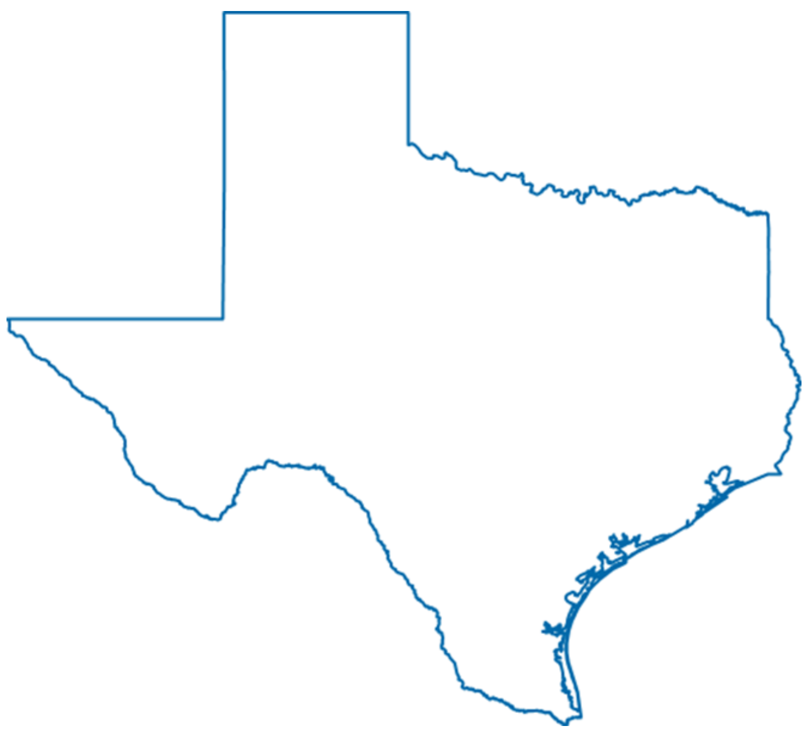
Public Utility Commission of Texas

Texas Technical Reference Manual

Version 5.0

Volume 3: Nonresidential Measures

Program Year (PY) 2018



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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 2001-2017 by Frontier Associates. 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 (katie.rich@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 & Verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

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

- Point estimates that provide a single deemed savings value that correspond 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 & 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 1-1: Nonresidential Deemed Savings by Measure Category

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	5.0 Update
Lighting	Lighting—Lamps and Fixtures	--	--	X	X	X	Building Type EFLH and CF additional categories and splits to existing categories. Code updates for IECC 2015 applied for most building types with ASHRAE 90.1-2013 for state funded building.
Lighting	Lighting Controls	--	--	X	X	X	Code updates for IECC 2015 and ASHRAE 90.1-2013 applied.
HVAC (Cooling)	AC Tune-Up	--	--	X	--	X	
HVAC (Cooling)	Package and Split-System (AC and Heat Pumps)	--	--	X	X	X	Updated efficiencies for IECC 2015 and added 24-hour building load shapes. Revised RUL table based on DOE survival curves. Revised baseline cooling efficiency tables for heat pumps to show electric resistance values. Corrected error on 11.3 to 20 tons baseline efficiencies for IEER.
HVAC (Cooling)	Chillers	--	--	X	X	X	Included Path A and Path B compliance options for chillers. Added 24-hour Retail loadshape. Revised RUL table based on DOE survival curves.
HVAC (Cooling)	Package Terminal Units and Room Air Conditioners (AC and Heat Pumps)	--	--	X	X	X	Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for IECC 2015. Updated RUL table based on DOE survival curves.
HVAC (Ventilation)	VFDs on AHU Supply Fans	--	X	X	--	--	Updated deemed energy/demand tables for revised peak demand definition.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	5.0 Update
HVAC (Cooling)	Condenser Air Evaporative Pre-Cooling	--	--	X	--	X	TRM v5.0 origin
Building Envelope	ENERGY STAR® Roofs	X	--	X	X	--	
Building Envelope	Window Treatments	X	--	X	X	--	
Food Service	ENERGY STAR® Combination Ovens Measure Overview	--	X	X	--	--	
Food Service	ENERGY STAR® Electric Convection Ovens	--	X	X	--	--	
Food Service	ENERGY STAR® Commercial Dishwashers	--	X	X	--	--	
Food Service	ENERGY STAR® Commercial Electric Hot Food Holding Cabinets	--	X	X	--	--	
Food Service	ENERGY STAR® Kitchen Electric Fryers	--	X	X	--	--	
Food Service	Pre-Rinse Spray Valves	--	X	X	--	--	
Food Service	ENERGY STAR® Electric Steam Cookers	--	X	X	--	--	

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	5.0 Update
Refrigeration	Door Heater Controls	--	X	X	--	--	
Refrigeration	ECM Evaporator Fan Motors	--	--	X	--	--	
Refrigeration	Electronic Defrost Control	--	--	X	--	--	
Refrigeration	Evaporator Fan Controls	--	--	X	--	--	
Refrigeration	Night Covers for Open Refrigerated Cases	--	X	X	--	--	
Refrigeration	High-Efficiency Solid & Glass Door Reach-in Cases	--	--	X	--	--	
Refrigeration	Strip Curtains for Walk-in Cooler/Freezer	--	X	--	--	--	
Refrigeration	Lowith No Anti-sweat Heat Glass Doors (Zero Energy Glass Doors)	--	X	X	--	--	
Miscellaneous	Vending Machine Controllers	--	X	X	--	--	
Miscellaneous	Lodging Guest Room Occupancy Sensor Control	--	X	--	--	--	
Miscellaneous	Pump-Off Controller	--	X	X	--	--	
Miscellaneous	ENERGY STAR® Pool Pumps	--	X	X	--	--	TRM v5.0 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: Calculator.

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, and 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, and other High Intensity Discharge (HID) lamps
- Light Emitting Diode (LED) screw-based lamps and 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 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 entered and used with the pre-loaded

[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.

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 this calculator.
- Fixture descriptions are selected from a Standard Fixture Wattage table.
- Factor Tables which contain stipulated operating hours, coincidence factors, and interactive HVAC factors.
- A Summary tab, where the final energy and demand calculations are displayed. 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 to all entities 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 in calculating 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 qualified by NEMA[3]. See High Efficiency Condition section for additional details.

LED lamps and fixtures must be qualified and listed by at least one of the following organizations: *DesignLights Consortium™ (DLC)*, *ENERGY STAR®*, or DOE LED Lighting Facts[4]. Links to these organizations and their qualified product lists are provided on the Texas Energy Efficiency website. Additionally, at the utilities discretion, LED products may receive approval if results of independent lab testing[5] (e.g. LM-79, LM-80, TM-21, ISTMT) show the products comply with the most current version of the DLC Technical Requirements.[6] In addition, when a product is non-qualified such as in the case of a product for which a qualification category has not been established, then a custom approach may also be used.[7] When programs such as DLC and ENERGY STAR® implement new technical requirements that

[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] DLC tech. requirements: https://www.designlights.org/content/qpl/productsubmit/categoryspecifications.

[7] If the QPL does not have a category for the lighting of interest to the customer, the utilities have worked with the EM&V team to submit these projects as custom lighting on a case-by-case basis.

enforce major shifts in product qualification, a grace period of 12 months may be used for implementation of the version change.

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.

[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.

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 2-1.

Table 2-1: 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

T12 Length	Lamp Count	Revised Lamp Wattage	Revised System Wattage
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
	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

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.

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[9], 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

[9] 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.

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[10,11]

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

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

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

Equation 4

Where:

kW_{pre}	=	*Total kW of existing measure (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)*
$kW_{installed}$	=	*Total kW of retrofit measure (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)*
LPD	=	*Acceptable Lighting Power Density based on building type from efficiency codes from Table 2-2 [W/ft2]*

[10] 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.

[11] 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.

Floor Area	=	*Floor area of the treated space where the lights were installed*
Hours	=	*Hours by building type from Table 2-4*
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 2-4*
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*

Each of the parameters in these equations, and the approach or their stipulated values, is 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 *Lighting Survey Form* maintained on the Texas Energy Efficiency website[12]. This table is used to assign identification codes and demand values (watts) to common fixture types (fluorescent, incandescent, HID, LED, etc.) used in commercial applications. The table is subdivided into lamp types such as linear fluorescent, compact fluorescent, mercury vapor, etc., with each subdivision sorted by fixture code. Each record, or row, in the Table contains a fixture code, which serves 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 in calculating 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 then periodically releases updates of the table.

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

[12] Frontier Associates *Lighting Survey Form*, *Fixture Description* tab: http://www.texasefficiency.com/images/documents/lsf_2013_v8.01_250%20rows.xlsm.

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. These values for interior space types are presented in Table 2-2.

In Table 2-3 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.

Table 2-2: New Construction LPDs for Interior Space Types by Building Type[13]

Facility Type	Lighting Power Density (W/ft^2)	Facility Type	Lighting Power Density (W/ft^2)
Automotive Facility	0.80	Multifamily	0.51
Convention Center	1.01	Museum	1.02
Courthouse	1.01	Office	0.82
Dining: Bar/Lounge/Leisure	1.01	Parking Garage	0.21
Dining: Cafeteria/Fast Food	0.90	Penitentiary	0.81
Dining: Family	0.95	Performing Arts	1.39
Dormitory	0.57	Police/Fire 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

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

Table 2-3: New Construction LPDs for Exterior Space Types[14]

Facility Type	Lighting Power Density (W/ft^2)			
	Zone 1	Zone 2	Zone 3	Zone 4
Uncovered Parking: Parking Areas and Drives	0.04	0.06	0.10	0.13
Building Grounds: Walkways $\geq$ 10 ft. wide, Plaza Areas, and Special Feature Areas	0.14	0.14	0.16	0.20
Building Grounds: Stairways	0.75	1.00	1.00	1.00
Building Grounds: Pedestrian Tunnels	0.15	0.15	0.20	0.30
Building Grounds: Landscaping (ASHRAE 90.1-2013 only)[15]	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)[16]	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[17]	--	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

Operating Hours (Hours) and Coincidence Factors (CFs)

Operating hours and peak demand coincidence factors are assigned by building type, as shown in Table 2-4. The building types used in this table are based on Commercial Buildings Energy Consumption Survey (CBECS)[18] building types, but have been modified for Texas.

[14] IECC 2015 Table C405.5.2(2) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.4.2-2. Differences between the two standards are noted.

[15] In June 2016, the TX 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.

[16] Ibid.

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

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

Table 2-4: Operating Hours and Coincidence Factors by Building Type[19]

Building Type Code	Building Type Description	Operating Hours	Summer Peak CF
Data Centers	Data Centers	4,008	77%
Educ. K-12, No Summer	Education (K-12 without Summer Session)	2,777	47%
Education, Summer	Education: College, University, Vocational, Day Care, and K-12 with Summer Session	3,577	69%
Non-24 Hour Retail	Food Sales—Non-24 Hour Supermarket/Retail	4,706	95%
24-Hr Restaurants	24 Hour Restaurants	7,311	90%
24-Hr Retail	24 Hour Supermarket/Retail	6,900	95%
Fast Food	Food Service—Fast Food	6,188	81%
Sit Down Rest.	Food Service—Sit-down Restaurant	4,368	81%
Health In	Health Care (In Patient)	5,730	78%
Health Out	Health Care (Out Patient)	3,386	77%
Lodging, Common	Lodging (Hotel/Motel/Dorm), Common Area	6,630	82%
Lodging, Rooms	Lodging (Hotel/Motel/Dorm), Rooms	3,055	25%
Manufacturing, 1 Shift**	Manufacturing, 1 shift operations is typically 9.5-11.5 hours per day and 4-6 days per week (<70 hours per week)	2,786	78%
Manufacturing, 2 Shifts**	Manufacturing, 2 shift operations is typically 18-20 hours per day and 5-6 days per week (70-120 hours per week)	5,188	85%
Manufacturing, 3 Shifts**	Manufacturing, 3 shift operations is typically 24 hours per day and 5-6 days per week (>120 hours per week)	6,414	85%
MF Common	Multi-family Housing, Common Areas	4,772	87%
Nursing Home	Nursing and Residential Care	4,271	78%
Office	Office	3,737	77%
Outdoor	Outdoor Lighting Photo-Controlled	3,996	0% (Winter peak = 61%)
Parking	Parking Structure	7,884	100%
Public Assembly	Public Assembly	2,638	56%
Public Order	Public Order and Safety	3,472	75%
Religious	Religious Worship	1,824	53%
Retail Non Mall/Strip	Retail (Excl. mall and strip center)	3,668	90%

[19] The operating hours and coincidence factors listed in this table 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 schedule may be claimed separately.

Building Type Code	Building Type Description	Operating Hours	Summer Peak CF
Enclosed Mall	Retail (Enclosed Mall)	4,813	93%
Strip/Non-Enclosed Mall	Retail (Strip Center and non-enclosed mall)	3,965	90%
Service (Non-Food)	Service (excl. food)	3,406	90%
Non-Refrig. Warehouse	Warehouse (non-refrigerated)	3,501	77%
Refrig. Warehouse	Warehouse (refrigerated)	3,798	84%

Note: These petition-approved values listed in this table come from PUCT Docket 39146. The exception to this is the Winter Peak factor of 61% for Outdoor Lighting (see Footnote 1313). Slight variations to these are found in other calculators and program manuals. A set of comparisons of HOU and CF across utilities are found in Appendix C.

* The CF for Data Centers, 24-Hr Restaurants, and Manufacturing, 1, 2 and 3 shift buildings were derived using the COMNET Appendix C—Schedules (Rev 3).[20]

** Manufacturing sites may be found with seasonability changes for shift operations. In these cases, the annual hours should be estimated and if they are found between two of the shift cases listed, then select the lower of the two.

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 but it also increases the heating load. Currently, the TRM only considers the additional cooling savings, and the heating penalty or increase in usage is ignored.

As Table 2-5 shows, four conditioned space types are used for the Texas programs. There is a single air-conditioned space type and two options for commercial refrigeration type spaces like walk-in coolers and refrigerated warehouses: Medium and Low temperature. Utility procedures state that if the actual application falls between these values, that 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 2-5: Deemed Energy and Demand Interactive HVAC Factors[21]

Space Conditioning Type	Energy Interactive HVAC Factor	Demand Interactive HVAC Factor
Air Conditioned	1.05	1.10
Med. Temp Refrigeration (33 to 41ºF)	1.25	1.25
Low Temp Refrigeration (-10 to 10ºF)	1.30	1.30
None (Unconditioned/Uncooled)	1.00	1.00

[20] https://comnet.org/appendix-c-schedules updated July 25, 2016.
[21] PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).

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[22]:

- 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[23]
- Light Emitting Diode: 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**: Lighting Power Density Factor
- **For New Construction Only**: Interior or Exterior Space Square Footage

[22] PUCT Docket 36779.
[23] PUCT Docket 38023.

- **For New Construction Only**: Verify if SECO compliance certification forms were filed[24]
- 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 Non-Operating Fixtures
- Post-Retrofit Fixture Configuration
- Post-Retrofit Lamp Wattage
- Post-Retrofit Lamp Specification Sheets
- Post-Retrofit Ballast Type
- Post-Retrofit Lighting Controls
- Post-Retrofit Counts of Operating Fixtures
- Equipment Operating Hours
- Lighting Measure Group (from Table 2-6).

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 "NonLED" 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.

[24] 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.

Table 2-6: Lighting Measure Groups to be used for Reporting Savings[25]

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)
Integral LED Lamp
High Intensity Discharge (HID)
Halogen

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Describes Effective Useful Life
- PUCT Docket 39146—Describes deemed values for energy and demand savings
- PUCT Docket 38023—Describes LED Installation and Efficiency Standards for non-residential 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[26])
- 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

[25] 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.

[26] 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.

- 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 9/19/2013
- United Illuminating Company and Connecticut Light & Power. Final Report, 2005 Coincidence Factor Study. http://webapps.cee1.org/sites/default/files/library/8828/CEE_Eval_CTCoincidenceFactorsC&ILightsHVAC_4Jan2007.PDF. Accessed 09/19/2013
- COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules updated July 25, 2016.

Document Revision History

Table 2-7: Nonresidential Lighting—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.

TRM Version	Date	Description of Change
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.

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: Calculator.

Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls would typically be installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, they 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 via 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 2-8.

Baseline Condition

The baseline condition assumes no existing or code required (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, day lighting, 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 k/W difference is replaced by a single kW value (the total fixture wattage controlled by the device).

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

Equation 5

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

Equation 6

Where:

$kW_{controlled}$ = *Total kW of controlled fixtures (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)*

$Hours$ = *Hours by building type from Table 2-4*

EAF = *Lighting control Energy Adjustment Factor, see Table 2-9*

PAF = *Lighting control Power Adjustment Factor, see Table 2-9*

CF = *Coincidence factor by building type, see Table 2-4*

$HVAC_{energy}$ = *Energy Interactive HVAC factor by building type, see Table 2-5*

$HVAC_{demand}$ = *Demand Interactive HVAC factor by building type, see Table 2-5*

See section 2.1.1 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 2-9. The EAF and PAF represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to a 24% 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 2-8: 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 2-9: Lighting Controls Energy and Power Adjustment Factors[27]

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[28]	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[29]	0.38	0.38

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[30]:

- Occupancy Sensor: 10 years

[27] Williams, Alison, Atkinson, Barbara, Garbesi, Karina, & 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.

[28] 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.

[29] For multiple control types, specify the installed control types by combining the control codes for the individual control types.

[30] 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.

- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 years.

Program Tracking Data & 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)
- Baseline Lighting Control Type Code
- Installed Lighting Control Type Code[31]
- Lighting Control Mount Type: Wall, Ceiling, Integrated Fixture, etc.
- Lighting Control Specification Sheets
- Controlled Fixture Configuration
- Controlled Fixture Lamp Type
- Controlled Fixture Wattage.

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, & Rubinstein, Francis, Lawrence Berkeley National Laboratory (LBNL). September 2011. Table 6, p. 14. Weighted average by 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.

[31] 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.

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.[32])

Document Revision History

Table 2-10: 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 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for Retrofit and New Construction projects.
v3.0	04/10/2015	TRM v3.0 update. Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a "controlled lighting watts" approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measure 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.

[32] 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.

2.2 NONRESIDENTIAL: HVAC

2.2.1 Air Conditioner or Heat Pump Tune-up Measure Overview

TRM Measure ID: NR-HV-TU

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 2-19 through Table 2-25

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

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. In order 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[33]

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

[33] 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 the 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 and 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 some or all 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 7

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

Equation 8

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 2-11.*
$HSPF_{pre}$	=	*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 2-11.*

Table 2-11: Default EER and HSPF per Size Category[34]

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, with the added specification that 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[35] HSPF, and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER[36] 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 $HSPF = 3.412 \times COP$.

[34] 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.

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

[36] 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.[37]

Heating energy savings are only applicable to heat pumps.

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

Equation 9

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

Equation 10

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

Equation 11

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 2-11 [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 2-11 [Btuh/W]*
$HSPF_{post}$	=	*Heating efficiency of the equipment after the tune-up [Btuh/W]*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone [hours]. See Table 2-21 through Table 2-25 in Section 2.2.2.*

Demand Savings Algorithms

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

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

Equation 12

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

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

Equation 13

Where:

DF_C = *Cooling Demand factor. See Table 2-21 through Table 2-25 in Section 2.2.2.*

DF_H = *Heating Demand factor. See Table 2-21 through Table 2-25 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. [38]

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is 3 years [39], and the estimated useful life of refrigerant charge adjustment is 10 years.[40] The other parts of the tune-up checklist

[38] 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.

[39] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx.

[40] 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 & 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 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 name plates are useful).

References and Efficiency Standards

This section is not applicable.

Document Revision History

Table 2-12: Nonresidential HVAC Single-Zone AC-HP 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.

2.2.2 Split System/Single Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: NR-HV-PS

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 2-19 through Table 2-25

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 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 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. In the event that the actual age of the unit is unknown, default values are provided.

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. In the event that this type of retrofit is performed, the tables from the HVAC Chillers measure will need to be referenced.

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 are 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 2-21 through Table 2-25. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- 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. An 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 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 an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 2-13 through Table 2-17 according to the capacity, system type, and age (based on year of manufacture) of the replaced system.[41] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-13 through Table 2-17 should be used. When the system age is unknown, assume an age of 17 years.[42]

Regarding the ER baseline efficiency tables, PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via early retirement programs, and included a category for 1990-1991. However, 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.

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-

[41] 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.

[42] 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, taking into account increments in efficiency standards that took place in the historical period.

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 2-13 through Table 2-17 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 2-13: ER Baseline Full-Load Efficiency for ACs

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER][43]	Package System < 5.4 tons [EER][44]	All Systems 5.4 to < 11.3 tons [EER][45]	All Systems 11.3 to < 20 tons [EER][45]	All Systems 20 to < 63.3 tons [EER][45]	All Systems ≥ 63.3 tons [EER][45]
≤ 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

[43] 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

[44] Ibid.

[45] 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 2-14: ER Baseline Part-Load Efficiency for ACs[46]

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][47]	All Systems 11.3 to < 20 tons [IEER][47]	All Systems 20 to < 63.3 tons [IEER][47]	All Systems ≥ 63.3 tons [IEER][47]
≤ 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 2-15: ER Baseline Full-Load Cooling Efficiency for HPs

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER][48]	Package System < 5.4 tons [EER][49]	All Systems 5.4 to < 11.3 tons [EER][50]	All Systems 11.3 to < 20 tons [EER][50]	All Systems 20 to < 63.3 tons [EER][50]	All Systems ≥ 63.3 tons [EER][50]
≤ 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

46 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.

47 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.

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

49 Ibid.

50 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 2-16: ER Baseline Part-Load Cooling Efficiency for HPs[51]

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][52]	All Systems 11.3 to < 20 tons [IEER][52]	All Systems 20 to < 63.3 tons [IEER][52]	All Systems ≥ 63.3 tons [IEER][52]
≤ 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 2-17: 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

[51] 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.

[52] 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 2-18. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.

Table 2-18: Baseline Efficiency Levels for ROB and NC Air Conditioners and Heat Pumps[53]

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source[54]
Air Conditioner	< 5.4	All	11.2 EER[55] 13.0 SEER (split) 11.8 EER[56] 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	

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

54 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.

55 There is no code specified EER for this size category. The code specified SEER value was converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ for systems < 5.4 tons. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

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

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source[54]
Heat Pump (cooling)[57]	< 5.4	Heat Pump	11.8 EER[58] 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)[59]	< 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 2-18.

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[60]:

- For early retirement projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling capacity
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences, cooling towers, and condensers).

[57] 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”.

[58] 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.

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

[60] From PUCT Docket #41070.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 14

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

Equation 15

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

Equation 16

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

Equation 17

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

Equation 18

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 2-18) [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 2-18) [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 19

DF	=	*Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-21 through Table 2-25)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 2-21 through Table 2-25)*

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 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 B.

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 are presented in Table 2-19 and Table 2-20. These building types are derived from the EIA CBECS study.[61]

The DF and EFLH values for packaged and split AC and HP units are presented in Table 2-21 through Table 2-25. 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 cannot use the deemed approach.

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

[61] 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.*

Table 2-19: Commercial HVAC Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[62]
Education	College	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 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
Large Multifamily	Midrise Apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.

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

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[62]
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[62]
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[62]
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 2-20: Commercial HVAC Floor Area and Floor Assumptions by Building Type[63]

Building Type	Principal Building Activity	Average Floor Area (ft^2)	Average # of Floors
Education	College	Not specified	Not specified
	Primary School	73,960	1
	Secondary School	210,887	2
Food Sales	Convenience	Not specified	1
	Supermarket	45,000	1
Food Service	Full-Service Restaurant	5,500	1
	Quick-Service Restaurant	2,500	1
Healthcare	Hospital	241,351	5
	Outpatient Healthcare	40,946	3
Large Multifamily	Midrise Apartment	33,740	4
Lodging	Large Hotel	122,120	6
	Nursing Home	Not specified	Not specified
	Small Hotel/Motel	43,200	4
Mercantile	Stand-Alone Retail	24,962	1
	Strip Mall	22,500	1
Office	Large Office	498,588	12
	Medium Office	53,628	3
	Small Office	5,500	1
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

63 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.

Table 2-21: DF and EFLH Values for Amarillo (Climate Zone 1)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	College	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	--	--	--	--
	Supermarket	0.29	219	--	--	--	--
Food Service	Full-Service Restaurant	0.83	1,020	0.83	1,020	0.43	1,123
	24Hr 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
	24Hr Quick Service	0.74	817	0.74	817	0.48	1,300
Healthcare	Hospital	0.72	2,185	--	--	--	--
	Outpatient Healthcare	0.71	2,036	0.71	2,036	0.27	579
Large Multifamily	Midrise Apartment	0.68	674	--	--	--	--
Lodging	Large Hotel	0.58	1,345	0.58	1,345	0.86	1,095
	Nursing Home	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
	24Hr 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	--	--	--	--
	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	--	--	--	--
Religious Worship	Religious Worship	0.57	387	--	--	--	--
Service	Service	0.83	790	--	--	--	--
Warehouse	Warehouse	0.34	173	--	--	--	--
Other	Other	0.29	173	0.29	173	0.27	340

Table 2-22: DF and EFLH Values for Dallas (Climate Zone 2)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	College	1.02	1,595	--	--	--	--
	Primary School	0.88	1,208	0.88	1,208	0.66	397
	Secondary School	1.02	1,084	1.02	1,084	0.59	489
Food Sales	Convenience	1.08	1,835	--	--	--	--
	Supermarket	0.58	615	--	--	--	--
Food Service	Full-Service Restaurant	1.09	1,823	1.09	1,823	0.50	688
	24Hr 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
	24Hr Quick-Service	1.08	1,765	1.08	1,765	0.60	794
Healthcare	Hospital	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	--	--	--	--
Lodging	Large Hotel	0.70	2,079	0.70	2,079	0.82	464
	Nursing Home	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
	24Hr 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	--	--	--	--
	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	--	--	--	--
Religious Worship	Religious Worship	0.55	567	--	--	--	--
Service	Service	1.09	1,412	--	--	--	--
Warehouse	Warehouse	0.84	597	--	--	--	--
Other	Other	0.55	567	0.55	567	0.28	153

Table 2-23: DF and EFLH Values for Houston (Climate Zone 3)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	College	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	--	--	--	--
	Supermarket	0.60	744	--	--	--	--
Food Service	Full-Service Restaurant	1.05	2,135	1.05	2,135	0.44	429
	24Hr 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
	24Hr Quick-Service	1.05	2,059	1.05	2,059	0.50	483
Healthcare	Hospital	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	--	--	--	--
Lodging	Large Hotel	0.70	2,531	0.70	2,531	0.33	250
	Nursing Home	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
	24Hr 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	--	--	--	--
	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	--	--	--	--
Religious Worship	Religious Worship	0.65	576	--	--	--	--
Service	Service	1.05	1,653	--	--	--	--
Warehouse	Warehouse	0.84	633	--	--	--	--
Other	Other	0.60	576	0.60	576	0.19	69

Table 2-24: DF and EFLH Values for Corpus Christi (Climate Zone 4)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	College	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	--	--	--	--
	Supermarket	0.54	894	--	--	--	--
Food Service	Full-Service Restaurant	0.98	2,530	0.98	2,530	0.35	292
	24Hr 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
	24Hr Quick-Service	0.93	2,440	0.93	2,440	0.34	296
Healthcare	Hospital	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	--	--	--	--
Lodging	Large Hotel	0.65	2,981	0.65	2,981	0.21	131
	Nursing Home	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
	24Hr 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	--	--	--	--
	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	--	--	--	--
Religious Worship	Religious Worship	0.58	629	--	--	--	--
Service	Service	0.98	1,959	--	--	--	--
Warehouse	Warehouse	0.73	665	--	--	--	--
Other	Other	0.54	629	0.54	629	0.08	39

Table 2-25: DF and EFLH Values for El Paso (Climate Zone 5)

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	College	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	--	--	--	
	Supermarket	0.38	347	--	--	--	--
Food Service	Full-Service Restaurant	0.76	1,276	0.76	1,276	0.28	613
	24Hr 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
	24Hr Quick-Service	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Hospital	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	--	--	--	--
Lodging	Large Hotel	0.63	1,701	0.63	1,701	0.21	440
	Nursing Home	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
	24Hr 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	--	--	--	--
	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	--	--	--	--
Religious Worship	Religious Worship	0.63	478	--	--	--	--
Service	Service	0.76	988	--	--	--	--
Warehouse	Warehouse	0.75	324	--	--	--	--
Other	Other	0.38	324	0.38	324	0.04	146

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, 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.[64]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 2-26. As previously noted, for ER units of unknown age, a default value of 17 years should be used. 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 B.

Table 2-26: Remaining Useful Life Early Retirement Systems[65]

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[66]	0.0

[64] 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.

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

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

Program Tracking Data & 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)
- Installed Equipment Type
- Installed Equipment Rated Cooling and Heating Capacities
- Installed Number of Units
- Installed Cooling and Heating Efficiency Ratings
- Installed Make & Model
- **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, 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 B.

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 2-27: Nonresidential HVAC Single-Zone AC-HP 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 B 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.

2.2.3 HVAC Chillers Measure Overview

TRM Measure ID: NR-HV-CH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 2-41 through Table 2-45.

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 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. In the event that the actual age of the unit is unknown, default values are provided. 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[67]:

- 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. In the event that this type of retrofit is performed, the tables from the Split/Single Packaged Air Conditioners and Heat Pumps measure will need to be referenced.
- Chiller Type Conversions: Conversion 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 are electric.
- The climate zone is determined from the county-to-climate-zone mapping table. [68]
- The building falls into one of the categories listed in Table 2-41 through Table 2-45. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- 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. An ROB approach should be used for these scenarios.

In the event that one of 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

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.

[67] Savings can also be claimed by a retrofit involving a change in equipment type (i.e. 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). In the event that this type of retrofit is performed, the tables from the following HVAC measure templates will need to be referenced: HVAC – Chillers, Split System/Single Packaged Heat Pumps and Air Conditioners

[68] 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).

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 an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 2-28 through Table 2-39 according to the capacity, chiller type, and age (based on year of manufacture) of the replaced system.[69] When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-28 through Table 2-39 should be used. When the system age is unknown, assume 21 years for Non-Centrifugal chillers and 26 years for Centrifugal chillers.

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[70], 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, common practice for energy efficiency programs in Texas is to allow systems older than 1990 to use the same baseline efficiencies as those listed for 1990-2001. This practice is reflected in the baseline efficiency tables, by showing the Year Installed as ≤ 2001 rather than 1990-2001.

ER Baseline: Air-Cooled Chillers

Table 2-28: ER Baseline Full-Load Efficiency of All Path A Air-Cooled Chillers[71]

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

[69] 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.

[70] IECC 2015 not enforced in Texas until program year 2018.

[71] 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 2-29: ER Baseline Full-Load Efficiency of All Path B Air-Cooled Chillers[72]

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 2-30: 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 2-31: 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

ER Baseline: Centrifugal Water-Cooled Chillers

Table 2-32: ER Baseline Full-Load Efficiency of Centrifugal Path A Water-Cooled Chillers[73]

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

72 Ibid.
73 Ibid.

Table 2-33: ER Baseline Full-Load Efficiency of Centrifugal Path B Water-Cooled Chillers[74]

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 2-34: 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 600 tons [kW/ton]	≥ 400 to < 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*	*0.733*
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.596	0.596	0.596	0.549	0.549	0.539
≥ 2018	0.550	0.550	0.550	0.520	0.500	0.500

Table 2-35: 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 600 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

[74] Ibid.

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

Table 2-36: ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path A Water-Cooled Chillers[75]

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 2-37: ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path B Water-Cooled Chillers[76]

Year Installed (Replaced System)	< 75 tons [kW/ton]	≥ 75 to <150 tons [kW/ton]	≥ 150 to <300 tons [kW/ton]	≥ 300 to <600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	*0.925*	*0.925*	*0.837*	*0.748*	*0.748*
2002–2009	0.790	0.790	0.718	0.639	0.639
2010–2017	0.800	0.790	0.718	0.639	0.639
≥ 2018	0.780	0.750	0.680	0.625	0.585

Table 2-38: 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

[75] Ibid.
[76] Ibid.

Table 2-39: 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 2-40, 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.[77] 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.

[77] 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 2-40: Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers[78]

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 2-40 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[79]:

- For early retirement projects only, the installed equipment cooling capacity must be within 80% to 120% of the replaced electric cooling capacity
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences, cooling towers, and condensers).

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Path A 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 20

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

Equation 21

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]*

$\eta_{baseline}$ = *Full-load efficiency of existing equipment (ER) or standard equipment (ROB/NC). Default values, based on system type, are given in Table 2-28, Table 2-32, or Table 2-36. For efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 22. [kW/Ton]*

$\eta_{installed}$ = *Rated full-load efficiency of the newly installed equipment [kW/Ton]—(Must exceed efficiency standards, shown in Table 2-40. For efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 22.)*

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

Equation 22

DF = *Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-41 through Table 2-45)*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 2-41 through Table 2-45)*

Path B Air and Water-Cooled Chillers

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

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]*
$\eta_{baseline}$	=	*Part-load efficiency of existing equipment (ER) or standard equipment (ROB/NC). Default values, based on system type, are given in Table 2-31, Table 2-35, or Table 2-39. For efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 22. [kW/Ton]*
$\eta_{installed}$	=	*Rated part-load efficiency of the newly installed equipment (Must exceed efficiency standards, shown in Table 2-40). For efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 22. [kW/Ton]*
DF	=	*Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-41 through Table 2-45)*
$EFLH_C$	=	*Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 2-41 through Table 2-45)*
PLF	=	*Part Load Factor for determing demand savings. Use values determined by climate zone and building type from Table 2-41 through Table 2-45.*

Air-to Water-Cooled Replacement: Adjustments for Auxiliary Equipment[80]

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

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

Equation 25

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

Equation 26

Where:

$HP_{CW\ pump}$	=	*Horsepower of the condenser water pump*
$HP_{CT\ fan}$	=	*Horsepower of the cooling tower fan*
0.746	=	*Conversion from HP to kW [kW/HP]*
0.86	=	*Assumed equipment efficiency*
0.80	=	*Assumed load factor*

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

8,760	=	*Annual run time hours*

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

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

Equation 27

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

Equation 28

Early Retirement Savings

The first year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the early retirement period and the replace-on-burnout period, and take into account 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 B.

Table 2-41 through Table 2-45 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.

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 building type and climate zone for chillers in Table 2-41 through Table 2-45. 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 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 used the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Table 2-41: DF and EFLH for Amarillo (Climate Zone 1)

Building Type	Principal Building Activity	Chiller[81]					
		Air Cooled			Water Cooled		
		DF	$EFLH_c$	PLF	DF	$EFLH_c$	PLF
Education	College	0.87	1,115	0.39	0.68	1,243	0.28
	Primary School	0.44	576	0.28	0.53	971	0.26
	Secondary School	0.70	802	0.39	0.58	1,772	0.28
Healthcare	Hospital	0.70	2,006	0.38	0.65	2,711	0.35
Large Multifamily	Midrise Apartment	0.41	421	0.23	0.50	1,098	0.23
Lodging	Large Hotel	0.58	1,283	0.64	0.59	1,553	0.58
	Nursing Home	0.41	428	0.23	0.50	1,115	0.23
Mercantile	Stand-Alone Retail	0.52	489	0.32	0.54	719	0.29
	24Hr Retail	0.67	681	0.37	0.62	974	0.31
Office	Large Office	0.70	1,208	0.64	0.61	1,506	0.42
Public Assembly	Public Assembly	0.44	774	0.28	0.53	1,306	0.26
Religious Worship	Religious Worship	0.52	294	0.32	0.54	433	0.29
Other	Other	0.41	294	0.23	0.50	433	0.23

Table 2-42: DF and EFLH for Dallas (Climate Zone 2)

Building Type	Principal Building Activity	Chiller[82]					
		Air Cooled			Water Cooled		
		DF	$EFLH_c$	PLF	DF	$EFLH_c$	PLF
Education	College	0.89	1,587	0.39	0.81	1,761	0.31
	Primary School	0.48	726	0.26	0.60	1,412	0.25
	Secondary School	0.84	1,170	0.43	0.54	2,234	0.31
Healthcare	Hospital	0.90	2,784	0.49	0.81	3,683	0.45
Large Multifamily	Midrise Apartment	0.68	1,060	0.39	0.66	2,053	0.33
Lodging	Large Hotel	0.80	2,086	0.75	0.71	2,627	0.69
	Nursing Home	0.68	1,077	0.39	0.66	2,085	0.33
Mercantile	Stand-Alone Retail	0.79	936	0.45	0.72	1,328	0.39
	24Hr Retail	0.89	1,307	0.44	0.79	1,975	0.37
Office	Large Office	0.92	1,711	0.70	0.70	2,062	0.46
Public Assembly	Public Assembly	0.48	976	0.26	0.60	1,898	0.25
Religious Worship	Religious Worship	0.79	563	0.45	0.72	799	0.39
Other	Other	0.48	563	0.26	0.54	799	0.25

81 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.

82 Ibid.

Table 2-43: DF and EFLH for Houston (Climate Zone 3)

Building Type	Principal Building Activity	Chiller[83]					
		Air Cooled			Water Cooled		
		DF	$EFLH_c$	PLF	DF	$EFLH_c$	PLF
Education	College	0.80	1,858	0.44	0.84	2,099	0.32
	Primary School	0.45	818	0.27	0.60	1,627	0.26
	Secondary School	0.77	1,306	0.44	0.55	2,404	0.32
Healthcare	Hospital	0.85	3,116	0.50	0.79	4,171	0.48
Large Multifamily	Midrise Apartment	0.65	1,295	0.41	0.66	2,467	0.36
Lodging	Large Hotel	0.71	2,499	0.68	0.73	3,201	0.73
	Nursing Home	0.65	1,315	0.41	0.66	2,506	0.36
Mercantile	Stand-Alone Retail	0.83	1,224	0.50	0.78	1,712	0.44
	24Hr Retail	0.80	1,513	0.42	0.74	2,427	0.36
Office	Large Office	0.92	1,820	0.73	0.71	2,312	0.49
Public Assembly	Public Assembly	0.45	1,100	0.27	0.60	2,188	0.26
Religious Worship	Religious Worship	0.83	737	0.50	0.78	1,031	0.44
Other	Other	0.45	737	0.27	0.55	1,031	0.26

Table 2-44: DF and EFLH for Corpus Christi (Climate Zone 4)

Building Type	Principal Building Activity	Chiller[84]					
		Air Cooled			Water Cooled		
		DF	$EFLH_c$	PLF	DF	$EFLH_c$	PLF
Education	College	0.80	2,340	0.47	0.87	2,583	0.34
	Primary School	0.45	937	0.29	0.61	1,845	0.28
	Secondary School	0.68	1,503	0.47	0.55	2,577	0.34
Healthcare	Hospital	0.79	3,455	0.53	0.82	4,637	0.53
Large Multifamily	Midrise Apartment	0.61	1,534	0.43	0.67	2,840	0.43
Lodging	Large Hotel	0.74	2,908	0.78	0.73	3,713	0.76
	Nursing Home	0.61	1,558	0.43	0.67	2,884	0.43
Mercantile	Stand-Alone Retail	0.75	1,394	0.52	0.76	1,953	0.47
	24Hr Retail	0.70	1,725	0.43	0.73	2,768	0.38
Office	Large Office	0.82	2,027	0.76	0.72	2,570	0.52
Public Assembly	Public Assembly	0.45	1,260	0.29	0.61	2,481	0.28
Religious Worship	Religious Worship	0.75	839	0.52	0.76	1,176	0.47
Other	Other	0.45	839	0.29	0.55	1,176	0.28

[83] Ibid.
[84] Ibid.

Table 2-45: DF and EFLH for El Paso (Climate Zone 5)

Building Type	Principal Building Activity	Chiller[85]					
		Air Cooled			Water Cooled		
		DF	$EFLH_c$	PLF	DF	$EFLH_c$	PLF
Education	College	0.93	1,278	0.39	0.96	1,458	0.28
	Primary School	0.61	751	0.30	0.53	1,113	0.27
	Secondary School	0.77	1,039	0.39	0.54	2,196	0.28
Healthcare	Hospital	0.71	2,355	0.37	0.59	2,992	0.34
Large Multifamily	Midrise Apartment	0.56	841	0.31	0.52	1,553	0.27
Lodging	Large Hotel	0.63	1,815	0.67	0.58	2,038	0.63
	Nursing Home	0.56	854	0.31	0.52	1,577	0.27
Mercantile	Stand-Alone Retail	0.64	722	0.34	0.55	948	0.29
	24Hr Retail	0.61	884	0.36	0.60	1,371	0.31
Office	Large Office	0.77	1,442	0.66	0.60	1,683	0.44
Public Assembly	Public Assembly	0.61	1,010	0.30	0.53	1,496	0.27
Religious Worship	Religious Worship	0.64	435	0.34	0.55	571	0.29
Other	Other	0.56	435	0.30	0.52	571	0.27

Measure Life and Lifetime Savings

Effective Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/Scroll/Reciprocating Chillers–20 years[86]
- Centrifugal Chillers–25 years[87]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 2-46. 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. 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 B.

[85] Ibid.

[86] 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.

[87] PUCT Docket No. 40885, review of multiple studies looking at the lifetime of Centrifugal Chillers as detailed in petition workpapers.

Table 2-46: Remaining Useful Life of Early Retirement Systems[88]

Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)
1	18.7	23.9
2	17.7	22.9
3	16.7	21.9
4	15.7	20.9
5	14.7	19.9
6	13.7	18.9
7	12.7	17.9
8	11.8	16.9
9	10.9	15.9
10	10.0	14.9
11	9.1	13.9
12	8.3	12.9
13	7.5	11.9
14	6.8	10.9
15	6.2	10.1
16	5.5	9.3
17	5.0	8.7
18	4.5	8.1
19	4.0	7.5
20	3.6	7.1
21	3.0	6.6
22	2.0	6.3
23	1.0	5.9
24[89]	0.0	5.6
25	N/A	5.4
26	N/A	5.0
27	N/A	4.0
28	N/A	3.0
29	N/A	2.0
30	N/A	1.0
31[90]	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

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

[89] 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.

[90] Ibid.

- 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)
- Installed Equipment Type (Compressor/Condenser Type)
- Installed Path (Path A or Path B)
- Installed Equipment Rated Capacity
- Installed Number of Units
- Installed Efficiency Rating
- Installed Make & Model
- **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, TX. 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 B.

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 2-47: Nonresidential HVAC Chillers 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 B 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 24Hr Retail loadshape. Updated RUL table based on DOE survival curves.

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 2-51 through Table 2-55

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 Calculations

Savings Methodology: Calculator.

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. In the event that the actual age of the unit is unknown, default values are provided.

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, 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. Includes all equipment configurations covered by the federal appliance standards, including with or without 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 are electric.[91]
- The climate zone is determined from the county-to-climate-zone mapping table.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios

In the event that one of 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

Early Retirement for PTAC/PTHP Systems

An early retirement scenario is only applicable for Standard Size PTAC/PTHP system types replacing system types with an equivalent cooling capacity or reduced cooling capacity (within 80% of existing capacity).

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 that same as for an 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.[92] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-48, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. When the system age is unknown, assume 17 years.[93]

[91] 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).

[92] 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.

[93] 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, taking into account increments in efficiency standards that took place in the historical period.

Table 2-48: ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units[94]

Equipment	Cooling Capacity [Btuh]	Baseline Cooling Efficiency [EER]	Baseline Heating Efficiency [COP]
PTAC	<7,000	11.0	--
	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 2-49 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 2-49: Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units[95]

Equipment	Category	Cooling Capacity [Btuh]	Minimum Cooling Efficiency [EER]	Minimum Heating Efficiency [COP]
PTAC	Standard Size	<7,000	*11.9*	--
		7,000-15,000	$14.0 - (0.300 \times \text{Cap}/1000)$	--
		>15,000	*9.5*	--
	Non-Standard Size	<7,000	*9.4*	--
		7,000-15,000	$10.9 - (0.213 \times \text{Cap}/1000)$	--
		>15,000	*7.7*	--
PTHP	Standard Size	<7,000	*11.9*	*3.3*
		7,000-15,000	$14.0 - (0.300 \times \text{Cap}/1000)$	$3.7 - (0.052 \times \text{Cap}/1000)$
		>15,000	*9.5*	*2.9*
	Non-Standard Size	<7,000	*9.3*	*2.7*
		7,000-15,000	$10.8 - (0.213 \times \text{Cap}/1000)$	$2.9 - (0.026 \times \text{Cap}/1000)$
		>15,000	*7.6*	*2.5*

[94] 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.
[95] IECC 2015 Table C403.2.3(3).
[96] 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.

Table 2-50 reflects the standards for Room Air Conditioners, specified in 10 CFR 430.32(b).

Table 2-50: Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units[97]

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

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 2-49 and Table 2-50.

The high-efficiency retrofits must also meet the following criteria[98]:

- For early retirement PTAC/PTHPs only, the high-efficiency equipment cooling capacity must be equal to or no less than 80% of the existing capacity. Equipment with a cooling capacity larger than the existing equipment must use the replace-on-burnout baseline.
- Non-Standard Size PTAC/PTHPs cannot be used for New Construction.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e. control sequences).

[97] 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.

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

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 29

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

Equation 30

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

Equation 31

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

Equation 32

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 (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 2-48 through Table 2-50)*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 2-48 and Table 2-49)*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h])—(Must exceed minimum federal standards found in Table 2-49 and Table 2-50)*

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 2-49)*

DF = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-21 through Table 2-25)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours], see Table 2-51 through Table 2-55.*

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 B.

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 2-51 through Table 2-55 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.

Table 2-51: PTAC/PTHP or RAC Equipment: DF and EFLH Values for Amarillo (CZ 1)

Building Types	Principle 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
	24Hr 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
	24Hr 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 2-52: PTAC/PTHP or RAC Equipment: DF and EFLH Values for Dallash (CZ 2)

Building Types	Principle 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
	24Hr 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
	24Hr 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 2-53: PTAC/PTHP or RAC Equipment: DF and EFLH Values for Houston (CZ 3)

Building Types	Principle 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
	24Hr 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
	24Hr 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 2-54: PTAC/PTHP or RAC Equipment: DF and EFLH Values for Corpus Christi (CZ 4)

Building Types	Principle 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
	24Hr 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
	24Hr 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 2-55: PTAC/PTHP or RAC Equipment: DF and EFLH Values for El Paso (CZ 5)

Building Types	Principle 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
	24Hr 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
	24Hr 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.[99]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 2-56.

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

Table 2-56: Remaining Useful Life of ER PTAC/PTHP Systems[100]

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[101]	0.0

[99] 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.

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

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

Program Tracking Data & 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 & Model
- **For ER ONLY**: Baseline Age and Method of Determination (e.g. nameplate, blueprints, customer reported, not available)
- Installed Equipment Type
- Installed Equipment Rated Capacity
- Installed Number of Units
- Installed Efficiency Rating
- Installed Make & Model.

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 2-57: Nonresidential HVAC PTAC-PTHP/Room AC 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.

2.2.5 HVAC Variable Frequency Drive (VFD) on Air Handler Unit (AHU) Supply Fans Measure Overview

TRM Measure ID: NR-HV-VF

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 2-59

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET)

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Look-up Tables (fan type, motor hp, Climate Zone, Building Type).

Measure Description

This measure involves the installation of a VFD on an existing AHU supply fan to replace either outlet damper or inlet guide vane part-load control. The fan is in a variable air volume (VAV) system with terminal VAV boxes. 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 particular eligible scenarios.

Eligibility Criteria

Supply fans may not have variable pitch blades. New construction and constant-volume systems are ineligible. Supply fans must be less than or equal to 100 HP.

Baseline Condition

The baseline is a centrifugal supply fan with a single-speed motor, a direct expansion (DX) air-conditioning (AC) unit, and VAV boxes. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2004 standards 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 or inlet guide vane.

High-Efficiency Condition

The high efficiency condition is installation of a VFD on an AHU supply fan. 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 %CFM for the hour, *i*[102];

$$\%CFM_i = 1.25 \times t_i + b$$

Equation 33

Where:

$$b = 100 - (1.25 \times t_{dbd})$$

Equation 34

Step 2—Calculate the %power[103] for the applicable baseline and the new VFD technology:

Baseline Technologies

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

Equation 35

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

Equation 36

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

Equation 37

VFD Technology

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

Equation 38

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:

[102] 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%.

[103] 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.

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

Equation 39

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

Equation 40

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 41

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 42

Total Peak Demand Saved Calculation, including interactive effects

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

Equation 43

Energy Savings are calculated in the following manner:

Step 1—Calculate the individual kWh consumption in each hour of the year and sum them; This is done for both the baseline and the new technologies:

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

Equation 44

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 45

Where:

$\%CFM_i$	=	*Part-load fan airflow at the i^{th} hour of the year*
t_i	=	*Dry bulb air temperature at i^{th} hour taken from TMY3 hourly weather data*

t_{dbd}	=	*ASHRAE 0.4% Cooling Dry Bulb Design Temperature for the reference city from 2013 ASHRAE Handbook—Fundamentals, Chapter 14, Appendix: Design Conditions for Selected Locations*
$\%power_i$	=	*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)*[104]
kW_{full}	=	*Fan motor power demand operating at the fan design 100% CFM*
kW_i	=	*Fan 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 design 100% per DEER 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*
schedule	=	*1 when building is occupied, 0.2 when building is unoccupied, see Table 2-58*
PDPF	=	*Peak demand probability factor from the applicable climate zone table in Volume 1.*
$Cooling_{EER}$	=	*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*
8760	=	*Total number of hours in a year*

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

Deemed Energy and Demand Savings Tables

Table 2-58: Yearly Motor Operation Hours by Building Type[105]

Building Type	Weekday Schedule	Weekend Schedule	Annual Building Occupied Hours	Annual Motor Operation Hours*
Hospitals & 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 & 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

* Motor operation hours are building occupied hours plus 20% of unoccupied hours

Table 2-59: Deemed Energy/Demand Savings Values for Outlet Damper Part-Load Fan Control

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.035	1,243	0.016	1,204	0.009	1,150	0.063	1,112	0.039	1,229
2	0.070	2,457	0.032	2,380	0.018	2,274	0.124	2,198	0.078	2,430
3	0.101	3,562	0.046	3,451	0.026	3,297	0.180	3,186	0.113	3,523
5	0.168	5,937	0.076	5,752	0.044	5,495	0.300	5,311	0.188	5,871
7.5	0.248	8,759	0.113	8,485	0.064	8,107	0.442	7,835	0.277	8,661
10	0.328	11,589	0.149	11,227	0.085	10,726	0.585	10,366	0.367	11,460
15	0.485	17,140	0.220	16,605	0.126	15,865	0.865	15,332	0.543	16,950
20	0.647	22,854	0.294	22,140	0.168	21,153	1.154	20,443	0.724	22,600
25	0.803	28,384	0.365	27,498	0.208	26,272	1.433	25,390	0.899	28,069
30	0.959	33,880	0.435	32,822	0.249	31,359	1.710	30,306	1.073	33,504
40	1.278	45,173	0.580	43,763	0.332	41,812	2.281	40,408	1.430	44,671
50	1.591	56,228	0.722	54,472	0.413	52,043	2.839	50,296	1.780	55,603
60	1.899	67,118	0.862	65,022	0.493	62,123	3.388	60,037	2.125	66,372
75	2.374	83,898	1.078	81,278	0.616	77,654	4.235	75,047	2.656	82,965
100	3.152	111,394	1.431	107,916	0.818	103,105	5.624	99,643	3.527	110,157

[105] 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.

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Large										
1	0.035	608	0.016	587	0.009	553	0.063	530	0.039	599
2	0.070	1,203	0.032	1,160	0.018	1,093	0.124	1,047	0.078	1,185
3	0.101	1,744	0.046	1,682	0.026	1,585	0.180	1,518	0.113	1,718
5	0.168	2,906	0.076	2,803	0.044	2,641	0.300	2,529	0.188	2,863
7.5	0.248	4,288	0.113	4,135	0.064	3,896	0.442	3,732	0.277	4,223
10	0.328	5,673	0.149	5,472	0.085	5,155	0.585	4,937	0.367	5,588
15	0.485	8,391	0.220	8,093	0.126	7,625	0.865	7,303	0.543	8,265
20	0.647	11,188	0.294	10,791	0.168	10,166	1.154	9,737	0.724	11,020
25	0.803	13,895	0.365	13,402	0.208	12,626	1.433	12,093	0.899	13,686
30	0.959	16,585	0.435	15,997	0.249	15,071	1.710	14,434	1.073	16,336
40	1.278	22,114	0.580	21,329	0.332	20,094	2.281	19,246	1.430	21,782
50	1.591	27,525	0.722	26,549	0.413	25,012	2.839	23,956	1.780	27,112
60	1.899	32,857	0.862	31,691	0.493	29,856	3.388	28,595	2.125	32,363
75	2.374	41,071	1.078	39,613	0.616	37,320	4.235	35,744	2.656	40,454
100	3.152	54,531	1.431	52,596	0.818	49,552	5.624	47,459	3.527	53,712
Office - Small										
1	0.035	550	0.016	530	0.009	497	0.063	476	0.039	542
2	0.070	1,087	0.032	1,049	0.018	983	0.124	940	0.078	1,072
3	0.101	1,576	0.046	1,520	0.026	1,426	0.180	1,363	0.113	1,554
5	0.168	2,627	0.076	2,533	0.044	2,376	0.300	2,272	0.188	2,589
7.5	0.248	3,876	0.113	3,738	0.064	3,506	0.442	3,352	0.277	3,820
10	0.328	5,129	0.149	4,945	0.085	4,638	0.585	4,436	0.367	5,054
15	0.485	7,586	0.220	7,314	0.126	6,860	0.865	6,561	0.543	7,476
20	0.647	10,114	0.294	9,752	0.168	9,147	1.154	8,748	0.724	9,968
25	0.803	12,562	0.365	12,112	0.208	11,361	1.433	10,864	0.899	12,380
30	0.959	14,994	0.435	14,458	0.249	13,560	1.710	12,968	1.073	14,777
40	1.278	19,992	0.580	19,277	0.332	18,081	2.281	17,291	1.430	19,702
50	1.591	24,885	0.722	23,994	0.413	22,505	2.839	21,522	1.780	24,523
60	1.899	29,704	0.862	28,641	0.493	26,864	3.388	25,690	2.125	29,273
75	2.374	37,130	1.078	35,802	0.616	33,580	4.235	32,113	2.656	36,591
100	3.152	49,300	1.431	47,535	0.818	44,585	5.624	42,638	3.527	48,584

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Education - K-12										
1	0.035	576	0.016	556	0.009	520	0.063	497	0.039	568
2	0.070	1,140	0.032	1,099	0.018	1,028	0.124	983	0.078	1,124
3	0.101	1,652	0.046	1,593	0.026	1,490	0.180	1,425	0.113	1,629
5	0.168	2,753	0.076	2,656	0.044	2,483	0.300	2,375	0.188	2,715
7.5	0.248	4,062	0.113	3,918	0.064	3,664	0.442	3,504	0.277	4,006
10	0.328	5,375	0.149	5,184	0.085	4,847	0.585	4,636	0.367	5,300
15	0.485	7,950	0.220	7,667	0.126	7,170	0.865	6,857	0.543	7,839
20	0.647	10,599	0.294	10,223	0.168	9,559	1.154	9,143	0.724	10,452
25	0.803	13,164	0.365	12,697	0.208	11,873	1.433	11,355	0.899	12,982
30	0.959	15,713	0.435	15,155	0.249	14,171	1.710	13,554	1.073	15,495
40	1.278	20,951	0.580	20,207	0.332	18,895	2.281	18,072	1.430	20,660
50	1.591	26,078	0.722	25,151	0.413	23,519	2.839	22,494	1.780	25,716
60	1.899	31,129	0.862	30,023	0.493	28,074	3.388	26,851	2.125	30,697
75	2.374	38,911	1.078	37,529	0.616	35,093	4.235	33,564	2.656	38,371
100	3.152	51,664	1.431	49,828	0.818	46,594	5.624	44,564	3.527	50,947
Education - College & University										
1	0.035	631	0.016	608	0.009	572	0.063	548	0.039	622
2	0.070	1,247	0.032	1,203	0.018	1,131	0.124	1,084	0.078	1,229
3	0.101	1,808	0.046	1,743	0.026	1,640	0.180	1,571	0.113	1,782
5	0.168	3,014	0.076	2,906	0.044	2,733	0.300	2,618	0.188	2,969
7.5	0.248	4,446	0.113	4,287	0.064	4,033	0.442	3,863	0.277	4,380
10	0.328	5,883	0.149	5,672	0.085	5,336	0.585	5,111	0.367	5,796
15	0.485	8,701	0.220	8,389	0.126	7,892	0.865	7,559	0.543	8,573
20	0.647	11,602	0.294	11,186	0.168	10,522	1.154	10,079	0.724	11,430
25	0.803	14,409	0.365	13,892	0.208	13,068	1.433	12,518	0.899	14,196
30	0.959	17,199	0.435	16,582	0.249	15,599	1.710	14,942	1.073	16,945
40	1.278	22,932	0.580	22,110	0.332	20,798	2.281	19,922	1.430	22,593
50	1.591	28,544	0.722	27,520	0.413	25,888	2.839	24,797	1.780	28,122
60	1.899	34,072	0.862	32,850	0.493	30,902	3.388	29,600	2.125	33,568
75	2.374	42,591	1.078	41,063	0.616	38,628	4.235	37,000	2.656	41,960
100	3.152	56,549	1.431	54,521	0.818	51,288	5.624	49,127	3.527	55,713

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Retail										
1	0.035	759	0.016	732	0.009	693	0.063	667	0.039	748
2	0.070	1,501	0.032	1,447	0.018	1,370	0.124	1,319	0.078	1,480
3	0.101	2,176	0.046	2,098	0.026	1,985	0.180	1,912	0.113	2,145
5	0.168	3,627	0.076	3,497	0.044	3,309	0.300	3,187	0.188	3,575
7.5	0.248	5,351	0.113	5,159	0.064	4,882	0.442	4,701	0.277	5,274
10	0.328	7,080	0.149	6,827	0.085	6,460	0.585	6,220	0.367	6,978
15	0.485	10,471	0.220	10,097	0.126	9,554	0.865	9,200	0.543	10,321
20	0.647	13,962	0.294	13,462	0.168	12,738	1.154	12,267	0.724	13,761
25	0.803	17,340	0.365	16,720	0.208	15,821	1.433	15,235	0.899	17,091
30	0.959	20,698	0.435	19,957	0.249	18,884	1.710	18,185	1.073	20,400
40	1.278	27,597	0.580	26,610	0.332	25,179	2.281	24,247	1.430	27,201
50	1.591	34,351	0.722	33,121	0.413	31,341	2.839	30,180	1.780	33,857
60	1.899	41,004	0.862	39,536	0.493	37,411	3.388	36,025	2.125	40,414
75	2.374	51,255	1.078	49,420	0.616	46,764	4.235	45,032	2.656	50,518
100	3.152	68,053	1.431	65,618	0.818	62,090	5.624	59,791	3.527	67,075
Restaurant - Fast Food										
1	0.035	934	0.016	902	0.009	855	0.063	824	0.039	921
2	0.070	1,846	0.032	1,782	0.018	1,690	0.124	1,628	0.078	1,821
3	0.101	2,676	0.046	2,584	0.026	2,450	0.180	2,361	0.113	2,640
5	0.168	4,459	0.076	4,306	0.044	4,083	0.300	3,934	0.188	4,400
7.5	0.248	6,579	0.113	6,353	0.064	6,024	0.442	5,804	0.277	6,492
10	0.328	8,705	0.149	8,406	0.085	7,970	0.585	7,680	0.367	8,589
15	0.485	12,875	0.220	12,433	0.126	11,788	0.865	11,359	0.543	12,704
20	0.647	17,166	0.294	16,577	0.168	15,718	1.154	15,145	0.724	16,939
25	0.803	21,320	0.365	20,588	0.208	19,521	1.433	18,810	0.899	21,038
30	0.959	25,448	0.435	24,574	0.249	23,301	1.710	22,452	1.073	25,111
40	1.278	33,931	0.580	32,766	0.332	31,068	2.281	29,936	1.430	33,481
50	1.591	42,234	0.722	40,784	0.413	38,671	2.839	37,261	1.780	41,674
60	1.899	50,414	0.862	48,683	0.493	46,161	3.388	44,478	2.125	49,746
75	2.374	63,018	1.078	60,854	0.616	57,701	4.235	55,598	2.656	62,182
100	3.152	83,672	1.431	80,798	0.818	76,612	5.624	73,819	3.527	82,562

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Restaurant - Sit-Down										
1	0.035	721	0.016	695	0.009	662	0.063	639	0.039	710
2	0.070	1,425	0.032	1,374	0.018	1,310	0.124	1,264	0.078	1,404
3	0.101	2,065	0.046	1,992	0.026	1,899	0.180	1,832	0.113	2,035
5	0.168	3,442	0.076	3,320	0.044	3,164	0.300	3,054	0.188	3,392
7.5	0.248	5,078	0.113	4,898	0.064	4,668	0.442	4,506	0.277	5,004
10	0.328	6,719	0.149	6,481	0.085	6,177	0.585	5,962	0.367	6,621
15	0.485	9,938	0.220	9,586	0.126	9,136	0.865	8,818	0.543	9,792
20	0.647	13,251	0.294	12,782	0.168	12,181	1.154	11,757	0.724	13,056
25	0.803	16,458	0.365	15,875	0.208	15,128	1.433	14,602	0.899	16,216
30	0.959	19,644	0.435	18,948	0.249	18,057	1.710	17,429	1.073	19,356
40	1.278	26,192	0.580	25,264	0.332	24,077	2.281	23,239	1.430	25,807
50	1.591	32,602	0.722	31,447	0.413	29,968	2.839	28,925	1.780	32,123
60	1.899	38,916	0.862	37,538	0.493	35,773	3.388	34,528	2.125	38,344
75	2.374	48,645	1.078	46,922	0.616	44,716	4.235	43,160	2.656	47,931
100	3.152	64,589	1.431	62,300	0.818	59,371	5.624	57,305	3.527	63,639

Table 2-60: Deemed Energy/Demand Savings Values for Inlet Damper Part-Load Fan Control

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.041	1,956	0.034	1,854	0.045	1,718	0.069	1,622	0.046	1,913
2	0.082	3,868	0.068	3,665	0.089	3,396	0.136	3,206	0.092	3,782
3	0.118	5,607	0.098	5,313	0.129	4,923	0.197	4,648	0.133	5,483
5	0.197	9,345	0.164	8,854	0.215	8,205	0.328	7,747	0.222	9,139
7.5	0.291	13,786	0.241	13,063	0.317	12,105	0.485	11,430	0.328	13,482
10	0.385	18,241	0.319	17,284	0.419	16,017	0.641	15,123	0.433	17,839
15	0.570	26,980	0.472	25,564	0.619	23,689	0.948	22,368	0.641	26,384
20	0.760	35,973	0.630	34,085	0.826	31,586	1.264	29,823	0.855	35,179
25	0.944	44,678	0.782	42,333	1.026	39,229	1.570	37,040	1.062	43,692
30	1.127	53,328	0.933	50,530	1.224	46,825	1.874	44,212	1.267	52,152
40	1.502	71,105	1.245	67,373	1.633	62,433	2.499	58,950	1.690	69,536
50	1.870	88,505	1.549	83,860	2.032	77,711	3.111	73,375	2.103	86,552
60	2.232	105,647	1.849	100,102	2.426	92,762	3.713	87,587	2.511	103,316
75	2.790	132,058	2.311	125,128	3.032	115,952	4.641	109,483	3.138	129,144
100	3.704	175,339	3.069	166,137	4.026	153,955	6.163	145,366	4.167	171,471

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Large										
1	0.041	944	0.034	890	0.045	811	0.069	756	0.046	916
2	0.082	1,866	0.068	1,759	0.089	1,603	0.136	1,494	0.092	1,812
3	0.118	2,705	0.098	2,551	0.129	2,324	0.197	2,167	0.133	2,626
5	0.197	4,508	0.164	4,251	0.215	3,873	0.328	3,611	0.222	4,377
7.5	0.291	6,650	0.241	6,271	0.317	5,713	0.485	5,327	0.328	6,458
10	0.385	8,800	0.319	8,298	0.419	7,560	0.641	7,049	0.433	8,545
15	0.570	13,015	0.472	12,273	0.619	11,181	0.948	10,425	0.641	12,638
20	0.760	17,353	0.630	16,364	0.826	14,908	1.264	13,900	0.855	16,850
25	0.944	21,552	0.782	20,323	1.026	18,516	1.570	17,264	1.062	20,928
30	1.127	25,725	0.933	24,258	1.224	22,101	1.874	20,606	1.267	24,980
40	1.502	34,301	1.245	32,345	1.633	29,468	2.499	27,475	1.690	33,307
50	1.870	42,694	1.549	40,260	2.032	36,678	3.111	34,199	2.103	41,457
60	2.232	50,964	1.849	48,057	2.426	43,783	3.713	40,822	2.511	49,487
75	2.790	63,704	2.311	60,071	3.032	54,728	4.641	51,028	3.138	61,859
100	3.704	84,583	3.069	79,759	4.026	72,665	6.163	67,752	4.167	82,133
Office - Small										
1	0.041	853	0.034	804	0.045	728	0.069	678	0.046	829
2	0.082	1,687	0.068	1,590	0.089	1,440	0.136	1,341	0.092	1,639
3	0.118	2,445	0.098	2,305	0.129	2,088	0.197	1,944	0.133	2,376
5	0.197	4,075	0.164	3,841	0.215	3,480	0.328	3,239	0.222	3,960
7.5	0.291	6,012	0.241	5,666	0.317	5,133	0.485	4,779	0.328	5,842
10	0.385	7,955	0.319	7,498	0.419	6,792	0.641	6,323	0.433	7,730
15	0.570	11,765	0.472	11,089	0.619	10,046	0.948	9,352	0.641	11,433
20	0.760	15,687	0.630	14,786	0.826	13,395	1.264	12,470	0.855	15,245
25	0.944	19,483	0.782	18,364	1.026	16,636	1.570	15,487	1.062	18,934
30	1.127	23,255	0.933	21,919	1.224	19,857	1.874	18,486	1.267	22,600
40	1.502	31,007	1.245	29,226	1.633	26,476	2.499	24,648	1.690	30,133
50	1.870	38,595	1.549	36,377	2.032	32,955	3.111	30,679	2.103	37,507
60	2.232	46,070	1.849	43,423	2.426	39,338	3.713	36,621	2.511	44,771
75	2.790	57,587	2.311	54,279	3.032	49,173	4.641	45,776	3.138	55,964
100	3.704	76,461	3.069	72,068	4.026	65,289	6.163	60,779	4.167	74,306

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Education - K-12										
1	0.041	896	0.034	845	0.045	762	0.069	710	0.046	872
2	0.082	1,771	0.068	1,671	0.089	1,507	0.136	1,403	0.092	1,723
3	0.118	2,568	0.098	2,422	0.129	2,184	0.197	2,034	0.133	2,498
5	0.197	4,279	0.164	4,036	0.215	3,640	0.328	3,391	0.222	4,163
7.5	0.291	6,313	0.241	5,955	0.317	5,371	0.485	5,002	0.328	6,142
10	0.385	8,353	0.319	7,879	0.419	7,106	0.641	6,619	0.433	8,127
15	0.570	12,355	0.472	11,653	0.619	10,510	0.948	9,789	0.641	12,020
20	0.760	16,473	0.630	15,538	0.826	14,013	1.264	13,052	0.855	16,026
25	0.944	20,459	0.782	19,298	1.026	17,405	1.570	16,211	1.062	19,905
30	1.127	24,420	0.933	23,034	1.224	20,774	1.874	19,350	1.267	23,759
40	1.502	32,560	1.245	30,712	1.633	27,699	2.499	25,800	1.690	31,678
50	1.870	40,528	1.549	38,227	2.032	34,478	3.111	32,113	2.103	39,430
60	2.232	48,378	1.849	45,631	2.426	41,155	3.713	38,333	2.511	47,067
75	2.790	60,472	2.311	57,039	3.032	51,444	4.641	47,916	3.138	58,834
100	3.704	80,292	3.069	75,734	4.026	68,305	6.163	63,620	4.167	78,116
Education - College & University										
1	0.041	978	0.034	922	0.045	838	0.069	782	0.046	950
2	0.082	1,934	0.068	1,823	0.089	1,657	0.136	1,546	0.092	1,878
3	0.118	2,803	0.098	2,643	0.129	2,402	0.197	2,241	0.133	2,723
5	0.197	4,672	0.164	4,405	0.215	4,004	0.328	3,735	0.222	4,538
7.5	0.291	6,892	0.241	6,498	0.317	5,907	0.485	5,511	0.328	6,694
10	0.385	9,120	0.319	8,598	0.419	7,816	0.641	7,291	0.433	8,858
15	0.570	13,488	0.472	12,716	0.619	11,560	0.948	10,784	0.641	13,101
20	0.760	17,984	0.630	16,955	0.826	15,413	1.264	14,379	0.855	17,467
25	0.944	22,336	0.782	21,058	1.026	19,143	1.570	17,858	1.062	21,694
30	1.127	26,661	0.933	25,135	1.224	22,849	1.874	21,316	1.267	25,895
40	1.502	35,548	1.245	33,514	1.633	30,465	2.499	28,421	1.690	34,527
50	1.870	44,247	1.549	41,715	2.032	37,921	3.111	35,376	2.103	42,975
60	2.232	52,816	1.849	49,794	2.426	45,265	3.713	42,228	2.511	51,299
75	2.790	66,021	2.311	62,243	3.032	56,581	4.641	52,785	3.138	64,124
100	3.704	87,658	3.069	82,642	4.026	75,126	6.163	70,085	4.167	85,140

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Retail										
1	0.041	1,176	0.034	1,109	0.045	1,015	0.069	954	0.046	1,142
2	0.082	2,324	0.068	2,192	0.089	2,006	0.136	1,886	0.092	2,257
3	0.118	3,369	0.098	3,177	0.129	2,908	0.197	2,734	0.133	3,273
5	0.197	5,615	0.164	5,296	0.215	4,846	0.328	4,556	0.222	5,454
7.5	0.291	8,284	0.241	7,813	0.317	7,150	0.485	6,721	0.328	8,047
10	0.385	10,961	0.319	10,337	0.419	9,460	0.641	8,893	0.433	10,647
15	0.570	16,212	0.472	15,289	0.619	13,992	0.948	13,154	0.641	15,747
20	0.760	21,616	0.630	20,385	0.826	18,655	1.264	17,538	0.855	20,996
25	0.944	26,846	0.782	25,318	1.026	23,170	1.570	21,782	1.062	26,077
30	1.127	32,044	0.933	30,221	1.224	27,656	1.874	26,000	1.267	31,126
40	1.502	42,726	1.245	40,294	1.633	36,875	2.499	34,667	1.690	41,502
50	1.870	53,181	1.549	50,155	2.032	45,898	3.111	43,150	2.103	51,658
60	2.232	63,482	1.849	59,869	2.426	54,788	3.713	51,507	2.511	61,663
75	2.790	79,352	2.311	74,836	3.032	68,485	4.641	64,384	3.138	77,079
100	3.704	105,359	3.069	99,363	4.026	90,930	6.163	85,485	4.167	102,341
Restaurant - Fast Food										
1	0.041	1,455	0.034	1,374	0.045	1,260	0.069	1,186	0.046	1,416
2	0.082	2,876	0.068	2,716	0.089	2,491	0.136	2,344	0.092	2,800
3	0.118	4,169	0.098	3,937	0.129	3,612	0.197	3,398	0.133	4,059
5	0.197	6,949	0.164	6,562	0.215	6,020	0.328	5,663	0.222	6,765
7.5	0.291	10,252	0.241	9,681	0.317	8,881	0.485	8,354	0.328	9,980
10	0.385	13,564	0.319	12,810	0.419	11,750	0.641	11,054	0.433	13,206
15	0.570	20,062	0.472	18,946	0.619	17,379	0.948	16,350	0.641	19,531
20	0.760	26,749	0.630	25,262	0.826	23,172	1.264	21,799	0.855	26,042
25	0.944	33,223	0.782	31,375	1.026	28,780	1.570	27,075	1.062	32,344
30	1.127	39,655	0.933	37,450	1.224	34,352	1.874	32,317	1.267	38,606
40	1.502	52,874	1.245	49,933	1.633	45,803	2.499	43,089	1.690	51,475
50	1.870	65,812	1.549	62,152	2.032	57,012	3.111	53,633	2.103	64,071
60	2.232	78,559	1.849	74,190	2.426	68,054	3.713	64,021	2.511	76,481
75	2.790	98,199	2.311	92,738	3.032	85,067	4.641	80,027	3.138	95,601
100	3.704	130,383	3.069	123,132	4.026	112,947	6.163	106,255	4.167	126,934

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Restaurant - Sit-Down										
1	0.041	1,118	0.034	1,054	0.045	974	0.069	918	0.046	1,085
2	0.082	2,210	0.068	2,084	0.089	1,926	0.136	1,815	0.092	2,146
3	0.118	3,203	0.098	3,021	0.129	2,792	0.197	2,631	0.133	3,111
5	0.197	5,339	0.164	5,035	0.215	4,653	0.328	4,385	0.222	5,185
7.5	0.291	7,876	0.241	7,428	0.317	6,864	0.485	6,470	0.328	7,649
10	0.385	10,421	0.319	9,828	0.419	9,082	0.641	8,560	0.433	10,120
15	0.570	15,413	0.472	14,537	0.619	13,432	0.948	12,661	0.641	14,968
20	0.760	20,551	0.630	19,382	0.826	17,910	1.264	16,882	0.855	19,958
25	0.944	25,524	0.782	24,072	1.026	22,244	1.570	20,967	1.062	24,787
30	1.127	30,466	0.933	28,733	1.224	26,551	1.874	25,026	1.267	29,587
40	1.502	40,622	1.245	38,311	1.633	35,401	2.499	33,368	1.690	39,449
50	1.870	50,562	1.549	47,686	2.032	44,064	3.111	41,534	2.103	49,103
60	2.232	60,356	1.849	56,922	2.426	52,599	3.713	49,579	2.511	58,613
75	2.790	75,444	2.311	71,153	3.032	65,748	4.641	61,973	3.138	73,266
100	3.704	100,171	3.069	94,472	4.026	87,297	6.163	82,284	4.167	97,279

Table 2-61: Deemed Energy/Demand Savings Values for Inlet Guide Vane Part-Load Fan Control

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.010	416	0.009	387	0.011	349	0.012	323	0.010	403
2	0.019	823	0.018	766	0.021	690	0.023	639	0.020	797
3	0.028	1,193	0.027	1,110	0.030	1,001	0.033	926	0.029	1,156
5	0.046	1,989	0.044	1,850	0.050	1,668	0.056	1,543	0.048	1,927
7.5	0.068	2,934	0.065	2,729	0.074	2,461	0.082	2,276	0.070	2,842
10	0.090	3,883	0.086	3,611	0.098	3,256	0.109	3,012	0.093	3,761
15	0.133	5,742	0.128	5,340	0.145	4,816	0.161	4,454	0.137	5,562
20	0.177	7,656	0.170	7,120	0.193	6,422	0.214	5,939	0.183	7,416
25	0.220	9,509	0.211	8,843	0.240	7,976	0.266	7,377	0.228	9,211
30	0.262	11,350	0.252	10,556	0.287	9,520	0.317	8,805	0.272	10,994
40	0.350	15,134	0.336	14,074	0.382	12,693	0.423	11,740	0.362	14,659
50	0.436	18,837	0.419	17,518	0.476	15,799	0.527	14,613	0.451	18,247
60	0.520	22,486	0.500	20,911	0.568	18,859	0.629	17,443	0.538	21,781
75	0.650	28,107	0.625	26,139	0.710	23,574	0.786	21,804	0.672	27,226
100	0.863	37,319	0.830	34,706	0.943	31,300	1.043	28,949	0.893	36,149

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Large										
1	0.010	199	0.009	184	0.011	162	0.012	148	0.010	190
2	0.019	393	0.018	363	0.021	321	0.023	292	0.020	376
3	0.028	569	0.027	526	0.030	465	0.033	424	0.029	546
5	0.046	948	0.044	877	0.050	776	0.056	706	0.048	910
7.5	0.068	1,399	0.065	1,294	0.074	1,145	0.082	1,042	0.070	1,342
10	0.090	1,851	0.086	1,713	0.098	1,514	0.109	1,379	0.093	1,775
15	0.133	2,738	0.128	2,533	0.145	2,240	0.161	2,040	0.137	2,626
20	0.177	3,651	0.170	3,378	0.193	2,987	0.214	2,719	0.183	3,501
25	0.220	4,534	0.211	4,195	0.240	3,709	0.266	3,377	0.228	4,348
30	0.262	5,412	0.252	5,007	0.287	4,427	0.317	4,031	0.272	5,190
40	0.350	7,216	0.336	6,677	0.382	5,903	0.423	5,375	0.362	6,921
50	0.436	8,982	0.419	8,310	0.476	7,348	0.527	6,690	0.451	8,614
60	0.520	10,722	0.500	9,920	0.568	8,771	0.629	7,986	0.538	10,283
75	0.650	13,402	0.625	12,400	0.710	10,964	0.786	9,983	0.672	12,853
100	0.863	17,795	0.830	16,464	0.943	14,557	1.043	13,255	0.893	17,066
Office - Small										
1	0.010	179	0.009	166	0.011	146	0.012	133	0.010	172
2	0.019	355	0.018	328	0.021	288	0.023	262	0.020	341
3	0.028	514	0.027	476	0.030	418	0.033	380	0.029	494
5	0.046	857	0.044	793	0.050	696	0.056	633	0.048	823
7.5	0.068	1,265	0.065	1,170	0.074	1,027	0.082	934	0.070	1,214
10	0.090	1,674	0.086	1,548	0.098	1,359	0.109	1,236	0.093	1,607
15	0.133	2,475	0.128	2,289	0.145	2,010	0.161	1,828	0.137	2,376
20	0.177	3,300	0.170	3,052	0.193	2,681	0.214	2,438	0.183	3,169
25	0.220	4,099	0.211	3,790	0.240	3,329	0.266	3,027	0.228	3,935
30	0.262	4,893	0.252	4,524	0.287	3,974	0.317	3,614	0.272	4,697
40	0.350	6,524	0.336	6,032	0.382	5,299	0.423	4,818	0.362	6,263
50	0.436	8,120	0.419	7,508	0.476	6,595	0.527	5,997	0.451	7,796
60	0.520	9,693	0.500	8,963	0.568	7,873	0.629	7,159	0.538	9,305
75	0.650	12,116	0.625	11,203	0.710	9,841	0.786	8,948	0.672	11,632
100	0.863	16,087	0.830	14,875	0.943	13,066	1.043	11,881	0.893	15,444

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Education - K-12										
1	0.010	189	0.009	175	0.011	153	0.012	139	0.010	182
2	0.019	373	0.018	345	0.021	302	0.023	275	0.020	359
3	0.028	541	0.027	501	0.030	438	0.033	398	0.029	520
5	0.046	902	0.044	835	0.050	729	0.056	664	0.048	867
7.5	0.068	1,330	0.065	1,231	0.074	1,076	0.082	979	0.070	1,279
10	0.090	1,760	0.086	1,629	0.098	1,423	0.109	1,295	0.093	1,692
15	0.133	2,603	0.128	2,410	0.145	2,105	0.161	1,916	0.137	2,503
20	0.177	3,471	0.170	3,213	0.193	2,807	0.214	2,555	0.183	3,337
25	0.220	4,311	0.211	3,991	0.240	3,486	0.266	3,173	0.228	4,145
30	0.262	5,146	0.252	4,764	0.287	4,162	0.317	3,787	0.272	4,948
40	0.350	6,861	0.336	6,351	0.382	5,549	0.423	5,050	0.362	6,597
50	0.436	8,540	0.419	7,906	0.476	6,906	0.527	6,286	0.451	8,211
60	0.520	10,194	0.500	9,437	0.568	8,244	0.629	7,503	0.538	9,801
75	0.650	12,742	0.625	11,796	0.710	10,305	0.786	9,379	0.672	12,252
100	0.863	16,918	0.830	15,662	0.943	13,683	1.043	12,452	0.893	16,267
Education - College & University										
1	0.010	206	0.009	190	0.011	168	0.012	153	0.010	197
2	0.019	407	0.018	376	0.021	332	0.023	302	0.020	390
3	0.028	589	0.027	545	0.030	481	0.033	438	0.029	565
5	0.046	982	0.044	909	0.050	801	0.056	730	0.048	942
7.5	0.068	1,449	0.065	1,341	0.074	1,182	0.082	1,078	0.070	1,390
10	0.090	1,918	0.086	1,774	0.098	1,564	0.109	1,426	0.093	1,839
15	0.133	2,836	0.128	2,624	0.145	2,314	0.161	2,109	0.137	2,721
20	0.177	3,782	0.170	3,499	0.193	3,085	0.214	2,812	0.183	3,627
25	0.220	4,697	0.211	4,345	0.240	3,831	0.266	3,492	0.228	4,505
30	0.262	5,606	0.252	5,187	0.287	4,573	0.317	4,168	0.272	5,378
40	0.350	7,475	0.336	6,915	0.382	6,097	0.423	5,557	0.362	7,170
50	0.436	9,304	0.419	8,608	0.476	7,590	0.527	6,917	0.451	8,925
60	0.520	11,106	0.500	10,275	0.568	9,060	0.629	8,257	0.538	10,653
75	0.650	13,882	0.625	12,844	0.710	11,324	0.786	10,322	0.672	13,316
100	0.863	18,432	0.830	17,053	0.943	15,036	1.043	13,704	0.893	17,681

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Retail										
1	0.010	247	0.009	229	0.011	203	0.012	187	0.010	237
2	0.019	488	0.018	452	0.021	401	0.023	369	0.020	468
3	0.028	708	0.027	655	0.030	582	0.033	535	0.029	679
5	0.046	1,180	0.044	1,092	0.050	970	0.056	892	0.048	1,131
7.5	0.068	1,740	0.065	1,611	0.074	1,430	0.082	1,317	0.070	1,669
10	0.090	2,303	0.086	2,131	0.098	1,893	0.109	1,742	0.093	2,208
15	0.133	3,406	0.128	3,153	0.145	2,799	0.161	2,576	0.137	3,266
20	0.177	4,541	0.170	4,203	0.193	3,733	0.214	3,435	0.183	4,355
25	0.220	5,640	0.211	5,221	0.240	4,636	0.266	4,267	0.228	5,409
30	0.262	6,732	0.252	6,231	0.287	5,533	0.317	5,093	0.272	6,456
40	0.350	8,976	0.336	8,309	0.382	7,378	0.423	6,790	0.362	8,608
50	0.436	11,172	0.419	10,342	0.476	9,183	0.527	8,452	0.451	10,714
60	0.520	13,336	0.500	12,345	0.568	10,962	0.629	10,089	0.538	12,789
75	0.650	16,670	0.625	15,431	0.710	13,702	0.786	12,611	0.672	15,986
100	0.863	22,134	0.830	20,488	0.943	18,193	1.043	16,744	0.893	21,226
Restaurant - Fast Food										
1	0.010	307	0.009	285	0.011	254	0.012	233	0.010	296
2	0.019	607	0.018	563	0.021	501	0.023	462	0.020	584
3	0.028	880	0.027	816	0.030	727	0.033	669	0.029	847
5	0.046	1,467	0.044	1,360	0.050	1,211	0.056	1,115	0.048	1,412
7.5	0.068	2,165	0.065	2,006	0.074	1,786	0.082	1,645	0.070	2,083
10	0.090	2,864	0.086	2,654	0.098	2,364	0.109	2,177	0.093	2,756
15	0.133	4,236	0.128	3,926	0.145	3,496	0.161	3,220	0.137	4,076
20	0.177	5,648	0.170	5,235	0.193	4,661	0.214	4,293	0.183	5,434
25	0.220	7,015	0.211	6,501	0.240	5,789	0.266	5,332	0.228	6,749
30	0.262	8,373	0.252	7,760	0.287	6,910	0.317	6,364	0.272	8,056
40	0.350	11,164	0.336	10,347	0.382	9,214	0.423	8,486	0.362	10,742
50	0.436	13,896	0.419	12,879	0.476	11,469	0.527	10,562	0.451	13,370
60	0.520	16,587	0.500	15,373	0.568	13,690	0.629	12,608	0.538	15,960
75	0.650	20,734	0.625	19,217	0.710	17,112	0.786	15,760	0.672	19,950
100	0.863	27,529	0.830	25,515	0.943	22,721	1.043	20,925	0.893	26,488

HP	Amarillo		Dallas		Houston		Corpus Christi		El Paso	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Restaurant - Sit-Down										
1	0.010	235	0.009	218	0.011	196	0.012	180	0.010	226
2	0.019	465	0.018	430	0.021	387	0.023	357	0.020	446
3	0.028	674	0.027	624	0.030	560	0.033	517	0.029	646
5	0.046	1,123	0.044	1,039	0.050	934	0.056	862	0.048	1,077
7.5	0.068	1,657	0.065	1,533	0.074	1,378	0.082	1,272	0.070	1,589
10	0.090	2,193	0.086	2,029	0.098	1,823	0.109	1,683	0.093	2,103
15	0.133	3,243	0.128	3,001	0.145	2,696	0.161	2,489	0.137	3,110
20	0.177	4,324	0.170	4,001	0.193	3,595	0.214	3,318	0.183	4,146
25	0.220	5,370	0.211	4,970	0.240	4,465	0.266	4,121	0.228	5,150
30	0.262	6,410	0.252	5,932	0.287	5,330	0.317	4,919	0.272	6,147
40	0.350	8,547	0.336	7,909	0.382	7,106	0.423	6,559	0.362	8,196
50	0.436	10,638	0.419	9,845	0.476	8,845	0.527	8,164	0.451	10,201
60	0.520	12,699	0.500	11,751	0.568	10,558	0.629	9,746	0.538	12,177
75	0.650	15,873	0.625	14,689	0.710	13,198	0.786	12,182	0.672	15,221
100	0.863	21,076	0.830	19,503	0.943	17,524	1.043	16,174	0.893	20,210

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 & 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
- Climate Zone
- Motor Horsepower
- Baseline Part-load Control Type (outlet damper, inlet damper, inlet guide vane).

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 2-62: Nonresidential HVAC-VFD 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% 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%.
v4.0	10/10/2016	TRM v4.0 update. Added reference for % power and corrected signs for variables in Equation 38.
v5.0	10/2017	TRM v5.0 update. Updated deemed energy/demand tables for revised peak demand definition.

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 2-64 through Table 2-68

Fuels Affected: Electricity

Decision/Action Type: Retrofit and New Construction (NC)

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Calculation

Savings Methodology: Algorithm.

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 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 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
- 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 are operation of a direct expansion (DX) unit or air-cooled chiller without evaporative pre-cooling.

High-Efficiency Condition

Evaporative pre-cooling systems must exceed evaporative effectiveness performance of 75 percent for average dry bulb temperature humidity during peak hours. Table **2-63** contains values that can be used as reference for evaluating evaporative effectiveness.

Table 2-63**: Average Weather during Peak Conditions**[106]

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 46

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

Equation 47

[106] 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 2-64 through Table 2-68.*
DRF	=	*Demand reduction factor. The average peak hour energy reduction divided by the rated full loaded demand. See Table 2-64 through Table 2-68.*

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 48

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 are presented in Table 2-19. These building types are derived from the EIA CBECS study.[107]

The DRF and $EFLH_{reduction}$ values for packaged and split AC are presented in Table 2-64 through Table 2-68. 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.

[107] 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.*

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 2-64: 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 2-65: DRF and EFLH Reduction Values for Ft 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 2-66: 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 2-67: 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 2-68: 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 & 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 & Model
- Installed Number of Units
- Installed Evaporative Pre-Cooling System Make & 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 2-69: Condenser Air Evaporative Pre-Cooling History

TRM Version	Date	Description of Change
v5.0	10/2017	TRM v5.0 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: Specific building types defined by each utility[108]

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET)

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Calculation

Savings Methodology: Calculators, Worksheets.

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[109]
- An initial solar reflectance of greater than or equal to 65%
- A maintenance of solar reflectance of greater than or equal to 50% three years after installation under normal conditions

[108] Building Types are specified in the respective calculators. These building types differ for utilities. It is believed that the cooling EFLH changes based on the building type, but it is unclear as to the reference of the EFLH being used for each.

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

- 75 percent of the roof surface over conditioned space must be replaced
- No significant obstruction of direct sunlight to roof
- The facility must be conditioned with cooling, heating, or both
- Be listed on the ENERGY STAR® list of qualified products.[110]

In the event that one of 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 is the thermal resistance (i.e. R-value) of the existing roof make-up, and the solar reflectance and emissivity of the surface layer. If the existing roof layers are known, the R-value of each layer in Table 2-72 is added together to get a total R-value of the roof assembly. If the existing layers are undetermined, the coefficient of heat transfer (i.e. U-value) of the roof assembly is assumed to be 0.066[111] and R-value is estimated to be 1/U (R=1/0.066=15.15). If the solar reflectance and emissivity are known, then they are used. If they are unknown, then they are determined by the surface layer material in Table 2-71.

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building. The unit type and average tonnage determine the kW/ton efficiency based on ASHRAE 90.1-1989.

Table 2-70. Assumed Cooling and Heating Efficiencies

System Type	Capacity [Tons]	Other Qualifier	Efficiencies
Unitary Air Conditioner	< 5.42	Split	10.0 SEER
		Packaged	9.7 SEER
	5.42 to 11.25	n/a	8.9 EER
	11.25 to 20	n/a	8.3 EER
	20 to 63.33	n/a	8.3 EER
	≥ 63.3	n/a	8.0 EER

[110] ENERGY STAR® Certified Roofs. http://www.energystar.gov/productfinder/product/certified-roof-products/. Accessed 08/15/2016.
[111] Post-1980 building vintage for Houston, TX in Table 19 of U.S. Department of Energy Commercial Reference Building Models of the National Building Stock. NREL. February 2011.

System Type	Capacity [Tons]	Other Qualifier	Efficiencies
Unitary Heat Pump (cooling)	< 5.42	Split	10.0 SEER
		Packaged	9.7 SEER
	5.42 to 11.25	n/a	8.9 EER
	11.25 to 20	n/a	8.3 EER
	20 to 63.33	n/a	8.3 EER
	≥ 63.3	n/a	8.5 EER
Unitary Heat Pump (heating)	< 5.42	Split	6.8 HSPF
		Packaged	6.6 HSPF
	5.4 to 11.25	n/a	3.0 COP
Air Cooled Chiller	≥ 11.25	n/a	2.9 COP
	< 150	Including Condenser	2.7 COP
	> 150	Including Condenser	2.5 COP
Water Cooled Chiller	< 150	Centrifugal	3.8 COP
	150 to 300		4.2 COP
	> 300		4.7 COP
	All	Reciprocating	3.8 COP
	< 150	Rotary, Screw or Scroll	3.8 COP
	150 to 300		4.2 COP
	> 300		4.7 COP
Room Air Conditioner	< 0.5	With Louvered Sides	8.0 EER
	0.5 to 0.67		8.5 EER
	0.67 to 1.17		9.0 EER
	1.17 to 1.66		8.8 EER
	> 1.67		8.2 EER
	< 0.5	Without Louvered Sides	8.0 EER
	0.5 to 1.67		8.5 EER
	> 1.67		8.2 EER

System Type	Capacity [Tons]	Other Qualifier	Efficiencies
Room Heat Pump (Cooling)	< 1.67	With Louvered Sides	8.5 EER
	> 1.67		8.5 EER
	< 1.17	Without Louvered Sides	8.0 EER
	> 1.17		8.0 EER
Room Heat Pump (Heating)	< 1.67	With Louvered Sides	8.5 HSPF
	> 1.67		8.5 HSPF
	< 1.17	Without Louvered Sides	8.0 HSPF
	> 1.17		8.0 HSPF
Packaged Terminal Air Conditioner	< 2.00	n/a	10.9—0.213 * CAP EER
Packaged Terminal Heat Pump (Cooling)	< 2.00	n/a	10.8—0.213 * CAP EER
Packaged Terminal Heat Pump (Heating)	< 2.00	n/a	2.9—0.026 * CAP COP
Electric Resistance Heat	All	n/a	1 COP
Gas Heat	All	n/a	0.80 AFUE

High-Efficiency Condition

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

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

If the project scope is only to add a new ENERGY STAR® material as the new surface layer, then the R-value used for the baseline condition is used for the high-efficiency condition. If the project scope is to add insulation and an ENERGY STAR® material as the new surface layer, then the R-value of the additional insulation is added to the R-value used for the baseline condition. If the entire roof assembly is rebuilt, then the R-value for each layer of the new roof construction is summed to get a total new R-value.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Across the Texas utilities, there are several ways of calculating energy and demand savings for ENERGY STAR® roofs. Each of these is described further below. In addition, a new high performance roofing calculator was developed in 2016. While one industry accepted roofing savings calculator would be ideal, such a calculator is not available at this time. Until then, a single calculator should be used for all projects by a utility.

Oncor and AEP use the algorithms below in their calculators to calculate their savings.

$$Demand\ Savings\ [kW] = \frac{A}{COP} \times \left[\left(\left(\frac{1}{R_{exist} + \left(\frac{1}{h_{in,air}}\right)} \right) - \left(\frac{1}{R_{prop} + \left(\frac{1}{h_{in,air}}\right)} \right) \right) \left(t_o - \frac{\varepsilon \Delta R}{h_o} - t_{in} \right) + \frac{(1-\rho_{exist})E_{tP}}{R_{exist} + \left(\frac{1}{h_{in,air}}\right) h_o} - \frac{(1-\rho_{prop})E_{tP}}{R_{prop} + \left(\frac{1}{h_{in,air}}\right) h_o} \right]$$

Equation 49

$$Energy\ Savings\ [kWh] = \frac{A}{COP} \times \left[\left(\frac{1}{R_{exist} + \left(\frac{1}{h_{in,air}}\right) - R_{prop} + \left(\frac{1}{h_{in,air}}\right)} \right) \left(\sum_{i=1}^{n} t_{o,i} - n \times \frac{\varepsilon \Delta R}{h_o} - n \times t_{in} \right) + \frac{(1-\rho_{exist}) \sum_{i=1}^{n} E_{t,i}}{R_{exist} + \left(\frac{1}{h_{in,air}}\right) h_o} - \frac{(1-\rho_{prop}) \sum_{i=1}^{n} E_{t,i}}{R_{prop} + \left(\frac{1}{h_{in,air}}\right) h_o} \right]$$

Equation 50

Where:

A	=	*Roof Area [ft²]*
h_o	=	*coefficient of heat transfer by long-wave radiation and convection at outer surface [Btu/hr-ºF-ft²], assumed to be 3.*
COP	=	*Equipment cooling efficiency [kW/ton], when efficiency ratings use a value*

		that do not have the units of kW/ton, a conversion to kW/ton needs to be performed. For EER, divide 12 by EER (i.e. kW/ton=12/=EER. For Coefficient of Performance, multiple COP by 3.412 to get EER, then divide 12 by EER.)
R	=	*The total thermal resistance value (R-value) of the roof [hr-ºF-ft²/Btu]. See Table 2-72.*
$h_{in,air}$	=	*The heat transfer coefficient for indoor air [Btu/hr-ºF-ft²], assumed to be 1.68.*
ρ	=	*Reflectance of surface (after three years) for solar radiation*
$E_{t,P}$	=	*Total peak solar radiation incident on surface during a cooling period [Btu/hr-ft²]. See Table 2-73.*
$\Sigma E_{t,I}$	=	*The sum of the hourly solar radiation incident during a cooling period [Btu/hr-ft²]. See Table 2-73.*
n	=	*The number of total cooling hours when solar radiation exist = 636*[112]
ε	=	*Emittance of surface for solar radiation*
ΔR	=	*Difference between long-wave radiation incident on surface from sky and radiation emitted by blackbody at outdoor air temperature [Btu/hr-ft²], assumed to be 20.*
t_o	=	*Outdoor air temperature*
t_{in}	=	*Indoor air temperature, assumed to be 75ºF*

CenterPoint Electric and Xcel Energy also use calculator-based method; however, their method is slightly different, and uses the following algorithms. These algorithms are pulled from their calculator.

$$\Delta Q\left[\frac{Btu}{hr}\right] = \Delta U \times A \times \Delta T = (\frac{1}{R_1} - \frac{1}{R_2}) \times A \times \Delta T$$

Equation 51

$$\Delta T = T_{sol-air} - T_{space} = T_{oa} + \frac{\propto}{h_o} \times \frac{I_{DT}}{24} - \frac{\varepsilon \times \Delta R}{h_o} - T_{space}$$

Equation 52

$$\Delta kW = \Delta Q \times 1.0 \times \frac{1}{12{,}000}$$

Equation 53

[112] Peak hours are set as the months of May to September, 1pm to 7pm weekdays.

$$\Delta kWh = \Delta kW \times EFLH$$

Equation 54

Where:

A	=	*Roof Area [ft²]*
ΔU	=	*Difference in pre- and post-retrofit overall coefficient of heat transfer*
ΔQ	=	*Heat transfer [Btu/hr]*
ΔT	=	*Temperature difference [ºF]*
R_1	=	*Thermal resistance pre-retrofit*
R_2	=	*Thermal resistance post-retrofit*
α	=	*Absorbance of surface for solar radiation*[113]
h_o	=	*Coefficient of heat transfer by long-wave radiation and convection at outer surface*[113]
I_{DT}	=	*Hourly solar radiation incident on surface*[113]*, deemed at 1,122*
ε	=	*Hemispherical emittance of the surface, assumed to be 1.0*
T_{oa}	=	*Outdoor air temperature [ºF]*
T_{sol}	=	*Sol-air temperature [ºF]*[114]
T_{space}	=	*Indoor temperature [ºF]*
ΔR	=	*Difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature*
1.0	=	*Assumed cooling efficiency [kW/ton]*
1/12,000	=	*Conversion from Btu to Tons/hr*
EFLH	=	*Effective full load hours [hours], assumed to be 2,000 hours*

Finally, El Paso Electric uses the methodology found in Docket No. 41070. This docket outlines a deemed method for calculating savings. Their algorithm and deemed input variables used to calculate savings are shown below:

[113] $I_{DT} = \frac{\alpha}{h_o} \times 1.15$. Per the C&I Standard Offer Program Calculator, ASHRAE recommended values for light colored surfaces = 0.15, for medium-colored surfaces = 0.23, and for dark-colored surfaces = 0.30. These values have been approximated using SHGF for a horizontal surface at 32º north latitude as described in 1993 ASHRAE Fundamentals, Chapter 27, Tables 14.

[114] Defined by ASHRAE as the temperature that would yield the same amount of heat transfer as the combination of incident solar radiation, radiant energy exchange with the surroundings, and convective heat exchange with the outdoor air.

$$Cooling\ Energy\ Savings\left[\frac{kWh}{ft^2}\right] = \frac{1}{EER} \times \frac{(\rho_{new} - \rho_{old}) \times E_{t,cooling}}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times 0.001$$

Equation 55

$$Heating\ Energy\ Penalty\left[\frac{kWh}{ft^2}\right] = \frac{1}{COP} \times \frac{(\rho_{old} - \rho_{new}) \times E_{t,heating}}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times \frac{1}{3412}$$

Equation 56

$$Total\ Energy\ Savings^{115} = Cooling\ Energy\ Savings - Heating\ Energy\ Penalty$$

Equation 57

$$Peak\ Demand\ Savings\ \left[\frac{kW}{ft^2}\right] = \frac{1}{EER} \times \frac{(\rho_{new} - \rho_{old}) \times I_t}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times 0.001$$

Equation 58

Where:

EER	=	*Energy efficiency ratio of the buildings air conditioner [Btu/W-hr]*
$E_{t,cooling}$	=	*Total solar radiation incident on the surface throughout the time when a building is in cooling mode [Btu/ft²]*
ρ_{new}	=	*Reflectance (at three years) of the new roof membrane*
ρ_{old}	=	*Reflectance of the original roof membrane*
R_{ins}	=	*R-value of the roof insulation [h-ft²-ºF/Btu]*
R_{cons}	=	*R-value of the roof construction [h-ft²-ºF/Btu]*
$R_{airfilm}$	=	*R-value of the air film [h-ft²-ºF/Btu]*
h_o	=	*Coefficient of heat transfer by long-wave radiation and convection at outer surface*
0.001	=	*Conversion kWh per Watt-Hr*
COP	=	*Coefficient of performance of building's electric heating system*
$E_{t,heating}$	=	*Total solar radiation incident on the surface throughout the time when a building is in heating mode [Btu/ft²]*
3412	=	*Conversion Btu per kWh*
I_t	=	*Total solar radiation incident on the surface during the summer peak hour [Btu/ft²-hr]*

Stipulated reflectance, emissivity, and R-values and solar data used for the calculations are presented next.

[115] For buildings with electric resistance heating.

Table 2-71: Reflectance and Emissivity of Surfaces

Roofing Type	New Reflectance	Aged Reflectance[116]	Emissivity
Black EPDM[117]	0.062	0.062	0.86
Gray EPDM	0.231	0.222	0.87
White EPDM	0.687	0.541	0.87
Smooth Bitumen	0.058	0.058	0.86
White Granular Bitumen	0.258	0.241	0.92
Dark Gravel on Built-Up Roof[118]	0.120	0.120	0.90
Light Gravel on Built-Up Roof	0.340	0.298	0.90
White-Coated Gravel on Built-Up Roof	0.650	0.515	0.90

[116] Calculated based on Aged Reflectance=0.2+ß (New Reflectance – 0.20), where ß=0.7 non-field applied coatings per http://coolroofs.org/resources/california-title-24 and https://publications.lbl.gov/islandora/object/ir%3A157365/datastream/PDF/view

[117] First 5 in list from Laboratory Testing of the Reflectance Properties of Roofing Materials. Florida Solar Energy Center. Parker, McIlvaine, Barkaszi, Beal, Anello. http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-670-00/

[118] Last 3 in list from Lawrence Berkley National Laboratory. http://energy.lbl.gov/coolroof/membrane.htm#membrane

Table 2-72: R-Values of Different Material [hr-ft^2-°F/Btu][119]

Roofing Material	R-Value	Membrane	R-Value
Asbestos—cement shingles	0.21	Permeable Felt	0.06
Asphalt Roll Roofing	0.15	Seal, 2 layers of mopped 15 lb felt	0.12
Asphalt Shingles	0.44	Sel, plastic film	0.00
Built-up Roofing (0.375”)	0.33	**Insulation Material**	**R-Value (per inch)**
Slate (0.5”)	0.05	None	0.00
Wood Shingles	0.94	Cellulose	3.70
Construction Material	**R-Value**	Fiberboard	2.78
Concrete 4”	0.08	Fiberglass	3.20
Concrete 8”	1.11	Perlite	2.78
Concrete 12”	1.23	Polystyrene	4.00
Brick 4”	0.80	Polyurethane	6.25
Wood Frame	0.10	Polyisocyanurate	7.00
Metal Frame	0.00	Polyisocyanurate Composite	4.17
Ceiling Material	**R-Value**	Polystyrene Bead Board	3.57
Acoustic Tile	0.06	Polystyrene Composite Board	3.32
Drywall Finish	0.45	Rock Wool	3.10
Plaster Finish	0.45	Vermiculite	2.13
Plenum	**R-Value**	Cork	3.57
Yes	0.61		
No	0.00		

Table 2-73: TMY2 Solar Data

Climate Zone	Peak Total Solar Radiation Incident [Btu/hr-ft^2]	Total Solar Radiation Incident [Btu/ft^2]
Amarillo, TX	329	124,314
Brownsville, TX	326	113,022
Dallas/Fort Worth, TX	335	117,686
Houston, TX	325	101,734
Austin, TX	342	116,511

[119] These values are listed in both the Oncor and the CalcSmart calculators, but a source for all of the values have not been provided.

Table 2-74: Deemed Values used in Algorithm for El Paso Electric[120]

Variable	Assumed Value
EER	8.5[121]
COP	1.0[122]
ρ_{new}	0.7[123]
ρ_{old}	0.062[124]
$E_{t,cooling}$	469,199[125]
$E_{t,heating}$	185,347[125]
I_t	217[126]
R_{ins}	16[127]
R_{cons}	2[128]
$R_{airfilm}$	0.92[129]
h_o	3[130]

Deemed Energy and Demand Savings Tables

The resulting deemed energy and demand savings values are presented in Table 2-75. Note that cool roofs have a negative heating impact, as reflected in the lower deemed savings value for Electric Resistance Heat versus Gas Heat.

Table 2-75: Cool Roof Deemed Savings for El Paso Electric

Region	Electric A/C and Gas Heat [kWh/ft^2]	Electric A/C and Electric Resistance Heat [kWh/ft^2]	Summer Peak Electric A/C [kW/ft^2]	Winter Peak Electric Resistance Heat [kW/ft^2]
West	0.6205	0.0099	0.0003	0.00

[120] All values and their sources were found in Docket No. 41070.
[121] Federal minimum for split and packaged systems, 11.25-20 tons from January 1st, 1994 through December 31st, 2009.
[122] Value for electric resistance heat.
[123] Minimum required by EPE Cool Roof Program.
[124] Reflectance of ethylene propylene diene monomer (EPDM) rubber. Sourced from http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-670-00. Accessed 09/12/2013.
[125] Total global horizontal irradiance when temperature is over 65ºF (typical building's thermal balance point) per El Paso TMY3 file.
[126] Total global horizontal irradiance during summer peak hour per El Paso TMY3 file.
[127] IECC 2000 Table 802.2(17).
[128] Typical value.
[129] ASHRAE Fundamentals 2006 27.2.
[130] ASHRAE Fundamentals 2006 18.22.

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 & 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 Roofing Surface layer or
- Existing Roofing Reflectance and
- Existing Roofing Emissivity
- New Roofing Construction, if rebuilding entire roof assembly
- New Insulation Type and Thickness, if adding insulation
- ENERGY STAR® Roofing Initial Solar Reflectance
- ENERGY STAR® Roofing Solar Reflectance after three years
- ENERGY STAR® Roofing Rated Life
- Building Type
- Cooling Equipment Type Serving Top Floor
- Heating System Type Serving Top Floor
- Average HVAC Equipment Tonnage of each unit serving top floor
- HVAC Equipment Rated Efficiency.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 41070—Provides deemed energy and demand savings values for El Paso, TX.
- PUCT Docket 36779—Provides EUL for commercial Cool Roof.

Relevant Standards and Reference Sources

- Oncor Technical Resource Manual. 2013.
- ENERGY STAR® Certified Cool Roof Products. http://www.energystar.gov/productfinder/product/certified-roof-products/. Accessed 09/12/2013.
- IECC 2000 Table 802.2(17)
- 2006 ASHRAE Fundamentals
- EUMMOT Commercial Standard Offer Program. Measurement and Verification Guidelines for Retrofit and New Construction Projects. http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf. Accessed 09/10/2013
- DEER 2014 EUL update.

Document Revision History

Table 2-76: Nonresidential Cool Roof 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. Table 2-72 through Table 2-75: 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 to Table 2-72. Added new high performance roof calculator for use in determining ENERGY STAR® roof savings.
v5.0	10/2017	TRM v5.0 update. No revisions.

2.3.2 Window Treatments Measure Overview

TRM Measure ID: NR-BE-WF

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 Calculations

Savings Methodology: Algorithms.

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 2-77 that do not have existing solar films or solar screens, are not shaded by exterior awnings, curtains, or overhangs, 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 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.[131] The method estimates 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 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 59

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

Equation 60

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

Equation 61

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

Equation 62

Where:

Demand Savings	*= Peak demand savings per window orientation*
Energy Savings	*= Energy savings per window orientation*
Afilm,o	*= Area of window film applied to orientation [ft2]*
SHGFo	*= Peak solar heat gain factor for orientation of interest [Btu/hr-ft2-year]. See Table 2-77.*
SHGo	*= Solar heat gain for orientation of interest [Btu/ft2-year]. See Table 2-77.*
SCpre	*= Shading coefficient for existing glass/interior-shading device. See Table 2-78.*
SCpost	*= Shading coefficient for new film/interior-shading device, from manufacturer specs*
COP	*= Cooling equipment COP based on Table 2-79 or actual COP equipment, whichever is greater*
3413	*= Conversion factor [Btu/kW]*

[131] See, for example, section 5.4 of the Equipment Efficiency Standards Appendices to the AEP companies' 2013 Commercial & Industrial Standard Offer Program Manual. Online. Available: http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf

Table 2-77: Solar Heat Gain Factors[132]

Orientation	Solar Heat Gain (SHG) [Btu/ft²-year]	Peak Hour Solar Heat Gain (SHGF) [Btu/hr-ft²-year]				
		Zone 1[133]	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 2-78: Recommended Shading Coefficient (SC) for Different Pre-Existing Shade Types

Shading Type	Shading Coefficient	Source[134]
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 ≤ 10°, 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

[132] 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.

[133] 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.

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

Table 2-79: Recommended COP for Different HVAC System Types

HVAC Type	COP	Source[135]
Air Conditioners & 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 a EUL of 10 years for this measure (EUL ID—GlazDaylt-WinFilm).

Program Tracking Data & 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.
- ASHRAE Standard 90.1-1999

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

- DEER 2014 EUL update.

Document Revision History

Table 2-80: Nonresidential Window Treatment 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.

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: Deemed Savings Values

Savings Methodology: Look-up Tables.

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 offers 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, or as a 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[136].

- Half-Size Combination Oven: A 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: A 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.

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[137]

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 2-81 below.

Table 2-81: Cooking Energy-Efficiency and Idle Energy Rate Requirements[138]

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 63

[137] 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.

[138] 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 64

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

Equation 65

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

Equation 66

kWh_{conv} and kWh_{st} are each calculated the same for both the base (baseline) and post (ENERGY STAR®) cases, as shown in Equation 65 and Equation 66, except they require their respective *η (Cooking Efficiencies),* E_{Idle} *(Idle Energy Rates) and* C_{cao} *(Production Capacity)* relative to Convection and Steam Modes as seen in Table 2-82.

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

Equation 67

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 2-82)*
E_{Idle}	=	*Idle energy rate [W]. (Differs for Convection-Mode and Steam–Mode, for Baseline and ENERGY STAR®. See Table 2-82*
$\eta cooking$	=	*Cooking energy efficiency [%]. (Differs for Convection-Mode and Steam–Mode, for Baseline and ENERGY STAR®. See Table 2-82)*
CCap	=	*Production capacity per pan [lb/hr]. (Differs for Convection-Mode and Steam–Mode, for Baseline and ENERGY STAR®. See Table 2-82)*
1000	=	*Wh to kWh conversion*

Table 2-82: Deemed Variables for Energy and Demand Savings Calculations

Parameter	Convection-Mode		Steam–Mode	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
kWhbase	See Table 2-83			
kWhpost				
Wfood	200			
thours	12			
tDays	365			
Npans	10			
CF[139]	0.92			
Efood	73.2		30.8	
ηcooking	72%	76%	49%	55%
EidleB	1,320	1,299	5,260	1,970
CCap	79	119	126	177

Deemed Energy and Demand Savings Tables

The energy and demand savings of High Efficiency Combination Ovens in Table 2-83 are calculated in the Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment using the default parameters shown above in Table 2-82.

Table 2-83: Deemed Energy and Demand Savings Values[140]

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 ENERGY STAR® calculator and with the DEER 2014 EUL update (EUL ID—Cook-ElecCombOven).

[139] California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed July 12, 2012, http://capabilities.the EM&V team.com/CeusWeb/Chart.aspx.

[140] 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 & 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
- Verification of ENERGY STAR® certification.

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 2-84: Nonresidential High-Efficiency Combination Oven 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.

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: Deemed Savings Values

Savings Methodology: Look-up Tables.

Measure Description

This section covers the savings from retrofit (early retirement), replacement, or new installation of a full-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 of energy rates of the oven, cooking efficiencies, operating hours, production capacities and building type. An 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®[141].

- Half-Size Combination Oven: A combination oven capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch.
- Full-Size Combination Oven: A combination oven capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch.
- Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[142]

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

[142] 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 2-85 below:

Table 2-85: Convection Oven Cooking Energy Efficiency and Idle Energy Requirements

Oven Capacity	Idle Rate (W)	Cooking Energy Efficiency (%)
Half-Size	≤ 1,000	≥ 71
Full-Size	≤ 1,600	≥ 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 68

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

Equation 69

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

Equation 70

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

Equation 71

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*
E_{Food}	=	*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 2-86: Deemed Variables for Energy and Demand Savings Calculations[143]

Variable	Full-Size	Half-Size
LB[145]	100	
Days	365	
CF[144]	0.92	
E_{food}[145]	73.2	
EFF_{base}[145]	65%	68%
EFF_{HE}[145]	71%	
$IDLE_{base}$[145]	2,000	1,030
$IDLE_{HE}$[145]	1,600	1,000
T_{on}	12	
PC_{base}[145]	90	45
PC_{HE}[145]	90	50

[143] 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 year. In an effort 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 2-66.

[144] California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed July12, 2012, http://capabilities.the EM&V team.com/CeusWeb/Chart.asnx.

[145] 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 2-87: 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 & 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
- Verification of ENERGY STAR® certification.

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 1/22/2015.

- ENERGY STAR® list of Qualified Commercial Ovens. http://www.energystar.gov/productfinder/download/certified-commercial-ovens. Accessed 1/22/2015.
- DEER 2014 EUL update.

Document Revision History

Table 2-88: Nonresidential High-Efficiency Convection Oven 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.

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: Deemed Savings Values

Savings Methodology: Look-up Tables.

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% more energy-efficient and 25% more water-efficient than standard models. The energy savings associated with ENERGY STAR® commercial dishwashers is 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 assure 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 2-89:

- Under Counter Dishwasher
- Stationary Rack, Single Tank, Door Type Dishwasher
- Single Tank Conveyor Dishwasher
- Multiple Tank Conveyor Dishwasher
- Pot, Pan & Utensil.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[146]

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 2-89: Nonresidential ENERGY STAR® Commercial Dishwashers Descriptions

Equipment Type	Equipment Description
Under Counter Dishwasher	A machine with 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.

[146] 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[147] or high temperature[148] machine as defined by Table 2-89, 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 2-90 below.

Table 2-90: High-Efficiency Requirements for Commercial Dishwashers[149]

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[150]	≤ 1.20	≤ 0.58[150]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

[148] High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

[149] Table 2-90 values are provided in ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers, Version 2.0. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Dishwasher_Program_Requirements.pdf.

[150] 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 72

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

Equation 73

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

Equation 74

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

Equation 75

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 2-91: 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}[151]	365				
t_{hours}[5]	18				
CF	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

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

152 California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.the EM&V team.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 2-92: 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 & 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.

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 2-93: Nonresidential ENERGY STAR® Commercial Dishwashers 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 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.

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: Deemed Savings Values

Savings Methodology: Look-up Tables.

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 off of 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.[153] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[154]

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

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[153] A list of ENERGY STAR® qualified products can be found on the ENERGY STAR® website: http://www.energystar.gov/productfinder/product/certified-commercial-hot-food-holding-cabinets/results. Accessed 08/05/2013.

[154] 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.

- Dual function equipment
- Heated transparent merchandising cabinets
- 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/ft^3 for all equipment sizes.

High-Efficiency Condition

Eligible equipment are set by ENERGY STAR® and based on the cabinet's interior volume. Table 2-94 summarizes Idle Energy Rates per ENERGY STAR® Version 2.0:

Table 2-94: Maximum Idle Energy Rate Requirements ENERGY STAR® Qualification

Product Category	Product Interior Volume [ft^3]	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

* V = Interior Volume = Interior Height x Interior Width x Interior Depth

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 76

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

Equation 77

Where:

E_{IdleB}	=	*Baseline idle energy rate [W]. See Table 2-95*
E_{IdleP}	=	*Idle energy rate after installation [W]. See Table 2-95*
V	=	*Product Interior Volume [ft^3]*
t_{hrs}	=	*Equipment operating hours per day [hrs.]*
t_{days}	=	*Facility operating days per year*
CF	=	*Peak coincidence factor*

Table 2-95: 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[155] [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 2-96: 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[156] and the DEER 2014 EUL update (EUL ID—Cook-Hold Cab)

Program Tracking Data & 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

[155] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.the EM&V team.com/CeusWeb/Chart.aspx. Accessed 07/12/12.

[156] 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." http://www.energystar.gov/ia/business/bulkpurchasinglb%20sp%20savings%20calc/commercial%20kitchen%20equipment%20calculator.xls. Accessed 09/14/11.

- Post-Retrofit Equipment Interior Cabinet Volume
- Post-Retrofit Equipment Size (Half, Three-Quarters, Full).

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 2-97: Nonresidential Hot Food Holding Cabinets 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.

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: Deemed Values

Savings Methodology: Look-up Tables.

Measure Description

This section presents the deemed savings methodology for the installation of an ENERGY STAR® Electric Fryer. Fryers which 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®[157].

- 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.[158]

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[157] ENERGY STAR® Program Requirements Product Specifications for Electric Fryers. Eligibility Criteria Version 2.0. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Fryers_Program_Requirements.pdf. Accessed 01/27/15.

[158] 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 2-98.

Table 2-98: High-Efficiency Requirements for Electric Fryers

Inputs	Standard	Large-Vat
Cooking energy efficiency	≥ 80%	≥ 80%
Idle energy rate [W]	≤ 1,000	≤ 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 78

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

Equation 79

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

Equation 80

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

Equation 81

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 2-99: Deemed Variables for Energy and Demand Savings Calculations[159]

Parameter	Standard-Sized Vat		Large-Vat	
	Baseline	Post Retrofit	Baseline	Post Retrofit
kWh_{base}	See Table 2-100			
kWh_{post}				
W_{food}	150			
t_{OpHors}	16		12	
t_{days}	365			
CF[160]	0.92			
E_{food}	167			
$\eta_{cooking}$	75%	80%	70%	80%
E_{idle}	1,050	1,000	1,350	1,110
C_{Cap}	65	70	100	110

[159] Deemed input values come from ENERGY STAR® Commercial Kitchen Equipment Calculator. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Accessed 01/30/2015.

[160] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.the EM&V team.com/CeusWeb/Chart.aspx. Accessed 07/12/12,

Deemed Energy and Demand Savings Tables

The energy and demand savings of Electric Fryers are deemed values. Table 2-100 provides these deemed values.

Table 2-100: 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	16,488	952	0.150
Large Vat	18,236	15,700	2,536	0.533

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).

Program Tracking Data & 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
- Verification of ENERGY STAR® certification.

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/ia/partners/product_specs/program_reqs/Commercial_Fryers_Program_Requirements.pdf. Accessed 01/22/2015.
- DEER 2014 EUL update.

Document Revision History

Table 2-101: Nonresidential Electric Fryers 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.

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 2-103

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Direct Install or Point of Sale

Deemed Savings Type: Deemed Values

Savings Methodology: Deemed.

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 to reduce 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 pre-rinse sprayer using 1.60 GPM.[161]

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.[162]

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

[162] 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 82

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

Equation 83

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 2-102: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
F_B	1.6[161]
F_P	1.25[161,162]
$U_B = U_P$	Fast Food Restaurant: 45 min/day/unit[163] Casual Dining Restaurant: 105 min/day/unit[163] Institutional: 210 min/day/unit[163] Dormitory: 210 min/day/unit[163] K-12 School: 105 min/day/unit[164]
T_H	120[165]
T_C	69[166]
Days[167]	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[168]	Fast Food Restaurant: 6.81% Casual Dining Restaurant: 17.36% Institutional: 5.85% Dormitory: 17.36% K-12 School: 11.35%

163 CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Valves.

164 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.

165 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.

166 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.

167 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.

168 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 2-103: 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.[161,166] This is consistent with PUCT Docket No. 36779.

Program Tracking Data & 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: http://interchange.puc.state.tx.us/WebApp/Interchange/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 2-104: Nonresidential Pre-Rinse Spray Valves 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.

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: Deemed Savings Values

Savings Methodology: Look-up Tables.

Measure Description

This document presents the deemed savings methodology for the installation of Electric Steam Cookers. Steam cookers are available in 3, 4, 5, or 6 pan and larger capacities. ENERGY STAR® qualified units are up to 50% 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.[169] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets[170]

Baseline Condition

Eligible baseline condition 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 2-105.

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

[170] 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 2-105: ENERGY STAR® Energy Efficiency and Idle Rate Requirements for Electric Steam Cookers[171]

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 84

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

Equation 85

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

Equation 86

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

Equation 87

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{post}	=	*Post annual energy consumption [kWh]*
ΔkWh	=	*Energy Savings = kWh_{base}—kWh_{post}*

171 ENERGY STAR®. "Commercial Steam Cookers Key Product Criteria.". http://www.energystar.gov/index.cfm?c=steamcookerspr_crit_steamcookers. Accessed 9/26/11

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 2-106: Deemed Variables for Energy and Demand Savings Calculations[172]

Parameter	Baseline Value	Post Retrofit Value
kWh_{base}	See Table 2-107	
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	
$t_{OpHours}$	12	
N_{OpDays}	365	
CF[173]	0.92	

[172] ENERGY STAR®. "Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment." Accessed 9/26/11. Equipment specifications from 2009 Food Service Technology Center (FSTC) research on available models. Equipment cost from 2010 EPA research on available models using AutoQuotes. http://www.energystar.gov/ia/business/bulk purchasing/bpsavings calc/commercial kitchen equipment calculator.xls.

[173] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.the EM&V team.com/CeusWeb/Chart.aspx. Accessed 07/12/12.

Table 2-107: Annual Energy Consumption and Daily Food Cooked[174]

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
	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

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.

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 & 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
- Verification of ENERGY STAR® certification.

References and Efficiency Standards

Petitions and Rulings

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

[174] The pre- and post- energy values are calculated using the ENERGY STAR® calculator and the inputs from Table 2-85 and Table 2-86. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

Relevant Standards and Reference Sources

- ENERGY STAR® specifications for Commercial Steam Cookers. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Steam_Cookers_Program_Requirements.pdf. Accessed 01/22/2015.
- DEER 2014 EUL update.

Document Revision History

Table 2-108: Nonresidential High-Efficiency Commercial Steam Cookers 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.

2.5 NONRESIDENTIAL: REFRIGERATION

2.5.1 Door Heater 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 Values

Savings Methodology: Look-up Tables**.**

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

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 from 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 88

The baseline assumes door heats are running on 8,760 operation. In the post-retrofit case, the duty for each hourly reading is calculated by assuming a linear relationship between indoor DP and duty cycle for each bin reading. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89ºF DP and all on (duty cycle of 100%) at 52.87ºF for a typical supermarket. Between these values, the door heaters' duty cycle changes proportionally:

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

Equation 89

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:

kWAsh = 0.109 per door or 0.0436 per linear foot of door175,176

For low temperature:

kW_{Ash} *= 0.191 per door or 0.0764 per linear foot of door*[177,178]

Equation 90

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

[176] 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.

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

[178] 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 91

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

Equation 92

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35% of the anti-sweat heat becomes a load on the refrigeration system[179], 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 93

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[180].

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 2-109.

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

Equation 94

Where:

a = *3.75346018700468*

b = *-0. 049642253137389*

c = *29.4589834935596*

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

[180] Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & 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 95

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 2-109: Values Based on Climate Zone City

Climate Zone	Summer Design Dry Bulb Temp[181]	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 96

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

Equation 97

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 98

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

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

Equation 99

While there might be instantaneous demand savings as a result 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 100

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.

[181] ASHRAE Climatic Region Data, 0.5% (ºF).

Table 2-110: 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 & 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: http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/40669_3_735684.pdf . Accessed 08/08/2013. http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/40669_7_736775.pdf . Accessed 08/08/2013.
- PUCT Docket 36779—Provides EUL for Anti-Sweat Heater Controls.

Relevant Standards and Reference Sources

- DEER 2014 EUL update.

Document Revision History

Table 2-111: Nonresidential Door Heater Controls 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 94 and Equation 95.
v5.0	10/2017	TRM v5.0 update. No revisions.

2.5.2 ECM Evaporator Fan Motor 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: Algorithm.

Measure Description

This document presents the deemed savings methodology for the installation of an Electronically Commutated Motor (ECM) in cooler and freezer display cases replacing existing evaporator fan motors. ECMs can reduce fan energy use up to approximately 65%, and can also provide higher efficiency, automatic variable-speed drive, lower motor operating temperatures, and less maintenance.

Eligibility Criteria

All ECMs must constitute suitable, size-for-size replacements of evaporator fan motors.

Baseline Condition

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 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 101

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

Equation 102

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

Equation 103

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

Equation 104

Freezer

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

Equation 105

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

Equation 106

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

Equation 107

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

Equation 108

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 2-112: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
W_{base}	See Table 2-113
W_{ee}	See Table 2-113
LF[182]	0.9
$DC_{EvapCool}$[183]	100%
$DC_{EvapFreeze}$[184]	94.4%
COP_{cooler}	See Table 2-114
$COP_{freezer}$	See Table 2-114
Hours[185]	8760 or 8273[186]
%OFF	0 or 46%

Table 2-113: Motor Sizes, Efficiencies and Input Watts[187]

Motor Eff. & 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

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

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

184 Ibid.

185 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.

186 Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf.

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

Table 2-114: 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 or not the motors have controls. Evaporator fan nameplate data is also required; rated power and efficiency.

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 & 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
- 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 2-115: Nonresidential ECM Evaporator Fan Motors 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.

2.5.3 Electronic Defrost Controls Measure Overview

TRM Measure ID: NR-RF-DF

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: Algorithm, Engineering estimates.

Measure Description

This document presents the deemed savings methodology for the installation of electronic defrost controls. The controls sense whether or not 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 number of defrosts. The energy and demand savings are calculated using the following equations:

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

Equation 109

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

Equation 110

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

Equation 111

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

Equation 112

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 & refrigeration type*

Table 2-116: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
DRF[188]	35%
Eff_{MT}[189]	Amarillo: 1.86 Dallas-Ft. Worth: 1.98 El Paso: 2.02 Houston: 1.86 McAllen: 1.98
Eff_{LT}[189]	Amarillo: 2.41 Dallas-Ft. Worth: 2.57 El Paso: 2.61 Houston: 2.41 McAllen: 2.57

188 Energy & 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.

189 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.[190]

Program Tracking Data & 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.

Document Revision History

Table 2-117: Nonresidential Electronic Defrost Controls 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.

190 Energy & Resource Solutions (2005). *Measure Life Study.* Prepared for The Massachusetts Joint Utilities.

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: Algorithm.

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

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 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 operation of the fan. The energy and demand savings are calculated using the following equations:

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

Equation 113

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

Equation 114

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 2-118: Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
kW_{evap}[191]	0.123 kW
kW_{circ}[192]	0.035 kW
DC_{comp}[193]	50%
DC_{evap}[194]	Cooler: 100% Freezer: 94%
BF[195]	Low Temp: 1.5 Medium Temp: 1.3 High Temp: 1.2

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

192 Wattage of fan used by Freeaire and Cooltrol.

193 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 & 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.

194 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).

195 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 & 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 2-119: Nonresidential Evaporator Fan Controls 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.

2.5.5 Night Covers for Open Refrigerated Display Cases Measure Overview

TRM Measure ID: NR-RF-RC

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 Value (per linear ft. of case)

Savings Methodology: Look-up Tables.

Measure Description

This document presents the deemed savings methodology for the installation of night covers on otherwise open vertical (multi-deck) and horizontal (or coffin-type) low-temperature and medium-temperature display cases to decrease 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

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 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% of the total cooling load of open vertical (or multi-deck) display cases.[196]
- Infiltration accounts for approximately 24% of the total cooling load of open horizontal (coffin or tub style) display cases.[196]

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

- 8% on vertical cases[196]
- 50% on horizontal cases.[197]

The energy savings due to the reduced infiltration load when night covers are installed will vary based on 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 115

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)

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

[197] 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 116

For Low Temperature (LT):

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

Equation 117

Where:

DB_{adj} = *Design dry-bulb temperature (ºF), based on climate zone, of ambient or space where the compressor/condensing units reside. Table 2-120 below lists design dry-bulb temperatures by climate zone.*

Table 2-120: 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)[198]
Amarillo, TX	96
Dallas-Ft. Worth, TX	100
El Paso, TX	101
Houston, TX	96
McAllen, TX	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.[199]
- 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 118

Where:

PLR = *Part Load Ratio*

$Q_{cooling}$ = *Cooling Load*

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

Qcapacity = Total Compressor Capacity[200]

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

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

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 119

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

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).

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

Equation 120

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

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 121

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 122

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

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

Equation 123

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 124

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 125

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, TX) was chosen to represent the entire state.[201] The deemed energy and demand savings are shown below.

Table 2-121: 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 Temp Cases	45	0
Night Covers on Horizontal Low Temp Cases	23	0
Night Covers on Vertical Medium Temp Cases	35	0
Night Covers on Horizontal Medium Temp 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).

Program Tracking Data & 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.

[201] 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.

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 2-122: Nonresidential Night Covers for Open Refrigerated Display Cases 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 119 and Equation 120.
v5.0	10/2017	TRM v5.0 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 & New Construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Calculation

Savings Methodology: Algorithm.

Measure Description

This document presents the deemed savings methodology for the installation of ENERGY STAR® or CEE certified Solid & 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

Sold- or glass-door reach-in refrigerators and freezers must meet CEE or ENERGY STAR® minimum efficiency requirements (See Table 2-124).

Baseline Condition

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 2-123.

Table 2-123: Baseline Energy Consumption[202][203]

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 2-124 below:

Table 2-124: Efficient Energy Consumption[204]

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 2-123 and Table 2-124, based on the volume of the units.

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[202] 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.

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

[204] 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 found below.

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

Equation 126

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

Equation 127

Where:

kWh_{base}	=	*Baseline maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 2-123.*
kWh_{ee}	=	*Efficient maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 2-124.*
V	=	*Chilled or frozen compartment volume [ft^3] (as defined in the Association of Home Appliance Manufacturers Standard HRF-1-1979)*
365	=	*Days per year*
8760	=	*Hours per year*
CF	=	*Summer Peak Coincidence Factor (1.0)*[205]

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[206].

Program Tracking Data & 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 Unit Volume
- Baseline Unit Door Type (Solid or Glass)
- Baseline Unit Temperature (Refrigerator or Freezer)
- Post-Retrofit Unit Volume

[205] 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.

[206] 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 & 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 2-125: Nonresidential Solid and Glass Door Refrigerators and Freezers 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.

2.5.7 Strip Curtains for Walk-In Refrigerated Storage Measure Overview

TRM Measure ID: NR-RF-SC

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit & New Construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Value (per door/opening)

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

Baseline efficiency case is a refrigerated walk-in space with nothing to impede air flow 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 as long as 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 2-126.

Table 2-126: Deemed Energy and Demand Savings for Freezers and Coolers[207]

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 & 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.

[207] 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 2-127: Nonresidential Walk-In Refrigerator and Freezer Strip Curtains 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.

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: Deemed Savings Values

Savings Methodology: Engineering 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

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 from 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 128

The baseline assumes door heats are running on 8,760 operation. In the post-retrofit case, it is assumed that the door heaters will be all off (duty cycle of 0%).

The instantaneous door heater power (kW_{ASH}) as a resistive load remains constant is per linear foot of door heater at:

For medium temperature:

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

For low temperature:

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

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 129

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

Equation 130

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[208], 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 131

[208] 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[209].

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 2-109:

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

Equation 132

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 133

209 Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & 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 134

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

Equation 135

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 136

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

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

Equation 137

While there might be instantaneous demand savings as a result 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 138

Table 2-128: 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 & 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 2-129: Nonresidential Zero-Energy Refrigerated Case Doors 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.

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: Deemed Value (per machine)

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 are deemed values for different sized vending machines. These values have been pieced together from different sources and studies. The energy and demand savings of Vending Machine Controllers are deemed values. The following tables provide these deemed values.

Table 2-130: Deemed Energy and Demand Savings Values by Equipment Type

Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW][210]
Control for Refrigerated Cold Drink Unit cans or bottles	1,612[211]	0.030
Control for Refrigerated Reach-in Unit any sealed beverage	1,086[212]	0.035
Control for Non-Refrigerated Snack Unit with lighting (including warm beverage)	387[213]	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 & 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.

[210] 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.
[211] Pacific Gas and Electric, Work Paper VMCold, Revision 3, August, 2009, Measure Code R97.
[212] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August, 2009, Measure Code R143.
[213] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August, 2009, Measure Code R98.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A: http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/40669_3_735684.PDF. Accessed 9/24/2013.
- 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. http://www.eceee.org/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper. Accessed 9/24/2013.
- DEER 2014 EUL update.

Document Revision History

Table 2-131: Nonresidential Vending Machine Controls 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.

2.6.2 Lodging Guest Room Occupancy Sensor Controls Measure Overview

TRM Measure ID: NR-MS-GR

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: Deemed Savings Calculation

Savings Methodology: Building Simulation.

Measure Description

This measure 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 use of this measure in college dormitories.[214] This measure is also commonly referred to as a guest room energy management (GREM) system.

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% 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.

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).

[214] 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.

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[215] 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.[216]

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 and HVAC+Lighting control configurations, and for three facility types: Motel and Hotel guest rooms, and Dormitory rooms.

[215] 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.

[216] A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 2-132: Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Representative City (Region)[217]	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & 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-Ft 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-Ft 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 2-133: Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & 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-Ft 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-Ft Worth (North)	0.134	452	0.154	617	0.134	517	0.154	676
Houston (South)	0.136	423	0.156	599	0.136	446	0.156	621
McAllen (Valley)	0.149	467	0.169	652	0.149	483	0.169	667
El Paso (West)	0.106	312	0.126	479	0.106	338	0.126	501

[217] Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo (Panhandle) was “Panhandle”, Dallas-Ft Worth (North) was “North”, Houston (South) was “South Central”, El Paso (West) was “Big Bend”, and McAllen (Valley) was “Rio Grande Valley”.

Table 2-134: Deemed Energy and Demand Savings for Dormitories per Room, by Region

Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & 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-Ft 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-Ft 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 is 10 years based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study[218]. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

Program Tracking Data & 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

[218] Energy & 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.

- Temperature Offset category (5 or 10 degrees)
- Control Type (HVAC-Only or HVAC & 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 2-135: Lodging Guest Room Occupancy Controls 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.

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 Algorithm

Savings Methodology: Engineering estimates, Field study, Algorithm

Measure Description

Pump-off Controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions, which is the condition 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[219]" 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[220] 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, 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 11th, 2014) with rod pumps operating on time clock controls or less efficient control devices.

High-Efficiency Condition

The efficient condition is the same existing well retrofitted with a pump-off controller.

[219] 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 downstroke causing extreme shock loading of the components which can result in premature equipment failure.

[220] 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.

Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*[221] (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*[222], 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[223].

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 139

$$Demand\ Savings\ [kW] = \frac{EnergySavings}{8760}$$

Equation 140[224]

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 141

$$POC\%On = \frac{Run_{Constant} + Run_{Coefficient} \times VolumetricEfficiency\% \times TimeClock\%On \times 100}{100}$$

Equation 142[225]

[221] 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).

[222] *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.

[223] The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

[224] The equations in the petition for peak demand simplify to the equation shown.

[225] 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 2-136*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 2-137*
SME	=	*Mechanical efficiency of sucker rod pump, see Table 2-136*
TimeClock%On	=	*Stipulated baseline timeclock setting, see Table 2-136*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956. Derived from SPE 16363*[226]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

Deemed Energy and Demand Savings Tables

Table 2-136: Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/ Deemed Values
LF (Load Factor)	25%[227]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[228]
Timeclock%On	65%[229]

[226] 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).

[227] *Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL*. TetraTech. March 28, 2011. Adjusted based on Field Measurements provided by ADM Associates, based on 2010 custom projects.

[228] Engineering estimate for standard gearbox efficiency.

[229] 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.

Table 2-137: NEMA Premium Efficiency Motor Efficiencies[230]

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 Equation 140.

Measure Life and Lifetime Savings

The EUL for this measure is 15 years[231].

Program Tracking Data & 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

[230] 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.

[231] 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.

- 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.[232]

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 42551—Provides energy and demand savings calculations and EUL

Relevant Standards and Reference Sources

- Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).
- 79 FR 30933. Full-Load Efficiencies for General Purpose Electric Motors [Subtype I]
- 2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group. Calmac Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.
- Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. TetraTech. March 28, 2011.

Document Revision History

Table 2-138: Pump-off Controller 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.

[232] 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 in order to improve the accuracy of POC saving estimates.

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: Deemed Savings Calculations

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.

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.[233] The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

Baseline Condition

The baseline condition is a 1-3 horsepower (HP) standard efficiency single-speed pool pump.

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[233] Hunt, A. & 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.

High-Efficiency Condition

The high efficiency condition is a 1-3 HP ENERGY STAR® certified variable speed pool pump.

Energy and Demand Savings Methodology

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.[234]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

Equation 143

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 144

$$kWh_{ES} = kWh_{HS} + kWh_{LS}$$

Equation 145

$$kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$$

Equation 146

$$kWh_{LS} = \frac{PFR_{LS} \times 60 \times hours_{LS} \times days}{EF_{LS} \times 1000}$$

Equation 147

[234] The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

Where:

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 2-139)*
$hours_{HS}$	=	*ENERGY STAR® variable speed pump high speed daily operating hours (Table 2-140)*
$hours_{LS}$	=	*ENERGY STAR® variable speed pump low speed daily operating hours (Table 2-140)*
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 2-139)*
PFR_{HS}	=	*ENERGY STAR® variable speed pump high speed flow rate [gal/min] (Table 2-140)*
PFR_{conv}	=	*ENERGY STAR® variable speed pump low speed flow rate [gal/min] (Table 2-140)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (Table 2-139)*
EF_{HS}	=	*ENERGY STAR® variable speed pump high speed energy factor [gal/W·hr] (Table 2-140)*
EF_{LS}	=	*ENERGY STAR® variable speed pump lowspeed energy factor [gal/W·hr] (Table 2-140)*
60	=	*Constant to convert between minutes and hours*
1,000	=	*Constant to convert from kilowatts to watts*

Table 2-139: Conventional Pool Pumps Assumptions[235]

New Rated Pump HP	$hours_{conv}$, limited hours[236]	$hours_{conv}$, 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

[235] Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[236] Limited Hours assumes that pump operating hours are 12 hours per day, based on 2016 commercial pool pump program data reviewed by the Texas Evaluation Contractor.

Table 2-140: ENERGY STAR® Pool Pumps Assumptions[237]

New Rated Pump HP	$Hours_{HS}$ limited hours [238]	$Hours_{HS}$ 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 148

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 2-139)*

$hours_{HS}$ = *ENERGY STAR® variable speed pump high speed daily operating hours (Table 2-140)*

$hours_{LS}$ = *ENERGY STAR® variable speed pump low speed daily operating hours (Table 2-140)*

$days$ = *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 2-141*

Table 2-141: Demand Factors

Operation	Summer DF	Winter DF
24/7 Operation	1.0	1.0
Seasonal/Limited Hours	1.0	0.5

[237] ENERGY STAR® PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[238] 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.

Deemed Energy Savings Tables

Table 2-142: ENERGY STAR® Variable Speed Pool Pump Energy Savings[239]

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[240]

Table 2-143: 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

[239] 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.
[240] Ibid.

Deemed Winter Demand Savings Tables

Table 2-144: 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 2-145: 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.[241]

Program Tracking Data & 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

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

    - Proof of purchase including quantity, make and model information

- For A Significant Sample of Projects where attainable (e.g. those projects that are selected for inspection, not midstream or retail programs)
    - Items listed for All Projects above
    - Decision/Action Type: Early Retirement, Replace-on-Burnout, or New Construction
    - Rated horsepower of existing pool pump
    - Existing and new pump operating hours.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 47612—Provides deemed savings for ENERGY STAR® pool pumps

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for pool pumps.

Document Revision History

Table 2-146: Pump-off Controller History

TRM Version	Date	Description of Change
v5.0	10/2017	TRM v5.0 origin.

APPENDIX A: NONRESIDENTIAL LIGHTING FACTORS COMPARISON TABLES

The following appendix shows a comparison of deemed values used across utilities and implementers for the following lighting measure inputs, by building type. Note the calculators used may not represent the most recent calculators, and are only provided here as a snapshot comparison of similarities and differences across utilities.

- Hours of Operation (HOU)
- Coincidence Factors (CF)
- Energy Adjustment Factors (EAF)
- Power Adjustment Factors (PAF).

Table A-1: Operating Hours Building Type, By Utility[242]

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[243]	LSF Calculators[244]	Oncor Calculator[245]
Educ. K-12, No Summer	Education (K-12 w/o Summer Session)	2,777	2,777	2,777
Education, Summer	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	3,577	3,577	3,577
Non-24-Hr Retail	Food Sales – Non-24-Hr Supermarket/Retail	4,706	4,706	4,706
24-Hr Retail	24-Hr Supermarket/Retail	6,900	6,900	6,900
Fast Food	Food Service – Fast Food	6,188	6,188	6,188
Sit-down Rest.	Food Service – Sit-down Restaurant	4,368	4,368	4,368
Health In	Health Care (In Patient)	5,730	5,730	5,730
Health Out	Health Care (Out Patient)	3,386	3,386	3,386
Lodging, Common	Lodging (Hotel/Motel/Dorm), Common Area	6,630	6,630	6,630
Lodging, Rooms	Lodging (Hotel/Motel/Dorm), Rooms	3,055	3,055	3,055
Manufacturing	Manufacturing	5,740	5,740	5,740
MF Common	Multi-family Housing, Common Areas	4,772	4,772	4,772
Nursing Home	Nursing and Residential Care	4,271	4,271	4,271
Office	Office	3,737	3,737	3,737
Outdoor	Outdoor Lighting Photo-Controlled	3,996	3,996	4,145*
Parking	Parking Structure	7,884	7,884	7,884
Public Assembly	Public Assembly	2,638	2,638	2,638

242 Discrepancies from PUCT Docket No. 39146 are denoted by an asterisk (*).
243 These values were sourced from PUCT Docket No. 39146, Table 8.
244 LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01.
245 Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1–Lighting (New Construction).

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[243]	LSF Calculators[244]	Oncor Calculator[245]
Public Order	Public Order and Safety	3,472	3,472	3,472
Religious	Religious Worship	1,824	1,824	1,824
Retail Non-mall/strip	Retail (Excl. Mall and Strip Center)	3,668	3,668	3,668
Enclosed Mall	Retail (Enclosed Mall)	4,813	4,813	4,813
Strip/Non-enclosed Mall	Retail (Strip Center and Non-enclosed Mall)	3,965	3,965	3,965
Service (Non-food)	Service (Excl. Food)	3,406	3,406	3,406
Non-refrig. Warehouse	Warehouse (Non-refrigerated)	3,501	3,501	3,501
Refrig. Warehouse	Warehouse (Refrigerated)	3,798	3,798	3,798
Enclosed Mall	Retail (Enclosed Mall)	4,813	4,813	4,813

Table A-2: Coincidence Factors Building Type, By Utility[246]

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[247]	LSF Calculators[248]	Oncor Calculator[249]
Educ. K-12, No Summer	Education (K-12 w/o Summer Session)	47%	47%	47%
Education, Summer	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	69%	69%	69%
Non-24-Hr Retail	Food Sales – Non-24-Hr Supermarket/Retail	95%	95%	95%
24-Hr Retail	24-Hr Supermarket/Retail	95%	95%	95%
Fast Food	Food Service – Fast Food	81%	81%	81%

[246] Discrepancies from PUCT Docket No. 39146 are denoted by an asterisk (*). In the event of two numbers in the cell, the first number refers to the Summer Peak CF, and the second number refers to the Winter Peak CF.
[247] These values were sourced from PUCT Docket No. 39146, Table 8.
[248] LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01.
[249] Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[247]	LSF Calculators[248]	Oncor Calculator[249]
Sit-down Rest.	Food Service – Sit-down Restaurant	81%	81%	81%
Health In	Health Care (In Patient)	78%	78%	78%
Health Out	Health Care (Out Patient)	77%	77%	77%
Lodging, Common	Lodging (Hotel/Motel/Dorm), Common Area	82%	82%	82%
Lodging, Rooms	Lodging (Hotel/Motel/Dorm), Rooms	25%	25%	25%
Manufacturing	Manufacturing	73%	73%	73%
MF Common	Multi-family Housing, Common Areas	87%	87%	87%
Nursing Home	Nursing and Residential Care	78%	78%	78%
Office	Office	77%	77%	77%
Outdoor	Outdoor Lighting Photo-Controlled	0%	0% / 61%*	64%*
Parking	Parking Structure	100%	100%	100%
Public Assembly	Public Assembly	56%	56%	56%
Public Order	Public Order and Safety	75%	75%	75%
Religious	Religious Worship	53%	53%	53%
Retail Non-mall/strip	Retail (Excl. Mall and Strip Center)	90%	90%	90%
Enclosed Mall	Retail (Enclosed Mall)	93%	93%	93%
Strip/Non-enclosed Mall	Retail (Strip Center and Non-enclosed Mall)	90%	90%	90%
Service (Non-food)	Service (Excl. Food)	90%	90%	90%
Non-refrig. Warehouse	Warehouse (Non-refrigerated)	77%	77%	77%
Refrig. Warehouse	Warehouse (Refrigerated)	84%	84%	84%

Table A-3: Operating Hour and Coincidence Factor Sources from Petition 39146

Table 8. Building Operating Hours and Coincidence Factors for Lighting Measures

Building Type	Operating Hours	Operating Hour Sources	Coincidence Factor	Coincidence Factor Sources
Education:K-12, w/o Summer Session	2,777	Navigant (2002) Weighted-average Calculation	0.47	RLW (2007)
Education: College, University, Vocational, Day Care, and K-12 w/ summer session	3,577	SCE (2007), weighted average calculation	0.69	RLW (2007)
Food Sales - Non-24-Hour Supermarket/Retail	4,706	CBECS (2003)/Navigant (2002), weighted ave calculation	0.95	RLW (2007)
Food Sales - 24 Hour Supermarket/Retail	6,900	Weighted Ave of Existing PUCT-Approved Value and Navigant (2002)	0.95	Existing PUCT-Approved Value
Food Service – fast food	6, 188	SCE (2007)	0.81	RLW (2007), weighted-average calculation
Food Service – Sit-down Restaurant	4,368	SCE (2007)	0.81	RLW (2007), weighted-average calculation
Health Care (Out-patient)	3,386	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Health Care (In-patient)	5,730	Navigant (2002) Weighted-average Calculation	0.78	See Explanation below
Lodging (Hotel/Motel/Dorm), Common Areas	6,630	Navigant (2002)Weighted-average Calculation	0.82	RLW (2007)
Lodging (Hotel/Motel/Dorm), Rooms	3,055	Navigant (2002)Weighted-average Calculation	0.25	See Explanation below
Manufacturing	5,740	Frontier Estimate	0.73	RLW (2007))
Multi-family Housing, Common Areas	4,772	Existing PUCT-Approved Value	0.87	RLW (2007)
Nursing and Resident Care	4,271	Navigant (2002) Weighted-average Calculation	0.78	RLW (2007)
Office	3,737	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Outdoor (street & parking)	3996	Oncor Street Lighting Tariff Filing	0.00	Oncor Street Lighting Tariff Filing
Parking Structure	7,884	Existing PUCT-approved value	1.00	Existing PUCT-approved value
Public Assembly	2,638	Navigant (2002) Weighted-average Calculation	0.56	Conn (2007); Weighted by XENCAP Study
Public Order and Safety	3,472	Navigant (2002) Weighted-average Calculation	0.75	Conn (2007); Weighted by XENCAP Study
Religious	1,824	Navigant (2002) Weighted-average Calculation	0.53	Conn (2007); Weighted by XENCAP Study
Retail (Excluding Malls and Strip Centers)	3,668	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007)
Retail (Enclosed Mall)	4,813	Navigant (2002)Weighted-average Calculation	0.93	RLW (2007)
Retail (Strip shopping and non-enclosed mall)	3,965	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007)
Service (Excluding Food)	3,406	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007) – assumed similar operations as Retail
Warehouse (Non-refrigerated)	3,501	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Warehouse (Refrigerated)	3,798	Navigant (2002) Weighted-average Calculation	0.84	RLW (2007)

Petition 39146, Table 8, References:

Navigant (2002)/XENCAP Study. Navigant Consulting, Inc. (September, 2002). U.S. Lighting Market Characterization: Volume I: National Lighting Inventory and Energy Consumption Estimate. U.S. Department of Energy Office or Energy Efficiency and Renewable Energy, Building Technologies Program.

SCE (2007) The citation for this report appears to be missing from the petition. The only SCE report in the petition is this one from 2006: Southern California Edison, Design & Engineering Services Customer Service Business Unit. (December 15, 2006). Fiber Optic Lighting in Low Temperature Reach-In Refrigerated Display Cases. Southern California Edison.

RLW (2007). United Illuminating Company and Connecticut Light & Power. Final Report, 2005 Coincidence Factor Study. http://webapps.cee1.org/sites/default/files/library/8828/CEE_Eval_CTCoincidenceFactorsC&ILightsHVAC_4Jan2007.PDF. Accessed 09/19/2013.

Oncor Street Lighting Tariff Filing. Only this general description is provided. There is no specific reference or citation.

Conn (2007). RLW Analytics. (September, 2006). CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study. Prepared for Connecticut Light & Power Company, Western Massachusetts Electric Company, United Illuminating Company.

Existing PUCT-Approved Value. A specific petition is not cited, but a table is presented that "….outlines the existing M&V Guidelines approved by the PUC.."

Operating Hours Calculation spreadsheet (lmc_vol1_final_tables.xls). This spreadsheet was prepared by Frontier, and it contains the detailed calculations that are presented in Appendix A of petition 39146.

Table A-4: Lighting Power Densities, By Building Type, By Utility

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[250]	LSF Calculators[251]
Automotive Facility	--	0.90	0.90
Convention Center	--	1.20	1.20
Court House	--	1.20	1.20
Dining: Bar Lounge/Leisure	--	1.30	1.30
Dining: Cafeteria/Fast Food	--	1.40	1.40
Dining: Family	--	1.60	1.60
Dormitory	--	1.00	1.00
Exercise Center	--	1.00	1.00
Gymnasium	--	1.10	1.10
Health Center	--	1.00	1.00
Hospital	--	1.20	1.20
Hotel	--	1.00	1.00
Library	--	1.30	1.30
Manufacturing Facility	--	1.30	1.30
Motel	--	1.00	1.00
Motion Picture Theater	--	1.20	1.20
Multi-family	--	0.70	0.70
Museum	--	1.10	1.10

[250] Oncor Calculator, 2013 N1 – Lighting (New Construction).
[251] LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01, TNMP v4.18.

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[250]	LSF Calculators[251]
Penitentiary	--	1.00	1.00
Performing Arts Theater	--	1.60	1.60
Police/Fire Station	--	1.00	1.00
Post Office	--	1.10	1.10
Retail	--	1.50	1.50
School/University	--	1.20	1.20
Sports Arena	--	1.10	1.10
Town Hall	--	1.10	1.10
Transportation	--	1.00	1.00
Warehouse	--	0.80	0.80
Workshop	--	1.40	1.40
Educ K-12, No Summer*	Education (K-12 w/o Summer Session)	--	--
Education, Summer*	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	--	--
Non-24-Hr Retail*	Food Sales – Non-24-Hr Supermarket/Retail	--	--
24-Hr Retail*	24-Hr Supermarket/Retail	--	--
Fast Food*	Food Service – Fast Food	--	--
Sit-down Rest.*	Food Service – Sit-down Restaurant	--	--
--	Food Service – Sit-down Restaurant - Dining: Bar Lounge/Leisure	--	--
Health In*	Health Care (In Patient)	--	--
Health Out*	Health Care (Out Patient)	--	--
Lodging, Common*	Lodging (Hotel/Motel/Dorm), Common Area	--	--
Lodging, Rooms*	Lodging (Hotel/Motel/Dorm), Rooms	--	--

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[250]	LSF Calculators[251]
Manufacturing*	Manufacturing	--	--
MF Common*	Multi-family Housing, Common Areas	--	--
Nursing Home*	Nursing and Residential Care	--	--
Office*	Office	1.00	1.00
--	Outdoor - Outdoor Uncovered Parking Area: Zone 1	--	0.04
--	Outdoor - Outdoor Uncovered Parking Area: Zone 2	--	0.06
--	Outdoor - Outdoor Uncovered Parking Area: Zone 3	--	0.10
--	Outdoor - Outdoor Uncovered Parking Area: Zone 4	--	0.13
Outdoor*	Outdoor Lighting Photo-Controlled	--	--
Parking*	Parking Structure	0.30	0.30
Public Assembly*	Public Assembly	--	--
--	Public Assembly - Convention Center	--	--
--	Public Assembly - Exercise Center	--	--
--	Public Assembly - Gymnasium	--	--
--	Public Assembly - Hospital	--	--
--	Public Assembly - Library	--	--
--	Public Assembly - Motion Picture Theater	--	--
--	Public Assembly - Museum	--	--
--	Public Assembly - Performing Arts Theater	--	--
--	Public Assembly - Post Office	--	--
--	Public Assembly - Sports Arena	--	--

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[250]	LSF Calculators[251]
--	Public Assembly - Transportation	--	--
--	Public Order and Safety - Court House	--	--
--	Public Order and Safety - Penitentiary	--	--
--	Public Order and Safety - Police/Fire Station	--	--
Public Order*	Public Order and Safety	--	--
Religious*	Religious Worship	1.30	1.30
Retail Non-mall/strip*	Retail (Excl. Mall and Strip Center)	--	--
Enclosed Mall*	Retail (Enclosed Mall)	--	--
Strip/Non-enclosed Mall*	Retail (Strip Center and Non-enclosed Mall)	--	--
Service (Non-food)*	Service (Excl. Food)	--	--
Non-refrig. Warehouse*	Warehouse (Non-refrigerated)	--	--
Refrig. Warehouse*	Warehouse (Refrigerated)	--	--

Table A-5: Energy Adjustment Factors By Utility[252]

Building Type Code	Control Codes	Operating Hours			
		Docket 40668[253]	LSF Calculators [254]	Oncor Calculator (Retrofit)[255]	Oncor Calculator (New Construction)[256]
No controls measures	None	1.00	1.00	1.00	1.00
Stipulated DC - Continuous Dimming	DC- cont	0.70	0.70	0.70	0.70
Stipulated DC - Multiple Step Dimming	DC- step	0.80	0.80	0.80	0.80
Stipulated DC - ON/OFF (Indoor)	Indoor DC - on/off	0.90	0.90	0.90	0.90
Stipulated DC - ON/OFF (Outdoor)	Outdoor DC - on/off	1.00	1.00	0.64*	0.64*
Stipulated Occupancy Sensor (OS)	OS	0.70	0.70	0.70	0.70
Stipulated OS w/DC - Continuous Dimming	OS - cont	0.60	0.60	0.60	0.60
Stipulated OS w/DC - Multiple Step Dimming	OS - step	0.65	0.65	0.65	0.65
Stipulated OS w/DC - ON/OFF (Indoor)	Indoor OS - on/off	0.65	0.65	0.65	0.65
Photocontrol	Photo	--	--	1.00*	--

252 Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (*). The EAF is applicable to all building types.
253 These values were sourced from PUCT Docket No. 40668, Page A-24.
254 LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01, TNMP v4.18.
255 Oncor Calculator, 2013 E1 – Lighting (Retrofit).
256 Oncor Calculator, 2013 N1 – Lighting (New Construction).

Table A-6: Demand Adjustment Factors By Utility[257]

Building Type Code	Control Codes	Demand Adjustment Factors					
		Docket 40668[258]		LSF Calculators[259]		Oncor Calculator [260]	
		K-12, No Summer	All Remaining Building Types	K-12, No Summer	All Remaining Building Types	K-12, No Summer	All Remaining Building Types
No Controls Measures	None	1.00	1.00	1.00	1.00	1.00	1.00
Stipulated DC - Continuous Dimming	DC- cont	0.76	0.70	0.76	0.70	0.76	0.70
Stipulated DC - Multiple Step Dimming	DC- step	0.84	0.80	0.84	0.80	0.84	0.80
Stipulated DC - ON/OFF (Indoor)	Indoor DC - on/off	0.92	0.90	0.92	0.90	0.92	0.90
Stipulated DC - ON/OFF (Outdoor)	Outdoor DC - on/off	1.00	1.00	1.00	1.00	0.64*	0.64*
Stipulated Occupancy Sensor (OS)	OS	0.80	0.75	0.80	0.75	0.80	0.75
Stipulated OS w/DC - Continuous Dimming	OS - cont	0.72	0.65	0.72	0.65	0.72	0.65
Stipulated OS w/DC - Multiple Step Dimming	OS - step	0.76	0.70	0.76	0.70	0.76	0.70
Stipulated OS w/DC - ON/OFF (Indoor)	Indoor OS - on/off	0.76	0.70	0.76	0.70	0.76	0.70
Photocontrol	Photo	--	--	--	--	--	--

[257] Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (*).
[258] These values were sourced from PUCT Docket No. 40668, Page A-24.
[259] LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01, TNMP v4.18.
[260] Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

APPENDIX B: MEASURE LIFE CALCULATIONS FOR EARLY RETIREMENT PROGRAMS

The following appendix describes the method of calculating savings for early retirement programs. 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. These calculations are provided in the Docket [43681].

Step 1: Determine the measure life for ER and ROB components of the calculated savings:

$$Early\ Retirement\ (ER) Period = ML_{ER} = RUL$$

Equation 149

$$Replace\ on\ Burnout\ (ROB) Period = \ ML_{ROB} = EUL - RUL$$

Equation 150

Where:

RUL	=	*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 estimated useful life as specified in applicable measure from Texas TRM (or approved petition)*

Step 2: Calculate the ER demand and energy savings and the ROB demand and energy savings:

$$\Delta kW_{ER} = kW_{replaced} - kW_{installed}$$

Equation 151

$$\Delta kW_{RPB} = kW_{baseline} - kW_{installed}$$

Equation 152

$$\Delta kWh_{ER} = kWh_{replaced} - kWh_{installed}$$

Equation 153

$$\Delta kWh_{RPB} = kWh_{baseline} - kWh_{installed}$$

Equation 154

Where:

ΔkW_{ER}	=	*Early retirement demand savings*
ΔkW_{ROB}	=	*Replace-on-burnout demand savings*
$kW_{replaced}$	=	*Demand of the retired system*[261]

[261] Retired system refers to the existing equipment that was in use before the retrofit has occurred.

$kW_{baseline}$	=	*Demand of the baseline ROB system*[262]
$kW_{installed}$	=	*Demand of the replacement system*[263]
ΔkWh_{ER}	=	*Early retirement energy savings*
ΔkWh_{ROB}	=	*Replace-on-burnout energy savings*
$kWh_{replaced}$	=	*Energy Usage of the retired system*[261]
$kWh_{baseline}$	=	*Energy Usage of the baseline ROB system*[262]
$kWh_{installed}$	=	*Energy Usage of the replacement system*[263]

Step 3: Calculate the avoided capacity and energy cost contributions of the total NPV for both the ER and ROB components:

$$NPV_{ER,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ER}}\right\} \times \Delta kW_{ER}$$

Equation 155

$$NPV_{ROB,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ROB}}\right\} \times \frac{(1+e)^{ML_{ER}}}{(1+d)^{ML_{ER}}} \times \Delta kW_{ROB}$$

Equation 156

$$NPV_{ER,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ER}}\right\} \times \Delta kWh_{ER}$$

Equation 157

$$NPV_{ROB,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ROB}}\right\} \times \frac{(1+e)^{ML_{ER}}}{(1+d)^{ML_{ER}}} \times \Delta kWh_{ROB}$$

Equation 158

Where:

$NPV_{ER,\,kW}$	=	*Net Present Value (kW) of ER projects*
$NPV_{ROB,\,kW}$	=	*Net Present Value (kW) of ROB projects*
$NPV_{ER,\,kWh}$	=	*Net Present Value (kWh) of ER projects*
$NPV_{ROB,\,kWh}$	=	*Net Present Value (kWh) of ROB projects*
e	=	*Escalation Rate* [264]

262 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)
263 Replacement system refers to the installed equipment that is in place after the retrofit has occurred.
264 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.

d	=	*Discount rate weighted average cost of capital (per utility)* [264]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [264]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [264]
ML_{ER}	=	*ER Measure Life (calculated in Equation 149)*
ML_{ROB}	=	*ROB measure life (calculated in Equation 150)*

<u>Note:</u> Demand and energy savings (ΔkW and ΔkWh) used to estimate NPV in Equation 155 through Equation 158 are the savings estimated using the same equations as have been in use for some time in the commercial HVAC programs (equations A-1 and A-2 in Petition 40083). However, the efficiency values used in estimating the equations differ from those used in Petitions 40083 and 40885: (1) the Early Retirement savings, earned for the RUL of the replaced system, are estimated using the difference between the efficiency of the replaced system and that of the installed system; (2) the replace-on-burnout savings, earned over the measure EUL minus the project's RUL, are estimated using the difference between the replace-on-burnout baseline efficiency and the efficiency of the installed system.

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total,kW} = NPV_{ER,kW} + NPV_{ROB,kW}$$

Equation 159

$$NPV_{Total,kWh} = NPV_{ER,kWh} + NPV_{ROB,kWh}$$

Equation 160

Where:

$NPV_{Total,\,kW}$	=	*Total capacity contributions to NPV of both ER and ROB component*
$NPV_{Total,\,kWh}$	=	*Total energy contributions to NPV of both ER and ROB 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 161

$$NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}$$

Equation 162

Where:

$NPV_{EUL, kW}$	=	*Capacity contributions to NPV without weighting, using original EUL*
$NPV_{EUL, kWh}$	=	*Energy contributions to NPV without weighting, using original EUL*

Step 6: Calculate the weighted demand and energy savings by dividing the combined capacity and energy cost contributions from the ER and ROB scenarios by the non-savings weighted capacity and energy cost contributions from the single EUL scenario. These weighted savings are claimed over the original measure EUL:

$$Weighted\ kW = \frac{NPV_{Total.kW}}{NPW_{EUL,kW}}$$

Equation 163

$$Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPW_{EUL,kWh}}$$

Equation 164

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 159*
$NPV_{Total, kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 160*
$NPV_{EUL, kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 161*
$NPV_{EUL, kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 162*