

Equation 104

$$kWh_{base} = W_{food} \times \frac{E_{food}}{\eta_{base}} + \left((1 - \eta_{tSteam}) \times E_{idleRate,base} + \eta_{tSteam} \times C_{pan} \times N_{pan} \times \frac{E_{food}}{\eta_{base}} \right) \times \left(t_{days} - \frac{W_{food}}{\eta_{base} \times N_{pan}} \right) \times \frac{N_{OpDays}}{1000}$$

Equation 105

$$kWh_{post} = W_{food} \times \frac{E_{food}}{\eta_{post}} + \left((1 - \eta_{tSteam}) \times E_{idleRate,post} + \eta_{tSteam} \times C_{pan} \times N_{pan} \times \frac{E_{food}}{\eta_{post}} \right) \times \left(t_{days} - \frac{W_{food}}{\eta_{post} \times N_{pan}} \right) \times \frac{N_{OpDays}}{1000}$$

Equation 106

[213] ENERGY STAR®. "Commercial Steam Cookers Key Product Criteria.". https://www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers. Accessed 11/13/19.

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{post}	=	*Post annual energy consumption [kWh]*
ΔkWh	=	*Energy Savings =* kWh_{base} — kWh_{post}
W_{food}	=	*Pounds of food cooked per day [lb/day]*
E_{food}	=	*ASTM energy to food [Wh/lb]*
η_{base}	=	*Baseline Cooking energy efficiency (Differs for boiler-based or steam generator equipment)*
η_{post}	=	*Post-retrofit Cooking energy efficiency*
η_{tSteam}	=	*Percent of time in constant steam mode [%]*
$E_{IdleRate, base}$	=	*Idle energy rate [W]. (Differs for boiler-based or steam-generator equipment)*
$E_{IdleRate, post}$	=	*Idle energy rate [W].*
C_{pan}	=	*Production capacity per pan [lb/hr]*
N_{pan}	=	*Number of pans*
N_{OpDays}	=	*Facility operating days per year [days/yr]*
t_{OpHrs}	=	*Average daily operating hours per day [hr]*
CF	=	*Peak coincidence factor*
1000	=	*Wh to kWh conversion factor*

Table 141: Deemed Variables for Energy and Demand Savings Calculations[214]

Parameter	Baseline Value	Post Retrofit Value
kWh_{base}	See Table 142	
kWh_{post}		
W_{food}	100	
E_{food}	30.8	
η	Boiler-based Efficiency: 26% Steam-Generator Efficiency: 30%	50%
η_{tSteam}	40%	
$E_{IdleRate}$	Boiler-based Idle Rate: 1,000 Steam Generator Idle Rate: 1,200	3-Pan: 400 4-Pan: 530 5-Pan: 670 6-Pan: 800
C_{pan}	23.3	16.7
N_{pan}	3, 4, 5, or 6	
t_{OpHrs}	12	
N_{OpDays}	365	
CF[215]	0.92	

Deemed Energy and Demand Savings Tables

The energy and demand savings of high efficiency steam cookers are deemed values. The following tables provide these deemed values.

Table 142: Annual Energy Consumption and Daily Food Cooked[216]

Steam Cooker Type	N_{pan}	kWh_{base}	kWh_{Post}	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
Boiler Based	3-Pan	19,416	7,632	11,784	2.475
	4-Pan	24,330	9,777	14,553	3.057
	5-Pan	29,213	11,946	17,268	3.627

214 ENERGY STAR®. "Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment." Accessed 09/26/11. Equipment specifications from 2009 Food Service Technology Center (FSTC) research on available models. Equipment cost from 2010 EPA research on available models using AutoQuotes. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx. Accessed 11/13/19.

215 California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Chart.aspx. Accessed 07/12/12.

216 The pre- and post- energy values are calculated using the ENERGY STAR® calculator and the inputs from Table 140 and Table 141. http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

Steam Cooker Type	N_{pan}	kWh_{base}	kWh_{Post}	Annual Energy Savings [kWh]	Peak Demand Savings [kW]
	6-Pan and Larger	34,080	14,090	19,990	4.199
Steam Generator	3-Pan	17,599	7,632	9,967	2.093
	4-Pan	21,884	9,777	12,107	2.543
	5-Pan	26,132	11,946	14,186	2.980
	6-Pan and Larger	30,360	14,090	16,270	3.417

Measure Life and Lifetime Savings.

The EUL has been defined for this measure as 12 years, consistent with both ENERGY STAR® specifications and DEER 2014 EUL update (EUL ID—Cook-ElecStmCooker).

Program Tracking Data and Evaluation Requirements

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

- High efficiency manufacturer and model number
- Number of pans
- Copy of ENERGY STAR® certification
- 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. Accessed 11/13/2019.
- DEER 2014 EUL update.

Document Revision History

Table 143: 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.

2.4.8 Demand Controlled Kitchen Ventilation

TRM Measure ID: NR-FS-KV

Market Sector: Commercial

Measure Category: Food Service

Applicable Building Types: Restaurants

Fuels Affected: Electricity

Decision/Action Type: Retrofit or 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 or 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.[217] 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.[218] 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

$$kWh_{savings} = AvgSav_{kWh/_{HP}} \times HP_{exhaust} \times Hrs_{day} \times Days_{yr} \times MAU + \left(Heat_{savings} + Cooling_{savings}\right) \times \frac{CFM_{outdoor}}{1000}$$

Equation 107

$$kW_{savings} = kWh_{savings} \times PWPLS$$

Equation 108

Where:

$AvgSav_{kWh/_{HP}}$ = *Average hourly energy savings per horsepower based on the building type, see Table 144*

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

Hrs_{day} = *Average daily operating hours, facility specific; if unknown, use defaults from Table 144*

$Days_{yr}$ = *Number of operational days per year, facility specific; if unknown use defaults from Table 144*

MAU = *Make-up Air Unit factor applied to account for presence of dedicated MAU; value = 1 if there is a dedicated MAU; see Table 144 for values when there is no dedicated MAU*

$Heat_{savings}$ = *Interactive heating savings per 1,000 CFM of outdoor air; see Table 145*

$Cooling_{savings}$ = *Interactive cooling savings per 1,000 CFM of outdoor air; see Table 145*

$CFM_{outdoor}$ = *Cubic feet per minute of outdoor air supplied by the HVAC system, facility specific*

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

[218] https://fishnick.com/ventilation/oalc/, Accessed August 2018.

$PWPLS \quad = \quad$ *Probability Weighted Peak Load Share; see Table 146*

Table 144: 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[219]	0.650	15	365	0.65
24-Hr Restaurant/Hotel[220]	0.631	24	365	0.65
School Café with summer[221]	0.566	11	325	0.51
School Café without summer	0.566	11	252	0.51

Table 145: Demand Controlled Kitchen Ventilation – Interactive HVAC Savings per 1,000 CFM

Climate Zone	Building Type	Energy Savings (kWh) per 1,000 CFM of outdoor air		
		ER Heat	HP Heat	Cooling
1	Casual Dining/Fast Food	4,264	1,890	315
	24-Hr Restaurant/Hotel	10,962	4,858	441
	School Café with summer	3,296	1,460	235
	School Café without summer	3,289	1,457	107
2	Casual Dining/Fast Food	2,467	1,093	581
	24-Hr Restaurant/Hotel	6,385	2,829	910
	School Café with summer	1,912	847	434
	School Café without summer	1,912	847	211
3	Casual Dining/Fast Food	1,669	740	616
	24-Hr Restaurant/Hotel	4,593	2,035	954
	School Café with summer	1,282	568	496
	School Café without summer	1,281	568	296
4	Casual Dining/Fast Food	1,019	452	721
	24-Hr Restaurant/Hotel	2,971	1,316	1,171
	School Café with summer	776	344	579
	School Café without summer	776	344	357
5	Casual Dining/Fast Food	2,094	928	529
	24-Hr Restaurant/Hotel	6,240	2,765	782
	School Café with summer	1,666	738	401
	School Café without summer	1,663	737	233

219 All values are the average of Casual and Quick Service Restaurant data from Future of DCV for Commercial Kitchens.
220 All values are the average of Hotel Restaurant data from Future of DCV for Commercial Kitchens.
221 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 144.

Table 146: Demand Controlled Kitchen Ventilation – Probability Weighted Peak Load Share[222]

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

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this VFD measure is 15 years per both the PUCT-approved Texas EUL filing (Docket No. 36779) and DEER 2014 (EUL ID—HVAC-VSD-fan).

Program Tracking Data and Evaluation Requirements

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

- Kitchen ventilation system exhaust fan horsepower
- Kitchen ventilation makeup air unit fan horsepower, if present
- Presence of dedicated makeup air unit
- Heating system type
- CFM of outdoor air supply

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

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

Document Revision History

Table 147: Demand Controlled Kitchen Ventilation Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

2.4.9 Commercial 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, replace-on-burnout, or new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure applies to 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.

Baseline Condition

The baseline condition is an ice maker meeting the federal standards published in 10 CFR 431 and listed in Table 148. 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 148: Ice Maker Baseline Efficiency[223]

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

[223] Code of Federal Regulations, Title 10 Part 431 for automatic commercial ice maker with capacities between 50 and 4,000 pounds per 24-hour period manufactured on or after January 28, 2018.

High-efficiency Condition

The high-efficiency ice machines must be ENERGY STAR® rated. To do so, they meet the following maximum energy consumption (kWh/100 lbs ice), as shown in Table 149.

Table 149: ENERGY STAR® Criteria - Automatic Ice Makers[224]

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

Savings for ice makers come from the increase in machine efficiency and can be calculated according to the following algorithms.

Savings Algorithms and Input Variables

$$Annual\ Energy\ Savings\ [kWh] = (UseRate_{base} - UseRate_{\mathrm{ESTAR}}) \times \frac{Harvest\ Rate}{100} \times Duty\ Cycle \times Days$$

[224] 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, Accessed August 2019.

Equation 109

$$Demand\ Savings\ [kW] = Annual\ Energy\ Savings\ \times PLS$$

Equation 110

Where:

$UseRate_{base}$	=	*The rated energy consumption (kWh) per 100 pounds of ice,* Table 148 *of the baseline machine.*
$UseRate_{ESTAR}$	=	*The rated energy consumption (kWh) per 100 pounds of ice,*
Harvest Rate	=	*Pounds of ice produced per 24 hours*
Duty Cycle	=	*Machine duty cycle, 80%*[225]
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,* Table 150

Table 150: Probability-weighted Peak Load Share - Ice Makers

Probability Weighted Peak Load Share (PLS)[226]		
Climate Zone	**Summer Peak**	**Winter Peak**
1	0.00012	0.00011
2		0.00011
3		0.00011
4		0.00012
5		0.00012

Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure.

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, Appendix B: Peak Demand Reduction Documentation for further details on

[225] 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.

[226] 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. Accessed August 2019.

peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for automatic ice makers is 8.5 years.[227]

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:

- Machine Type
  - IMH, RC, or SCU
  - Batch or continuous
- Machine harvest rate
- Climate zone
- Annual days of use

References and Efficiency Standards

Petitions and Rulings

None

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, Accessed August 2019.

Document Revision History

Table 151: Commercial Ice Makers Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

[227] 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.

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-linear foot of display case basis.

Eligibility Criteria

Not applicable.

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 ($t_{d\text{-}out}$) using the following equation:

$$t_{d-in} = 0.005 \times t_{d-out}^2 + 0.172 \times t_{d-out} + 19.870$$

Equation 111

The baseline assumes door heaters are running on an 8,760 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 percent) at 52.87ºF for a typical supermarket. 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 112

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 at:

For medium temperature:

$$kW_{ASH} = 0.109\ per\ door\ or\ 0.0436\ per\ linear\ foot\ of\ door$$ [228,229]

For low temperature:

$$kW_{ASH} = 0.191\ per\ door\ or\ 0.0764\ per\ linear\ foot\ of\ door$$ [230,231]

Equation 113

[228] (Pennsylvania TRM) State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.

[229] Three door heater configurations are presented: standard, low-heat, and no-heat. The standard configuration was chosen on the assumption that low-heat and no-heat door cases will be screened from participation.

[230] (Pennsylvania TRM) State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.

[231] Three door heater configurations are presented: Standard, low-heat, and no-heat. The standard configuration was chosen on the assumption that low-heat and no-heat door cases will be screened from participation.

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 114

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

Equation 115

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,[232] the cooling load contribution from door heaters can be given by:

$$Q_{ASH}(ton - hrs) = 0.35 \times kW_{ASH} \times \frac{3413\frac{Btu}{hr}}{12000\frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 116

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 0.87.[233]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 152.

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

Equation 117

Where:

a	=	3.75346018700468
b	=	-0. 049642253137389
c	=	29.4589834935596

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

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

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	=	*ambient design temperature+ 15*

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 118

Where:

a	=	*9.86650982829017*
b	=	*-0.230356886617629*
c	=	*22.905553824974*
d	=	*0.00218892905109218*
e	=	*-2.48866737934442*
f	=	*-0.248051519588758*
g	=	*-7.57495453950879 x* 10^{-6}
h	=	*2.03606248623924*
i	=	*-0.0214774331896676*
j	=	*0.000938305518020252*
PLR	=	*1/1.15 = 0.876956521739*
SCT	=	*Ambient design temperature+10*

Table 152: Values Based on Climate Zone City

Climate Zone	Summer Design Dry Bulb Temp[234]	SCT_{MT}	SCT_{LT}	EER_{MT}	EER_{LT}
Amarillo	96	111	106	6.44	4.98
Dallas-Ft. Worth	100	115	110	6.05	4.67
El Paso	101	116	111	5.95	4.59
Houston	96	111	106	6.44	4.98
McAllen	100	115	110	6.05	4.67

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 119

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

Equation 120

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 121

Total energy savings is a result of the baseline and post-Retrofit case:

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

Equation 122

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:

$$Peak\ Demand\ Savings = \frac{kWh_{refrig-baseline} - kWh_{refrig-post}}{8760}$$

Equation 123

Deemed Energy and Demand Savings Tables

The energy and demand savings of anti-sweat door heater controls are deemed values based on city and refrigeration temperature. The following table provides these deemed values.

[234] ASHRAE Climatic Region Data, 0.5% (°F).

Table 153: Deemed Energy and Demand Savings Values by Location and Refrigeration Temperature in kWh per Linear Foot of Display Case

Pre-rinse Spray Valve Electric Savings	Medium Temperature		Low Temperature	
	Annual Energy Savings [kWh/ft.]	Peak Demand Savings [kW/ft.]	Annual Energy Savings [kWh/ft.]	Peak Demand Savings [kW/ft.]
Amarillo	364	0.007	668	0.015
Dallas	249	0.005	457	0.011
El Paso	405	0.008	745	0.018
Houston	180	0.003	330	0.007
McAllen	137	0.003	251	0.006

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years per the PUCT approved Texas EUL filing (Docket No. 36779). It is also consistent with the DEER 2014 EUL update (EUL ID—GrocDisp-FixtDrGask).

Program Tracking Data and Evaluation Requirements

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

- Regional climate zone
- Refrigeration temperature

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. Accessed 11/13/2019. https://interchange.puc.texas.gov/Documents/40669_7_736775.PDF. Accessed 11/13/2019.
- PUCT Docket 36779—Provides EUL for Anti-Sweat Heater Controls

Relevant Standards and Reference Sources

- DEER 2014 EUL update

Document Revision History

Table 154: 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 117 and Equation 118.
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.

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 deemed savings 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 124

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapCool} \times \left(1 + \frac{1}{COP_{cooler}}\right)$$

Equation 125

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

Equation 126

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

Equation 127

Freezer

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

Equation 128

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapFreeze} \times \left(1 + \frac{1}{COP_{freezer}}\right)$$

Equation 129

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

Equation 130

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

Equation 131

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}	=	*Coefficient of performance of compressor in the cooler*
$COP_{freezer}$	=	*Coefficient of performance of compressor in the freezer*
Hours	=	*The annual operating hours are assumed to be 8,760 for cases and 8,273 for walk-ins*
%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%.*

Table 155: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
W_{base}	See Table 156
W_{ee}	See Table 156
LF[235]	0.9
$DC_{EvapCool}$[236]	100%
$DC_{EvapFreeze}$[237]	94.4%
COP_{cooler}	See Table 157
$COP_{freezer}$	See Table 157
Hours[238]	8760 or 8273[239]
%OFF	0 or 46%

235 "ActOnEnergy; Business Program-Program Year 2, June 2009 through May 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009.

236 "Efficiency Maine; Commercial Technical Reference User Manual No. 2007-1." Published 3/5/07.

237 Ibid.

238 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.

239 Efficiency Vermont, Technical Reference User Manual 2014-87, 3/16/2015. Hours of operation accounts for defrosting periods where motor is not operating. https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf.

Table 156: Motor Sizes, Efficiencies, and Input Watts[240]

Motor Eff. and Power Table							
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	18%	50	41%	22	66%	14
1/40 HP (16-23W)	19.5	21%	93	41%	48	66%	30
1/20 HP (37W)	37	26%	142	41%	90	66%	56
1/15 HP (49W)	49.0	26%	188	41%	120	66%	74
1/4 HP	186.5	33%	559	41%	455	66%	283
1/3 HP	248.7	35%	714	41%	607	66%	377

Table 157: Compressor Coefficient of Performance Based on Climate and Refrigeration Type (COP_{cooler} or $COP_{freezer}$)

Representative Climate City	Summer Design Dry Bulb Temperature, ASHRAE Fundamentals 2009	COP_{cooler}	$COP_{freezer}$
Amarillo	96	1.88	1.46
Fort Worth	100	1.77	1.37
El Paso	101	1.74	1.35
Houston	96	1.89	1.46
McAllen	100	1.77	1.37

Deemed Energy and Demand Savings Tables

The energy and demand savings of ECMs are calculated using a deemed algorithm, based on city, refrigeration temperature, and whether the motors have controls. Evaporator fan nameplate data, rated power, and efficiency is also required.

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 15 years as defined by the DEER 2014 EUL update (EUL ID—GrocDisp-FEvapFanMtr & GrocWlkIn-WEvapFanMtr).

Program Tracking Data and Evaluation Requirements

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

- Regional climate zone

240 The first four rows are from the Pennsylvania TRM and the last two rows are estimated using logarithmic linear regression of smaller motor efficiencies.

- Building type
- Motor efficiency
- Motor power rating
- Evaporator fan control type
- Refrigeration temperature

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.

Document Revision History

Table 158: 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.

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 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 following equations:

$$Energy\ [kWh] = \Delta kWh_{defrost} + \Delta kWh_{heat}$$

Equation 132

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

Equation 133

$$\Delta kWh_{heat} = \Delta kWh_{defrost} \times 0.28 \times Eff$$

Equation 134

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

Equation 135

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*
Hours	=	*Number of hours defrost occurs over a year without defrost controls*
DRF	=	*Defrost reduction factor—percent reduction in defrosts required per year*
0.28	=	*Conversion of kW to tons; 3,413 Btuh/kW divided by 12,000 Btuh/ton*
Eff	=	*Estimated efficiency based on climate and refrigeration type*

Table 159: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
DRF[241]	35%
Eff_{MT}[242]	Amarillo: 1.86 Dallas-Ft. Worth: 1.98 El Paso: 2.02 Houston: 1.86 McAllen: 1.98
Eff_{LT}[242]	Amarillo: 2.41 Dallas-Ft. Worth: 2.57 El Paso: 2.61 Houston: 2.41 McAllen: 2.57

[241] Energy and Resource Solutions (2005). *Measure Life Study.* Prepared for The Massachusetts Joint Utilities; supported by 3rd party evaluation: Independent Testing was performed by Intertek Testing Service on a Walk-in Freezer that was retrofitted with Smart Electric Defrost capability.

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

Deemed Energy and Demand Savings Tables

Not applicable.

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 10 years.[243]

Program Tracking Data and Evaluation Requirements

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

- Hours that defrost occurs over a year without defrost controls
- Load of electric defrost
- Refrigeration temperature (low temperature or medium temperature)
- Climate zone (Amarillo, Dallas-Fort Worth, El Paso, Houston, or McAllen)

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.

[243] Energy and Resource Solutions (2005). *Measure Life Study.* Prepared for The Massachusetts Joint Utilities.

Document Revision History

Table 160: 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.

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 following equations:

$$Energy\ [kWh] = \Delta kW \times 8760$$

Equation 136

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

Equation 137

Where:

kW_{evap} = *Connected load kW of each evaporator fan*

kW_{circ} = *Connected load kW of the circulating fan*

n_{fans} = *Number of evaporator fans*

DC_{comp} = *Duty cycle of the compressor*

DC_{evap} = *Duty cycle of the evaporator fan*

BF = *Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running*

8760 = *Annual hours per year*

Table 161: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
kW_{evap}[244]	0.123 kW
kW_{circ}[245]	0.035 kW
DC_{comp}[246]	50%
DC_{evap}[247]	Cooler: 100% Freezer: 94%
BF[248]	Low Temp: 1.5 Medium Temp: 1.3 High Temp: 1.2

244 Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts.

245 Wattage of fan used by Freeaire and Cooltrol.

246 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.

247 An evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day).

248 Bonus factor (1+ 1/COP) assumes 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.

Deemed Energy and Demand Savings Tables

Not applicable.

Measure Life and Lifetime Savings.

The EUL has been defined for this measure as 16 years per the PUCT approved Texas EUL filing (Docket No. 36779). This is consistent with the DEER 2014 EUL update (EUL ID—GrocWlkIn-WEvapFMtrCtrl).

Program Tracking Data and Evaluation Requirements

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

- Number of evaporator fans controlled
- Refrigeration type
- Refrigeration temperature

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 162: 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.

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 to decrease the cooling load of the case during the night. It is recommended that these film-type covers have small, perforated holes to decrease the build-up of moisture.

Eligibility Criteria

Any suitable 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 material sold as a night cover. The cover must be applied for a period of at least 6 hours per night. Vertical strip curtains may be in use 24 hours per day.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The following outlines the assumptions and approach used to estimate demand and energy savings due to the installation of night covers on open low- and medium-temperature, vertical and horizontal display cases. Heat transfer components of the display case include infiltration (convection), transmission (conduction), and radiation. This work paper assumes that installing night covers on open display cases will only reduce the infiltration load on the case. Infiltration affects cooling load in the following ways:

- Infiltration accounts for approximately 80 percent of the total cooling load of open vertical (or multi-deck) display cases.[249]
- Infiltration accounts for approximately 24 percent of the total cooling load of open horizontal (coffin or tub style) display cases.[249]

Installing night covers for a period of 6 hours per night can reduce the cooling load due to infiltration by:

- 8% on vertical cases[249]
- 50% on horizontal cases.[250]

The energy savings due to the reduced infiltration load when night covers are installed will vary based on the outdoor temperature and climate zone. As a result, the energy savings must be determined for each climate zone and typical outdoor temperatures when the covers are applied.

Once the infiltration load for each type of case was determined, the following steps were followed to determine the compressor power requirements and energy savings. It is important to reiterate that heat transfer in display cases occurs due to convection, conduction, and radiation. The analysis presented here is limited to the cooling load imposed by convection (infiltration) only and not the total cooling load of a particulate display case.

- In the base case, it is assumed that no night covers are installed on the cases and the infiltration cooling load for each bin can be given by:

$$Q_{baselineInfiltration}[ton - hours] = \frac{Q_{baselineInfiltration}[Btuh] \times Bin - hours}{12{,}000\ \left[\frac{Btu}{ton}\right]}$$

Equation 138

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios (EER) obtained from manufacturers' data.

- Determine the saturated condensing temperature (SCT)

[249] ASHRAE 2006. Refrigeration Handbook. Retail Food Store Refrigeration and Equipment. Atlanta, Georgia. p. 46.1, p. 46.5, p. 46.10.

[250] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. 2005. Run ID D03- 205. The EM&V team, Inc. p. 7-74 and 7-75. DEER.

For medium temperature (MT):

$$SCT = DB_{adj} + 15$$

Equation 139

For low temperature (LT):

$$SCT = DB_{adj} + 10$$

Equation 140

Where:

DB_{adj} = *Design dry-bulb temperature (ºF), based on climate zone, of ambient or space where the compressor/condensing units reside. Table 163 below lists design dry-bulb temperatures by climate zone.*

Table 163: Various Climate Zone Design Dry Bulb Temperatures and Representative Cities

Representative Climate Zone	Summer Design Dry Bulb Temperature, ASHRAE Climatic Region Data, 0.5% (ºF)[251]
Amarillo, Texas	96
Dallas-Ft. Worth, Texas	100
El Paso, Texas	101
Houston, Texas	96
McAllen, Texas	100

- Determine the EER for both MT and LT applications.
- Compressor performance curves were obtained from a review of manufacturer data for reciprocating compressors as a function of SCT, cooling load, and cooling capacity of compressor.[252]
- Part-load ratio (PLR) is the ratio of total cooling load (from Cooling Load Calculation Section) to compressor capacity. It indicates the percentage of compressor capacity needed to remove the total cooling load. It is calculated by the following equation:

$$PLR = \frac{Q_{cooling}}{Q_{capacity}}$$

Equation 141

Where:

PLR = *Part load ratio*

$Qcooling$ = *Cooling load*

[251] ASHRAE 2009 Handbook Fundamentals.
[252] Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPSCNRRN009 (rev.0.2007).

Qcapacity = *Total compressor capacity*[253]

$$Q_{capacity} = Q_{cooling} \times 1.15$$

Equation 142

$$PLR = \frac{1}{1.15} = 0.87$$

Equation 143

To simplify the analysis, it is assumed that PLR remains constant for the post-retrofit condition.

The energy efficiency ratio (EER) is a measure of how efficient a cooling system operates at a particular temperature. It is defined as the ratio of useful energy transfer to the work input. For refrigeration systems, it is the ratio of heat removed by the compressor (Btu/h) to the input power (Watts). The higher the EER the greater the efficiency of the system.

For medium temperature compressors, the following equation is used to determine the EER_{MT} (Btu/hr/watts). The equation uses SCT (from step 2), and a PLR of 0.87 (from step 3b).

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

Equation 144

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*

For low temperature compressors, the following equation is used to determine the EER_{LT} *(Btu/hr/watts). The equation uses SCT (from step 2), and a PLR of 0.87 (from step 3b).*

[253] Compressor capacity is determined by multiplying baseline cooling load by a compressor over-sizing factor of 15 percent.

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

Equation 145

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 = 0.00938305518020252

Convert EER to kW/ton

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

Equation 146

Energy used by the compressor to remove heat imposed due to infiltration in the base case for each bin reading is determined based on the calculated cooling load and EER, as outlined below.

$$kWh_{baseline-refrig-bin} = Q_{baseline-infiltration}[ton - hours] \times \frac{kW}{ton}$$

Equation 147

Total annual baseline refrigeration energy consumption is the sum of all bin values.

$$kWh_{baseline-refrig} = \sum kWh_{baseline-refrig-bin}$$

Equation 148

In the post-retrofit case, it is assumed that night covers are installed on the cases during the nights from midnight to 6:00 AM. During the day, the cases are uncovered and the total cooling load for each bin can be given by:

$$Q_{post-retrofit}[ton-hours] = \frac{Q_{baseline-infiltration}\,[Btuh] \times Daytime_{bin-hrs}}{12{,}000\,\left[\frac{Btuh}{ton}\right]} + \frac{(Q_{baseline-infiltration}\,[Btuh] - Q_{reduced-infiltration}\,[Btuh]) \times Nighttime_{bin-hrs}}{12{,}000\,\left[\frac{Btuh}{ton}\right]}$$

Equation 149

Steps 2 through 7 are repeated in the post-retrofit case to calculate the post-retrofit energy and demand usage.

The energy savings were determined as the difference between the baseline energy use and post-retrofit energy use:

$$\Delta kWh_{total} = kWh_{totalBaseline} - kWh_{totalPostRetrofit}$$

Equation 150

Deemed Energy and Demand Savings Tables

The energy and demand savings of night covers are based on PG&E Night Covers Work Paper. PG&E modeled the infiltration load of refrigerator cases without night covers and refrigerators with night covers to derive the energy savings. The PG&E report estimated savings for several climate zones. The climate zone (Amarillo, Texas) was chosen to represent the entire state.[254] The deemed energy and demand savings are shown below.

Table 164: Modeled Deemed Savings for Night Covers for Texas (per Linear Foot)

Measure	Energy Savings [kWh/ft]	Demand Savings [kW/ft]
Night Covers on Vertical Low-temperature Cases	45	0
Night Covers on Horizontal Low-temperature Cases	23	0
Night Covers on Vertical Medium-temperature Cases	35	0
Night Covers on Horizontal Medium-temperature Cases	17	0

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 5 years in the DEER 2014 EUL update (EUL ID—GrocDisp-DispCvrs).

[254] PUCT Docket No. 40669, page A-2 states that Amarillo, Texas was chosen as a conservative climate zone due to little variation between climate zones. This statement has not been expanded upon.

Program Tracking Data and Evaluation Requirements

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

- Display case type
- Refrigeration temperature

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

Document Revision History

Table 165: 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 for Equation 144 and Equation 145.
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.

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 and 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 reach-in doors for refrigerators and freezers, which are significantly more efficient. The high-efficiency criteria, developed by ENERGY STAR® and the Consortium for Energy Efficiency (CEE), relate the volume of the appliance to its daily energy consumption. These reach-in cases have better insulation and higher-efficiency than save energy over regular refrigerators and freezers. The unit of measurement is volume in cubic feet of the unit. These four most common sized refrigerators and freezers are reported here.

Eligibility Criteria

Solid- or glass-door reach-in refrigerators and freezers must meet CEE or ENERGY STAR® minimum efficiency requirements (See Table 167).

Baseline Condition

The baseline efficiency case is a regular 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 166.

Table 166: Baseline Energy Consumption[255,256]

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 CEE or ENERGY STAR® minimum efficiency requirements, as shown in Table 167 below:

Table 167: Efficient Energy Consumption[257]

Efficiency Standards	Refrigerator Daily Consumption [kWh]	Freezer Daily Consumption [kWh]
Solid Door		
0 < V < 15	0.089V + 1.411	0.250V + 1.250
15 ≤ V < 30	0.037V + 2.200	0.400V—1.000
30 ≤ V < 50	0.056V + 1.635	0.163V + 6.125
V ≥ 50	0.060V + 1.416	0.158V + 6.333
Glass Door		
0 < V < 15	0.118V + 1.382	0.607V + 0.893
15 ≤ V < 30	0.140V + 1.050	0.733V—1.000
30 ≤ V < 50	0.088V + 2.625	0.250V + 13.500
V ≥ 50	0.110V + 1.500	0.450V + 3.500

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 166 and Table 167, based on the volume of the units.

255 The baseline energy consumption has been estimated by the Foodservice Technology Center (FSTC), based on data of energy consumption of baseline Commercial refrigerators compiled by the California Energy Commission.

256 V = Interior volume [ft3] of a refrigerator or freezer (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).

257 ENERGY STAR® Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 2.0, U.S. Environmental Protection Agency. Accessed on 07/7/10. http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req.pdf.

The savings calculations are specified as:

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

Equation 151

$$Peak\ Demand\ [kW] = \frac{\Delta kWh}{8760} \times CF$$

Equation 152

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 166.*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 167.*
V	=	*Chilled or frozen compartment volume [ft³] (as defined in the Association of Home Appliance Manufacturers Standard HRF-1-1979)*
365	=	*Days per year*
8760	=	*Hours per year*
CF	=	*Summer peak coincidence factor (1.0)*[258]

Deemed Energy and Demand Savings Tables

Not applicable.

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years, per the PUCT Texas EUL filing (Docket No. 36779). This is consistent with the 2008 DEER database.[259]

<u>Program Tracking Data and Evaluation Requirements</u>

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

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

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[258] 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.

[259] DEER 2008, December 2008 Final Report.

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- ENERGY STAR® Commercial Refrigerators and Freezers. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CRF. Accessed 08/20/2013.
- Association of Home Appliance Manufacturers. HRF-1: Household Refrigerators, Combination Refrigerator-Freezers, and Household Freezers.

Document Revision History

Table 168: 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.

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 and 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 the main door is opened, reducing the cooling load. This results in a reduced compressor run-time, reducing energy consumption. This assumes that a walk-in door is open 2.5 hours per day every day, and 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 in a polyethylene strip curtain added to the walk-in cooler or freezer. Any suitable material sold as a strip cover for a walk-in unit is eligible if it covers the entire doorway.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Savings are derived from an M&V study.

Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are based on the assumption that the walk-in door is open 2.5 hours per day, every day, and the strip curtain covers the entire doorframe, and are shown below in Table 169.

Table 169: Deemed Energy and Demand Savings for Freezers and Coolers[260]

Savings	Coolers	Freezers
Energy [kWh]	422	2,974
Demand [kW]	0.05	0.35

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 4 years, per the PUCT Texas EUL filing (Docket No. 36779) and by the DEER 2014 EUL update (EUL ID—GrocWlkIn-StripCrtn).

Program Tracking Data and Evaluation Requirements

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

- Unit temperature (refrigerator or freezer)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- DEER 2014 EUL update

[260] Values based on analysis prepared by ADM for FirstEnergy utilities in Pennsylvania, provided by FirstEnergy on June 4th, 2010. Based on a review of deemed savings assumptions and methodologies from Oregon and California.

Document Revision History

Table 170: 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.

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 or 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

This measure cannot be used in conjunction with anti-sweat heat (ASH) controls. It is not eligible to be installed on cases above 0ºF.

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 (kWhASH) and the reduction in load on the refrigeration (kWhrefrig). These savings are calculated using the following procedures:

Indoor dew point ($t_{d\text{-}in}$) can be calculated from outdoor dew point ($t_{d\text{-}out}$) using the following equation:

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

Equation 153

The baseline assumes door heats are running on an 8,760 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 foot of door heater at:

For medium temperature:

kW_{Ash} = 0.109 per door or 0.0436 per linear foot of door

For low temperature:

kW_{Ash} = 0.191 per door or 0.0764 per linear foot of door

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 154

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

Equation 155

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,[261] the cooling load contribution from door heaters can be given by:

$$Q_{ASH}(ton - hrs) = 0.35 \times kW_{ASH} \times \frac{3413\frac{Btu}{hr}}{12000\frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 156

[261] *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 0.87.[262]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 152:

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

Equation 157

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	=	*ambient design temperature+ 15*

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 158

[262] *Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls.* Pacific Gas and Electric Company. May 29, 2009.

Where:

a	=	9.86650982829017
b	=	-0.230356886617629
c	=	22.905553824974
d	=	0.00218892905109218
e	=	-2.4886737934442
f	=	-0.248051519588758
g	=	$-7.57495453950879 \times 10^{-6}$
h	=	2.03606248623924
i	=	-0.0214774331896676
j	=	0.000938305518020252
PLR	=	0.87
SCT	=	ambient design temperature+10

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 159

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

Equation 160

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 161

Total energy savings is a result of the baseline and post-Retrofit case:

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

Equation 162

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:

$$Peak\ Demand\ Savings = \frac{kWh_{refrig-baseline} - kWh_{refrig-post}}{8760}$$

Equation 163

Table 171: Deemed Energy and Demand Savings Values by Location and Refrigeration Temperature in kWh per Linear Foot of Display Case

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]
Amarillo	1,132	0.129	2,074	0.237
Dallas	1,143	0.131	2,101	0.240
El Paso	1,147	0.131	2,109	0.241
Houston	1,132	0.129	2,074	0.237
McAllen	1,143	0.131	2,101	0.240

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years per the PUCT approved Texas EUL filing (Docket No. 36779) and the DEER 2014 EUL update (EUL ID—GrocDisp-ZeroHtDrs).

Program Tracking Data and Evaluation Requirements

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

- 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 172: 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.

2.5.9 Door Gaskets for Walk-in and Reach-in Coolers and Freezers

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 (RET)

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. An average baseline gasket efficacy[263] of 90 percent is assumed for this measure.

[263] 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.[264,265] 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 173 below.

Table 173: Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)

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[266] 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[267] to establish a cooling degree day (CDD) correlations across the 16 California climate zones. Figure 3 provides a summary comparison for coolers and Figure 4 for freezers. The resulting correlations are strong, with an R^2 of 0.85 for coolers and an R^2 of 0.88 for freezers, respectively.

[264] 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.
[265] Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010.
[266] 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. 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.
[267] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/zip/alltmy3a.zip

Figure 3: Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-in Display Cases (Coolers)

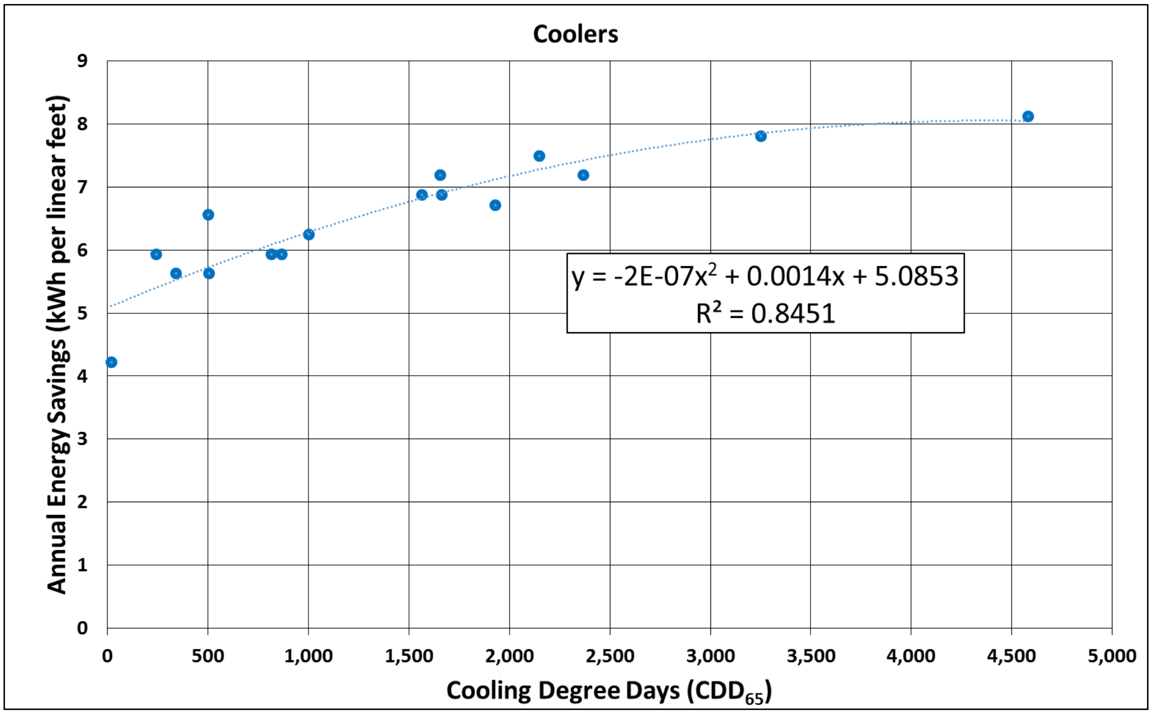
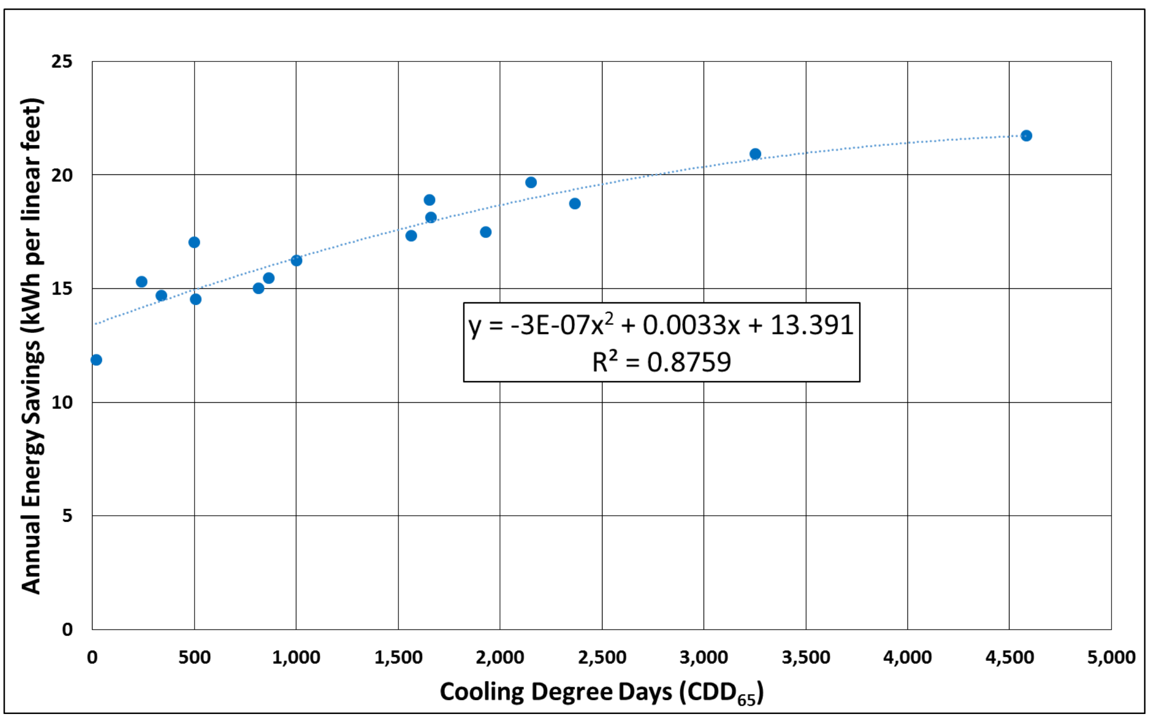


Figure 4: Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-in Display Cases (Freezers)



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 was applied to the PG&E results at 90 percent efficacy (as shown in Table 173 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 174 below.

Table 174: 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 (8760 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 164

$$Demand\ Savings\ [kW] = \frac{kWh_{Savings}}{8760} \times L$$

Equation 165

Where:

ΔkWh/ft = *Annual energy savings per linear foot of gasket (see Table 175)*

L = *Total gasket length (ft)*

Deemed Energy and Demand Savings Tables

Table 175: 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 (8760 hours).

Measure Life and Lifetime Savings

The EUL for this measure is 4 years, according to the California Database of Energy Efficiency Resources (DEER 2014).[268]

Program Tracking Data and Evaluation Requirements

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

- Building type (convenience store, supermarket, restaurant, refrigerated warehouse)
- Refrigerator type (walk-in or reach-in cooler or freezer)
- Total length of installed gasket (ft.)
- Presence of existing gasket (yes/no)
- Optional (if applicable): length of ineffective baseline gasket (feet), general description of baseline gasket condition (e.g., good, moderate, poor, non-existent), and primary reason for baseline gasket ineffectiveness (partial tear, torn and dislocated, rotted/dry, poor fit/shrink, missing, or other)

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.

[268] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 176: 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.

2.6 NONRESIDENTIAL: MISCELLANEOUS

2.6.1 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 section presents the deemed savings methodology 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

Not applicable.

Baseline Condition

Eligible baseline equipment is a 120-volt single phase vending machine manufactured and purchased prior to August 31, 2012.

High-efficiency Condition

Eligible equipment is a refrigerated vending machine or non-refrigerated snack machine (including warm beverage machines) without any controls. It is assumed that the display lighting has not been permanently disabled.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Not applicable

Deemed Energy and Demand Savings Tables

Energy and demand savings for different sized vending machines are deemed values, pieced together from different sources and studies, outlined in the following tables.

Table 177: Deemed Energy and Demand Savings Values by Equipment Type

Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW][269]
Control for Refrigerated Cold Drink Unit cans or bottles	1,612[270]	0.030
Control for Refrigerated Reach-in Unit any sealed beverage	1,086[271]	0.035
Control for Non-refrigerated Snack Unit with lighting (including warm beverage)	387[272]	0.006

Measure Life and Lifetime Savings

The EUL has been defined for this measure as 5 years per the PUCT approved Texas EUL filing (Docket No. 36779) and the DEER 2014 EUL update (EUL ID—Plug-VendCtrler).

Program Tracking Data and Evaluation Requirements

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

- Vending machine type - refrigerated cold drink unit, refrigerated reach-in unit, or non-refrigerated snack unit with lighting

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A:

[269] 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.

[270] Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

[271] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

[272] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF. Accessed 11/14/2019.

- 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. Accessed 11/14/2019.
- DEER 2014 EUL update.

Document Revision History

Table 178: 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.

2.6.2 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 (RET)

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.[273]

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.

[273] 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 quite 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 hotel/motel 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. 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[274] 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.[275]

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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[274] 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.

[275] A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 179: Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Representative City (Region)[276]	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)	0.059	267	0.075	380	0.059	341	0.075	441
Dallas-Fort Worth (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-Fort Worth (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 180: Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Representative City (Region)	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-Fort Worth (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-Fort Worth (North)	0.134	452	0.154	617	0.134	517	0.154	676

[276] 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".

Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC and Lighting		HVAC-Only		HVAC and Lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
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

Table 181: Deemed Energy and Demand Savings for Dormitories per Room, by Region

Representative City (Region)	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)	0.034	136	0.061	319	0.034	152	0.061	316
Dallas-Fort Worth (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-Fort Worth (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, Appendix B: Peak Demand Reduction Documentation” for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

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[277]. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

[277] Energy and Resource Solutions (2005). *Measure Life Study.* Prepared for the Massachusetts Joint Utilities; Table 1-1, Prescriptive Common Measure Life Recommendations, Large C&I retrofit, HVAC Controls, EMS.

Program Tracking Data and Evaluation Requirements

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

- HVAC system and equipment type
- Climate zone/region
- Temperature offset category (5 or 10 degrees F)
- Control type (HVAC-only, HVAC and lighting)
- Business/room type
- 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 182: 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.

2.6.3 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"[278] occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

Eligibility Criteria

The POC measure retrofit is available for existing wells (wells with an existing API number[279] 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.

[278] 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.

[279] 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 existing 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*[280] (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,*[281] 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. However, to develop Texas-specific stipulated values, field and metering data will be collected in 2015 and used to calibrate and update the savings calculation methods and input variables for a future version of the TRM.[282]

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 166

$$Demand\ Savings\ [kW] = \frac{EnergySavings}{8760}$$

Equation 167[283]

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 168

$$POC\%On = \frac{Run_{Constant} + Run_{Coefficient} \times VolumetricEfficiency\% \times TimeClock\%On \times 100}{100}$$

Equation 169[284]

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[280] 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).

[281] *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.

[282] The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

[283] The equations in the petition for peak demand simplify to the equation shown.

[284] 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%).

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 183*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 184*
SME	=	*Mechanical efficiency of sucker rod pump, see Table 183*
TimeClock%On	=	*Stipulated baseline timeclock setting, see Table 183*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956. Derived from SPE 16363* [285]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

[285] Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production,* (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

Deemed Energy and Demand Savings Tables

Table 183: Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/ Deemed Values
LF (Load Factor)	25%[286]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[287]
Timeclock%On	65%[288]

Table 184: NEMA Premium Efficiency Motor Efficiencies[289]

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 (8760 hours) is used, as shown in Equation 167.

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[286] *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.

[287] Engineering estimate for standard gearbox efficiency.

[288] A TimeClock%On of 80% is typical from observations in other jurisdictions, but that was adjusted to 65% for a conservative estimate. This value will be reevaluated once Texas field data is available.

[289] DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50.

Measure Life and Lifetime Savings

The EUL for this measure is 15 years.[290]

Program Tracking Data and Evaluation Requirements

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

- Motor make
- 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[291]

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.

[290] 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.

[291] 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.

- Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011.

Document Revision History

Table 185: 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.

2.6.4 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): Replace-on-burnout, new construction, early retirement

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[292].

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.[293] The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

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[292] 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

[293] Hunt, A. and Easley, S., 2012, "*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/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

Baseline Condition

The baseline condition is a 1 to 3 horsepower (hp) standard efficiency single-speed pool pump.

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. ENERGY STAR® has not published updates to the calculator for version 2.0; therefore, the deemed input assumptions that follow are based on certification version 1.0. This measure will be updated when the ENERGY STAR® Pool Pump Savings Calculator is updated to version 2.0.

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.[294]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

Equation 170

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:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours_{conv} \times days}{EF_{conv} \times 1000}$$

Equation 171

$$kWh_{ES} = kWh_{HS} + kWh_{LS}$$

Equation 172

$$kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$$

[294] 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.

Equation 173

$$kWh_{LS} = \frac{PFR_{LS} \times 60 \times hours_{LS} \times days}{EF_{LS} \times 1000}$$

Equation 174

Where:

kWh_{HS}	=	*ENERGY STAR® variable speed pool pump energy at high speed [kWh]*
kWh_{LS}	=	*ENERGY STAR® variable speed pool pump energy at low speed [kWh]*
$hours_{conv}$	=	*Conventional single-speed pump daily operating hours (Table 186)*
$hours_{HS}$	=	*ENERGY STAR® variable speed pump high speed daily operating hours (Table 187)*
$hours_{LS}$	=	*ENERGY STAR® variable speed pump low speed daily operating hours (Table 187)*
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] (Table 186)*
PFR_{HS}	=	*ENERGY STAR® variable speed pump high speed flow rate [gal/min] (Table 187)*
PFRconv	=	*ENERGY STAR® variable speed pump low speed flow rate [gal/min] (Table 187)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (Table 186)*
EF_{HS}	=	*ENERGY STAR® variable speed pump high speed energy factor [gal/W·hr] (Table 187)*
EF_{LS}	=	*ENERGY STAR® variable speed pump low speed energy factor [gal/W·hr] (Table 187)*
60	=	*Constant to convert between minutes and hours*
1,000	=	*Constant to convert from kilowatts to watts*

Table 186: Conventional Pool Pumps Assumptions[295]

New Rated Pump HP	$hours_{conv}$, limited hours[296]	$hours_{conv}$, 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			89.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ 3			102.6667	1.9987

Table 187: ENERGY STAR® Pool Pumps Assumptions[297]

New Rated Pump HP	$Hours_{HS}$ limited hours 298	$Hours_{HS}$ 24/7 Operation	$Hours_{LS}$ limited hours	$Hours_{LS}$ 24/7 Operation	PFR_{HS} (gal/min)	EF_{HS} (gal/W·h)	PFR_{LS} (gal/min)	EF_{LS} (gal/W·h)
≤ 1.25	6	12	6	12	70.00	3.01	40.30	6.78
1.25 < hp ≤ 1.75					78.00	2.74	41.80	6.71
1.75 < hp ≤ 2.25					89.70	2.40	44.80	6.50
2.25 < hp ≤ 2.75					90.00	2.44	45.70	5.96
2.75 < hp ≤ 3					102.00	1.99	51.00	6.07

Demand Savings Algorithms

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \left(\frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right)\right] \times \frac{DF}{days}$$

Equation 175

Where:

kWh_{HS} = *ENERGY STAR® variable speed pool pump energy at high speed [kWh]*

kWh_{LS} = *ENERGY STAR® variable speed pool pump energy at low speed [kWh]*

$hours_{conv}$ = *Conventional single-speed pump daily operating hours (Table 186)*

$hours_{HS}$ = *ENERGY STAR® variable speed pump high speed daily operating hours*

[295] Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[296] 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.

[297] ENERGY STAR® PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[298] Total pump operating hours at high and low speed are assumed to match conventional pump operating hours. Number of hours spent at high speed and low speed are estimated to meet requirements of the Texas Administrative Code, Title 25, Part 1, Chapter 2655, Subchapter L, Rule §265.187 which requires pool volume turnover every 6 hours.

		(Table 187)
$hours_{LS}$	=	*ENERGY STAR® variable speed pump low speed daily operating hours (Table 187)*
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 188*

Table 188: Demand Factors

Operation	Summer DF	Winter DF
24/7 Operation	1.0	1.0
Seasonal/Limited Hours	1.0	0.5

Deemed Energy Savings Tables

Table 189: ENERGY STAR® Variable Speed Pool Pump Energy Savings[299]

New Rated Pump HP	Year-Round Operation		Seasonal Operation (7 months)
	24/7 Operation	Limited Hours	
	kWh Savings	kWh Savings	kWh Savings
≤ 1.25	8,117	4,058	2,366
1.25 < hp ≤ 1.75	8,993	4,497	2,622
1.75 < hp ≤ 2.25	8,866	4,433	2,585
2.25 < hp ≤ 2.75	10,723	5,362	3,126
2.75 < hp ≤ 3	11,320	5,660	3,300

Deemed Summer Demand Savings Tables[300]

Table 190: ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings—For All Operating Profiles

New Rated Pump (HP)	Demand Savings (kW)
≤ 1.25	0.927
1.25 < hp ≤ 1.75	1.027
1.75 < hp ≤ 2.25	1.012
2.25 < hp ≤ 2.75	1.224
2.75 < hp ≤ 3	1.292

299 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.
300 Ibid.

Deemed Winter Demand Savings Tables

Table 191: ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings

New Rated Pump HP	Year-Round Operation. 24/7 Demand Savings (kW)	Year-Round and Seasonal Operation, Limited Hours Demand Savings (kW)
≤ 1.25	0.927	0.463
1.25 < hp ≤ 1.75	1.027	0.513
1.75 < hp ≤ 2.25	1.012	0.506
2.25 < hp ≤ 2.75	1.224	0.612
2.75 < hp ≤ 3	1.292	0.646

Claimed Peak Demand Savings

Table 192: ENERGY STAR® Variable Speed Pool Pump Claimed Demand Savings

New Rated Pump (HP)	Demand Savings (kW)
≤ 1.25	0.927
1.25 < hp ≤ 1.75	1.027
1.75 < hp ≤ 2.25	1.012
2.25 < hp ≤ 2.75	1.224
2.75 < hp ≤ 3	1.292

Additional Calculators and Tools

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.

Measure Life and Lifetime Savings

According to DEER 2014, the estimated useful life for this measure is 10 years.[301]

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
  - Pool pump rated horsepower
  - Climate zone

[301] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

- Proof of purchase including quantity, make, and model information
- Copy of ENERGY STAR® certification

- 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-nurnout, 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

Document Revision History

Table 193: 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.

2.6.5 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.

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, and assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night.

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.

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 176

$$kW_{savings} = kWh_{savings} \times PWPLS$$

Equation 177

Where:

W_{active}	=	*total wattage of the equipment, including computer and monitor, in active/idle mode; see Table 194*
$hrs_{active_{pre}}$	=	*annual number of hours the computer is in active/idle mode before computer management software is installed; see Table 195*
$hrs_{active_{post}}$	=	*annual number of hours the computer is in active/idle mode after computer management software is installed; see Table 195*
W_{sleep}	=	*total wattage of the equipment, including computer and monitor, in sleep mode; see Table 194*
$hrs_{sleep_{pre}}$	=	*annual number of hours the computer is in sleep mode before computer management software is installed; see Table 195*
$hrs_{sleep_{post}}$	=	*annual number of hours the computer is in sleep mode after computer management software is installed; see Table 195*
W_{off}	=	*total wattage of the equipment, including computer and monitor, in off mode; see Table 194*
$hrs_{off_{pre}}$	=	*annual number of hours the computer is in off mode before computer management software is installed; see Table 195*
$hrs_{off_{post}}$	=	*annual number of hours the computer is in off mode after computer management software is installed; see Table 195*
1,000	=	*Conversion factor: 1 kW / 1,000 W*
$PWPLS$	=	*Probability weighted peak load share; see Table 196*

Table 194: Computer Power Management - Equipment Wattages[302]

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional Monitor[303]	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 195: Computer Power Management – Operating Hours[304]

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-work days/year)	6,294	1,175	0	2,105	2,466	5,480
Typical school (8 hours/day, 5 days/week, 113 non-school days/year)	6,006	727	0	1,970	2,754	6,063

Table 196: Computer Power Management – Probability Weighted Peak Load Share, All Activity Types

Climate Zone	Summer PWPLS	Winter PWPLS
1	0.108	0.018
2	0.104	0.020
3	0.110	0.020
4	0.103	0.023
5	0.125	0.047

[302] 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.

[303] Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR Office Equipment Calculator.

[304] 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.

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 194, Table 195, and Table 196. The following tables provide these deemed values.

Table 197: Computer Power Management - Deemed Energy Savings Values, All Climate Zones

Equipment	Office	School
Conventional LCD Monitor	92.1	95.0
Conventional Computer	238.5	246.2
Conventional Notebook	71.5	73.8
ENERGY STAR Monitor	75.5	77.8
ENERGY STAR Computer	132.5	136.9
ENERGY STAR Notebook	40.8	42.2

Table 198: Computer Power Management - Deemed Demand Savings Values, Office

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Conventional LCD Monitor	0.010	0.002	0.010	0.002	0.010	0.002	0.010	0.002	0.012	0.004
Conventional Computer	0.026	0.004	0.025	0.005	0.026	0.005	0.025	0.005	0.030	0.011
Conventional Notebook	0.008	0.001	0.007	0.001	0.008	0.001	0.007	0.002	0.009	0.003
ENERGY STAR Monitor	0.008	0.001	0.008	0.001	0.008	0.002	0.008	0.002	0.009	0.004
ENERGY STAR Computer	0.014	0.002	0.014	0.003	0.015	0.003	0.014	0.003	0.017	0.006
ENERGY STAR Notebook	0.004	0.001	0.004	0.001	0.005	0.001	0.004	0.001	0.005	0.002

Table 199: Computer Power Management - Deemed Demand Savings Values, School

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Conventional LCD Monitor	0.010	0.002	0.010	0.002	0.010	0.002	0.010	0.002	0.012	0.004
Conventional Computer	0.027	0.004	0.026	0.005	0.027	0.005	0.025	0.006	0.031	0.012
Conventional Notebook	0.008	0.001	0.008	0.001	0.008	0.001	0.008	0.002	0.009	0.003
ENERGY STAR Monitor	0.008	0.001	0.008	0.002	0.009	0.002	0.008	0.002	0.010	0.004
ENERGY STAR Computer	0.015	0.002	0.014	0.003	0.015	0.003	0.014	0.003	0.017	0.006
ENERGY STAR Notebook	0.005	0.001	0.004	0.001	0.005	0.001	0.004	0.001	0.005	0.002

Measure Life and Lifetime Savings

The EUL of this measure is based on the useful life of the computer equipment which is being controlled, 3 years.[305]

Program Tracking Data and Evaluation Requirements

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

- Type of equipment
  - Conventional or ENERGY STAR®
  - Monitor, computer, or notebook
- Type of application
  - Office or education

References and Efficiency Standards

Petitions and Rulings

This section is not applicable

Relevant Standards and Reference Sources

This section is not applicable

Document Revision History

Table 200: Computer Power Management Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

[305] Internal Revenue Service, 1.35.6.10, Property and Equipment Capitalization, Useful life for Laptop and Desktop Equipment. https://www.irs.gov/irm/part1/irm_01-035-006 July, 2016.

2.6.6 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: Replace-on-burnout, new construction, early retirement

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 15 years. To determine the remaining useful life of an existing unit, see Table 205. 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 and sold in the United States from December 19, 2010 to June 1, 2016, effectively replacing legislation commonly referred to as EPAct 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)[306].

With these changes, motors ranging from one to 500 hp bearing the “NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

[306] 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.k. Accessed September 2019.

Additiontally, 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)[307] (see Table 204) 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)[308], as listed in Table 206.

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 204.

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.

[307] 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.k. Accessed September 2019.
[308] 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.k. Accessed September 2019.

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 201 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 178

Demand Savings Algorithms

HVAC Applications:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{Hrs}\right) \times CF$$

Equation 179

Industrial Applications[309]:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{8{,}760\ hours}\right)$$

Equation 180

Where:

hp = *Nameplate horsepower data of the motor*

0.746 = *hp-to-kWh conversion Factor (kW/hp)*[310]

LF = *Estimated load factor (if unknown, see Table 201 or Table 202)*

[309] Assumes 3-shift operating schedule

[310] 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

$\eta_{baseline,ROB}$ = *Original motor efficiency (if unknown, see Table 204)*[311]

η_{post} = *Efficiency of the newly installed motor*

Hrs = *Estimated annual operating hours (if unknown, see Table 201 or Table 202)*

CF = *Coincidence Factor (see Table 201)*

$kWh_{savings,ROB}$ = *Total energy savings for a new construction or ROB project*

$kW_{savings,ER}$ = *Total demand savings for a new construction or ROB project*

Table 201: Premium Efficiency Motors – HVAC Assumptions by Building Type

Building Type	Load Factor[312]	CF[313]	HVAC Fan Hours[314]
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

[311] In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 203

[312] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. Accessed September 2019 http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

[313] 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

[314] Factors are equivalent to Table 74 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 202: Premium Efficiency Motors – Industrial Assumptions by Building Type

Industrial Processing	Load Factor[315]	Hours[316]					
		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 203: Rewound Motor Efficiency Reduction Factors[317]

Motor Horsepower	Efficiency Reduction Factor
< 40	0.010
≥ 40	0.005

[315] United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. Accessed 09/2019. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf
[316]United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. Accessed 09/2019. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf
[317] 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

Table 204: Premium Efficiency Motors – Replace-on-Burnout Baseline Efficiencies by Motor Size[306,310]

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
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	95.4	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

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 (15—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 205*); 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 205: Remaining Useful Life (RUL) of Replaced Motor

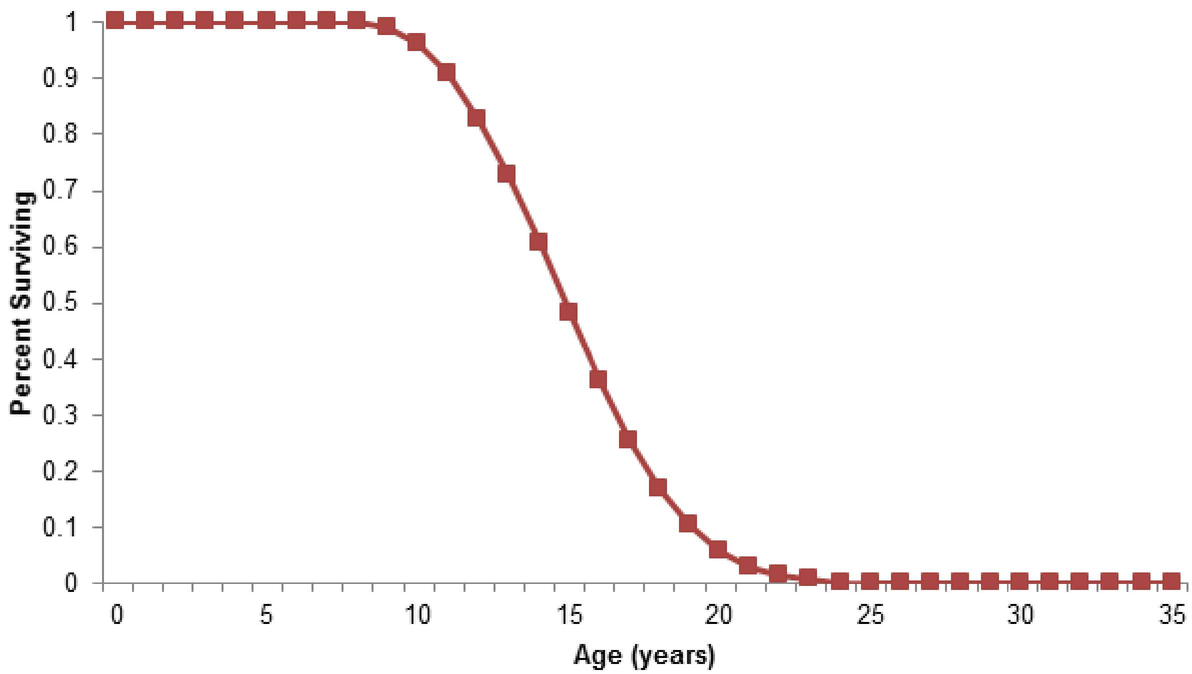
Age of Replaced Motor (years)	RUL (years)	Age of Replaced Motor (years)	RUL (years)
1	13.9	10	5.0
2	12.9	11	4.2
3	11.9	12	3.6
4	10.9	13	3.0
5	9.9	14	2.5
6	8.9	15	2.0
7	7.9	16	1.0
8	6.9	17[318]	0.0
9	5.9		

[318] RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see **Error! Reference source not found.**). Systems older than 17 years should use t he ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

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 5.

Figure 5: Survival Function for Premium Efficiency Motors[319]



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 5. 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.

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[319] 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.

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 181

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 182

It follows that total lifetime energy savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations as follows:

$$kWh_{savings,ER} = kWh_{savings,RUL} \times RUL + kWh_{savings,EUL} \times (EUL - RUL)$$

Equation 183

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 184

Industrial Applications:

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8{,}760\ hours}$$

Equation 185

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 186

Industrial Applications:

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8{,}760\ hours}$$

Equation 187

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 188

Where:

$\eta_{baseline,ER}$ = *Original motor efficiency for remaining EUL time period (if unknown, see Table 206)*[320]

$kWh_{savings,RUL}$ = *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 206: Premium Efficiency Motors – Early Retirement Baseline Efficiencies by Motor Size[308]

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

[320] Ibid.

hp	Open Motors: $\eta_{baseline, ER}$			Closed Motors: $\eta_{baseline, ER}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
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

Deemed Energy and Demand Savings Tables

This section is not applicable

Measure Life and Lifetime Savings

The median estimated useful life (EUL) premium efficiency motors is 15 years[321].

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
- Estimated load factor
- Original motor and newly installed motor efficiency
- Description of motor service
- 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

This section is not applicable

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

[321] 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 207: Premium Efficiency Motors Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 origin.

2.6.7 Central Domestic Hot Water (DHW) Controls Measure Overview

TRM Measure ID: NR-MS-DC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Multifamily, lodging, nursing homes, dormitories, prisons, offices, and education

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET) and new construction (NC)

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

$$Annual\ Pump\ Energy\ Savings\ [kWh] = kW_{pump} \times (Pump\%On\_base - Pump\%On\_eff) \times Hours$$

Equation 189

$$Pump\ Demand\ Savings\ [kW] = Annual\ Pump\ Energy\ Savings\ \times PLS$$

Equation 190

Where:

kW_{pump} = *The demand used by the circulation pump, obtained from the project site. If unknown, assume 0.075 watts.*

Pump%On_base = *Baseline pump operation as percentage of time, 100%.*

Pump%On_eff = *Efficient pump operation as percentage of time, 7%*[322]*.*

Hours = *Hours per year, 8760.*

PLS = *Probability weighted peak load share,* Table 208*.*

Table 208: Central DHW Controls - Probability Weighted Peak Load Share[323]

Building Type	Commercial		Lodging[324]	
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
Zone 4	0.00016	0.00011	0.00012	0.00015
Zone 5	0.00018	0.00011	0.00012	0.00014

322 A 93% 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%; and “Energy-Efficiency Controls for Multifamily Domestic Hot Water Systems,” New York State Energy Research and Development Authority, average reduction of 99%.

323 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. Accessed August 2019.

324 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.

Thermal Distribution Savings Algorithm

$$Annual\ Thermal\ Energy\ Savings\ [kWh] = \#\ Units\ \times kWh_{reference}\ \times HDDAdjustment$$

Equation 191

$$Thermal\ Demand\ Savings\ [kW] = Annual\ Thermal\ Energy\ Savings\ \times PLS$$

Equation 192

Where:

# Units	=	*The number of dwelling units at the project site.*
$kWh_{reference}$	=	*Annual kWh energy savings from reference study, Table 209.*
HDDAdjustment	=	*Climate adjustment for Texas heating degree days, Table 210.*
PLS	=	*Probability weighted peak load share, Table 208.*

Table 209: Central DHW Controls - Reference kWh by Water Heater and Building Type[325]

Water Heater Type	Electric Resistance		Heat Pump	
Building Type	Low Rise	High Rise	Low Rise	High Rise
kWh Reference	539	332	211	130

Table 210: Central DHW Controls - HDD Adjustment Factors[326]

Climate Zone	HDD Adjustment
Zone 1	1.9
Zone 2	1.1
Zone 3	0.7
Zone 4	0.5
Zone 5	1.1

Deemed Energy Savings Tables

Table 211 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.

[325] 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.
[326] 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).

Table 211: 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 212 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 212: 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 213: 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
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

Pump Size	Climate Zone	Commercial		Lodging	
		Summer Peak kW	Winter Peak kW	Summer Peak kW	Winter Peak kW
≥ 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 214: 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for central DHW controls is 15 years.[327]

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

[327] DEER 2014.

- Water heater type: Electric resistance or heat pump
- If lodging, number of lodging units at project site

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- DEER 2014 EUL update.

Document Revision History

Table 215: Central DHW Controls Revision History

TRM Version	Date	Description of Change
v7.0	10/2019	TRM v7.0 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].

Option 1—Weighting Savings and Holding Measure Life Constant

Step 1: Determine the measure life for first-tier (FT) and second-tier (ST) components of the calculated savings:

$$First\ Tier\ (FT)\ Period = ML_{FT} = RUL$$

Equation 193

$$Second\ Tier\ (ST)\ Period = ML_{ST} = EUL - RUL$$

Equation 194

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:

$$\Delta kW_{FT} = kW_{replaced} - kW_{installed}$$

Equation 195

$$\Delta kW_{ST} = kW_{baseline} - kW_{installed}$$

Equation 196

$$\Delta kWh_{FT} = kWh_{replaced} - kWh_{installed}$$

Equation 197

$$\Delta kWh_{ST} = kWh_{baseline} - kWh_{installed}$$

Equation 198

Where:

ΔkW_{FT}	=	*First-tier demand savings*
ΔkW_{ST}	=	*Second-tier demand savings*
$kW_{replaced}$	=	*Demand of the first-tier baseline system, usually the retired system*[328]
$kW_{baseline}$	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[329]
$kW_{installed}$	=	*Demand of the replacement system*[330]
ΔkWh_{FT}	=	*First-tier energy savings*
ΔkWh_{ST}	=	*Second-tier energy savings*
$kWh_{replaced}$	=	*Energy Usage of the first-tier baseline system, usually the retired system*[328]
$kWh_{baseline}$	=	*Energy Usage of the second-tier baseline system, usually the baseline ROB system*[329]
$kWh_{installed}$	=	*Energy Usage of the replacement system*[330]

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 199

$$NPV_{ST,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ST}}\right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kW_{ST}$$

Equation 200

$$NPV_{FT,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{FT}}\right\} \times \Delta kWh_{FT}$$

Equation 201

$$NPV_{ST,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ST}}\right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kWh_{ST}$$

Equation 202

Where:

$NPV_{FT,\ kW}$	=	*Net Present Value (kW) of first-tier projects*
$NPV_{ST,\ kW}$	=	*Net Present Value (kW) of second-tier projects*

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328 Retired system refers to the existing equipment that was in use before the retrofit has occurred.

329 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).

330 Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

$NPV_{FT,\,kWh}$	=	*Net Present Value (kWh) of first-tier projects*
$NPV_{ST,\,kWh}$	=	*Net Present Value (kWh) of second-tier projects*
e	=	*Escalation Rate* [331]
d	=	*Discount rate weighted average cost of capital (per utility)* [331]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [331]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [331]
ML_{FT}	=	*First-tier Measure Life (calculated in Equation 193)*
ML_{ST}	=	*Second-tier measure life (calculated in Equation 194)*

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total,kW} = NPV_{FT,kW} + NPV_{T,kW}$$

Equation 203

$$NPV_{Total,kWh} = NPV_{FT,kWh} + NPV_{ST,kWh}$$

Equation 204

Where:

$NPV_{Total,\,kW}$	=	*Total capacity contributions to NPV of both first-tier and second-tier component*
$NPV_{Total,\,kWh}$	=	*Total energy contributions to NPV of both first-tier and second-tier component*

Step 5: Calculate the capacity and energy cost contributions to the NPV without weighting by demand and energy savings for a scenario using the original EUL:

$$NPV_{EUL,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}$$

Equation 205

$$NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}$$

Equation 206

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*

[331] 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 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:

$$Weighted\ kW = \frac{NPV_{Total.kW}}{NPW_{EUL,kW}}$$

Equation 207

$$Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPW_{EUL,kWh}}$$

Equation 208

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 203*
$NPV_{Total,\ kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 204*
$NPV_{EUL,\ kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 205*
$NPV_{EUL,\ kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 206*

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:

$$EUL_{kW} = \left. ln\left[\frac{NPV_{Total,kW} \times (d-e)}{\Delta kW_{FT} \times AC_{kW} \times (1+e)}\right] \middle/ ln\left[\frac{(1+e)}{(1+d)}\right] \right.$$

Equation 209

$$EUL_{kWh} = \left. ln\left[\frac{NPV_{Total,kWh} \times (d-e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1+e)}\right] \middle/ ln\left[\frac{(1+e)}{(1+d)}\right] \right.$$

Equation 210

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.