

# Public Utility Commission of Texas

**Texas Technical Reference Manual**

**Version 4.0**

**Volume 3: Nonresidential Measures**

**Program Year ( PY) 2017**

**Last Revision Date:**

**November 1, 2016**



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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 2001-2015 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2015 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@tetrattech.com](mailto:lark.lee@tetrattech.com)) and PUCT staff ([katie.rich@puc.texas.gov](mailto:katie.rich@puc.texas.gov)).

# 1. INTRODUCTION

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This volume of the TRM contains the deemed savings for nonresidential measures that have been approved for use in Texas by the PUCT. This volume includes instructions regarding various savings calculators and reference sources of the information. The TRM serves as a centralized source of deemed savings values; where appropriate, Measurement & 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	4.0 Update
Lighting	Lighting - Lamps and Fixtures	--	--	X	X	X	Added LPD values and tracking data requirements for exterior space type Zones used in Codes and Standards.
Lighting	Lighting Controls	--	--	X	X	X	
HVAC (Cooling)	AC Tune-Up	--	--	X	--	X	TRM v4.0 origin
HVAC (Cooling)	Package and Split-System (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 split and packaged units less than 5.4 tons to be consistent with updated federal standards.
HVAC (Cooling)	Chillers	--	--	X	X	X	Used modeling approach to update DF and EFLH for applicable building types and climate zones.
HVAC (Cooling)	Package Terminal Units and Room Air Conditioners (AC and Heat Pumps)	--	--	X	X	X	
HVAC (Ventilation)	VFDs on AHU Supply Fans	--	X	X	--	--	
Building Envelope	Cool Roof	X	--	X	X	--	Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials to Table 2-49. Added new high performance roof calculator for use in determining energy star roof savings
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	--	--	

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	4.0 Update
Food Service	ENERGY STAR® Commercial Dishwashers	--	X	X	--	--	Added high-efficiency requirements for pots, pans, and utensils
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	--	--	
Refrigeration	Door Heater Controls	--	X	X	--	--	Update Deemed kW <sub>ash</sub> for Medium temperature cases and add kW <sub>ash</sub> for Low temperature cases. Added more significant digits to the input variables a-j for equations 82 and 83.
Refrigeration	ECM Evaporator Fan Motors	--	--	X	--	--	Updated the methodology to incorporate the type of motor replaced and added values for both coolers and freezers
Refrigeration	Electronic Defrost Control	--	--	X	--	--	
Refrigeration	Evaporator Fan Controls	--	--	X	--	--	
Refrigeration	Night Covers for Open Refrigerated Cases	--	X	X	--	--	Added more significant digits to the input variables a-j for equations 107 and 108.
Refrigeration	High-Efficiency Solid & Glass Door Reach-in Cases	--	--	X	--	--	
Refrigeration	Strip Curtains for Walk-in Cooler/Freezer	--	X	--	--	--	

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	4.0 Update
Refrigeration	Low/No Anti-sweat Heat Glass Doors (Zero Energy Glass Doors)	--	X	X	--	--	Updated savings methodology to be consistent with the door heater controls measure.
Miscellaneous	Vending Machine Controllers	--	X	X	--	--	
Miscellaneous	Lodging Guest Room Occupancy Sensor Control	--	X	--	--	--	
Miscellaneous	Pump-Off Controller	--	X	X	--	--	
Solar Electric	Solar Photovoltaics	--	--	X	--	X	Removed deemed savings option for energy. Provided new method for calculating summer and winter demand savings and provided deemed summer and winter demand savings lookup tables.

## 2. NONRESIDENTIAL MEASURES

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### 2.1 NONRESIDENTIAL: LIGHTING

#### 2.1.1 Lamps and Fixtures Measure Overview

**TRM Measure ID:** NR- LT-LF

**Market Sector:** Commercial

**Measure Category:** Lighting

**Applicable Building Types:** All Commercial, Multifamily common areas

**Fuels Affected:** Electricity (Interactive HVAC effects: Electric/Gas space heating)

**Decision/Action Types:** Retrofit (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<sup>1</sup> with or without the use of reflectors.
- Fluorescent Electrodeless Induction lamps and fixtures
- Compact Fluorescent Lamp (CFL) screw-based lamps and hard-wired pin-based fixtures
- Pulse-start (PSMH) and Ceramic Metal Halide (CMH) lamps, 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*<sup>2</sup>). 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

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

<sup>2</sup> Maintained by 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 certified, as follows:

High-performance (HP) and reduced-watt (RW) T8 linear fluorescent lamps and ballasts need to be certified by the *Consortium for Energy Efficiency* (CEE). See High Efficiency Condition section for additional details.

LED lamps and fixtures must be certified and listed by at least one of the following organizations: *DesignLights Consortium* (DLC), *ENERGY STAR*®, Lighting Design Lab (LDL), or DOE LED Lighting Facts. Links to these organizations and their certified LED equipment 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<sup>3</sup> (e.g. LM-79, LM-80, TM-21, ISTMT) show the products comply with the most current version of the DLC Technical Requirements.<sup>4</sup>

**Exempt Lighting for New Construction.** Some types of new construction lighting fixtures are exempt from inclusion in the interior lighting demand savings calculation, but they are still included in the total installed lighting power calculations for a project. Exempt fixtures are those that do not provide general/ambient/area lighting, have separate control devices, and are installed in one of the following applications<sup>5</sup>:

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

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<sup>3</sup> DLC test lab requirements: <https://www.designlights.org/content/QPL/ProductSubmit/LabTesting>

<sup>4</sup> DLC tech. requirements: <https://www.designlights.org/content/qpl/productssubmit/categoryspecifications>

<sup>5</sup> IECC 2009, Section 505.5.1

- 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.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
  - 2.1. Task lighting for medical and dental purposes.
  - 2.2. Display lighting for exhibits in galleries, museums, and monuments.
3. Lighting for theatrical purposes, including performance, stage, film production, and video production.
4. Lighting for photographic processes.
5. Lighting integral to equipment or instrumentation and installed by the manufacturer.
6. Task lighting for plant growth or maintenance.
7. Advertising signage or directional signage.
8. In restaurant building and areas, lighting for food warming or integral to food preparation equipment.
9. Lighting equipment that is for sale.
10. Lighting demonstration equipment in education facilities.
11. Lighting approved because of safety or emergency considerations, inclusive of exit lights.
12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
13. Lighting in retail display windows, provided the display area is enclosed by ceiling height partitions.
14. Furniture-mounted supplemental task lighting that is controlled by automatic shut off.

## **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**

<b>T12 Length</b>	<b>Lamp Count</b>	<b>Revised Lamp Wattage</b>	<b>Revised System Wattage</b>
48 inch – Std, HO, and VHO (4 feet)	1	32	31
	2	32	58
	3	32	85
	4	32	112
	6	32	170
	8	32	224
96 inch - Std (8 feet) 60/75W	1	59	69
	2	59	110
	3	59	179
	4	59	219
	6	59	330
	8	59	438*
96 inch-HO and VHO (8 feet) 95/110W	1	86	101
	2	86	160
	3	86	261
	4	86	319
	6	86	481
	8	86	638

T12 Length	Lamp Count	Revised Lamp Wattage	Revised System Wattage
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<sup>6</sup>, and high performance T8 lamps that are on the T8 Replacement Lamp products list developed by the Consortium for Energy Efficiency (CEE) as published on its website.

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

## 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.

<sup>6</sup> Changes to the DOE Federal standards for electronic ballasts effective November 2014 met both the CEE performance specification and the NEMA Premium requirements, so CEE discontinued their specification and qualifying product lists. A legacy ballast list from January 2015 is still available.

## **Retrofit<sup>7,8</sup>:**

$$Energy\ Savings = (kW_{pre} - kW_{installed}) \times Hours \times (HVAC_{energy})$$

Equation 1

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

Equation 2

## **New Construction:**

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

Equation 3

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

Equation 4

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/ft<sup>2</sup>]

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

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

$CF$  = Coincidence factor by building type from Table 2-4

$HVAC_{energy}$  = 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.

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<sup>7</sup> For non-operating fixtures, the baseline demand may be adjusted by using values from the Standard Wattage Table. The number of non-operating fixtures will be limited to 10% of the total fixture count per facility.

<sup>8</sup> The energy and demand savings calculations should also account for lighting controls that are present on either the *pre* or *installed* lighting systems, and should also be adjusted for eligible rebated lighting controls on the installed lighting system. The EAF and PAF factors in the Lighting Controls measure section should be used for these calculations.

## **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<sup>9</sup>. 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 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

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<sup>9</sup> Frontier Associates *Lighting Survey Form, Fixture Description* tab:  
[http://www.texasefficiency.com/images/documents/lstf\\_2013\\_v8.01\\_250%20rows.xlsm](http://www.texasefficiency.com/images/documents/lstf_2013_v8.01_250%20rows.xlsm).

**Table 2-2: New Construction LPDs for Interior Space Types by Building Type<sup>10</sup>**

Facility Type	Lighting Power Density ( W/ft <sup>2</sup> )	Facility Type	Lighting Power Density ( W/ft <sup>2</sup> )
Automotive Facility	0.90	Multi-Family	0.70
Convention Center	1.20	Museum	1.10
Courthouse	1.20	Office	1.00
Dining: Bar/Lounge/Leisure	1.30	Parking Garage	0.30
Dining: Cafeteria	1.40	Penitentiary	1.00
Dining: Family	1.60	Performing Arts	1.60
Dormitory	1.00	Police/Fire Stations	1.00
Exercise Center	1.00	Post Office	1.10
Gymnasium	1.10	Religious Buildings	1.30
Health Care – Clinic	1.00	Retail	1.50
Hospital	1.20	School/University	1.20
Hotel	1.00	Sports Arena	1.10
Library	1.30	Town Hall	1.10
Manufacturing	1.30	Transportation	1.00
Motel	1.00	Warehouse	0.80
Motion Picture	1.20	Workshop	1.40

**Table 2-3: New Construction LPDs for Exterior Space Types**

Facility Type	Lighting Power Density (W/ft <sup>2</sup> )			
	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 ≥ 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 Entrances and Exits: Entry Canopies	0.25	0.25	0.4	0.4
Sales Canopies: Free-standing and Attached	0.60	0.60	0.80	1.00
Outdoor Sales: Open Areas	0.25	0.25	0.50	0.70
Building Facades	--	0.10	0.15	0.20
Entrances and Gatehouse Inspection Stations	0.75	0.75	0.75	0.75
Loading Areas for Emergency Vehicles	0.50	0.50	0.50	0.50

<sup>10</sup> Source per *Lighting Survey Form: ANSI/ASHRAE/IESNA Standard 90.1 -2007 Table. 9.5.1, p. 62 & IECC 2009 Table. 505.5.2, p. 59.*

## **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)<sup>11</sup> building types, but have been modified for Texas.

**Table 2-4: Operating Hours and Coincidence Factors by Building Type<sup>12</sup>**

<b>Building Type Code</b>	<b>Building Type Description</b>	<b>Operating Hours</b>	<b>Summer Peak CF</b>
Educ. K-12, No Summer	Education (K-12 w/o Summer Session)	2,777	47%
Education, Summer	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	3,577	69%
Non-24 Hour Retail	Food Sales – Non-24 Hour Supermarket/Retail	4,706	95%
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	Manufacturing	5,740	73%
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%
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 1013). 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.			

## **Interactive HVAC Factors (HVAC energy, demand)**

<sup>11</sup> DOE-EIA Commercial Building Energy Consumption Survey.

<sup>12</sup> 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.

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<sup>13</sup>**

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

## Deemed Energy and Demand Savings Tables

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

## Claimed Peak Demand Savings

Refer to Volume 1, 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<sup>14</sup>:

- 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

<sup>13</sup> PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).

<sup>14</sup> PUCT Docket 36779.

- Integral LED Lamps: 9 years<sup>15</sup>
- 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
- **For New Construction Only:** Lighting Power Density Factor
- **For New Construction Only:** Interior or Exterior Space Square Footage
- Conditioned Space Type: cooling equipment type, refrigerated space temperature range, heating fuel type, % 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 2-5)

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<sup>15</sup> PUCT Docket 38023.



## **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.

**Table 2-6: Lighting Measure Groups to be used for Reporting Savings<sup>16</sup>**

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**

- DOE’s LED Lighting Facts showcases LED products for general illumination from manufacturers who commit to testing products and reporting performance results. <http://www1.eere.energy.gov/buildings/ssl/ledlightingfacts.html>. Accessed 09/19/2013.
- ENERGY STAR® requirements for Commercial LED Lighting. [http://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=LTG](http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG). Accessed 09/19/2013.
- Design Lights Consortium. [www.designlights.org](http://www.designlights.org). Accessed 09/19/2013.

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<sup>16</sup> 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.

- 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.
- U.S. Lighting Market Characterization report, September 2002, [http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lmc\\_vol1\\_final.pdf](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](http://webapps.cee1.org/sites/default/files/library/8828/CEE_Eval_CTCoincidenceFactorsC&ILightsHVAC_4Jan2007.PDF). Accessed 09/19/2013.

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

## 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 kW difference is replaced by a single kW value (the total fixture wattage controlled by the device).

$$\text{Energy Savings} = kW_{\text{controlled}} \times \text{EAF} \times \text{Hours} \times \text{HVAC}_{\text{energy}}$$

Equation 5

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

Equation 6

Where:

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

Hours = Hours by building type from Table 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

$\text{HVAC}_{\text{energy}}$  = Energy Interactive HVAC factor by building type, see Table 2-5

$\text{HVAC}_{\text{demand}}$  = 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<sup>17</sup>**

Control Type	Sub-Category	Control Codes	EAF	PAF
None	n/a	None	0.00	0.00
Occupancy	n/a	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 <sup>18</sup>	n/a	Outdoor	0.00	0.00
Personal Tuning	n/a	PT	0.31	0.31
Institutional Tuning	n/a	IT	0.36	0.36
Multiple/Combined Types	Various combinations	Multiple <sup>19</sup>	0.38	0.38

## Deemed Energy and Demand Savings Tables

This section is not applicable.

<sup>17</sup> 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.

## 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<sup>20</sup>:

- Occupancy Sensor: 10 years
- 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<sup>21</sup>
- Lighting Control Mount Type: Wall, Ceiling, Integrated Fixture, etc.

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<sup>18</sup> No control savings are allowed for outdoor controls because they are already required by code. ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

<sup>19</sup> For multiple control types, specify the installed control types by combining the control codes for the individual control types.

<sup>20</sup> GDS Associates. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG). June 2007. This report only specifies an EUL for Occupancy Sensors and Photocells, so it is assumed that the same EUL was applied to time clocks. <http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures>.

<sup>21</sup> For a control type that combines multiple features (e.g. occupancy + daylighting), specify the installed control types by combining the control codes for the individual control types.

- Lighting Control Specification Sheets
- Controlled Fixture 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, Barbasi, 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.

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

- 2009 IECC (Commercial buildings)
- ASHRAE 90.1-2010 (Public/State buildings)
- ANSI/ASHRAE/IESNA Standard 90.1 -2007

## 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	No revisions
v2.1	01/30/2015	Corrections to Equation 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for Retrofit and New Construction projects.
v3.0	04/10/2015	Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a “controlled lighting watts” approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measure and added interior/exterior location.
v4.0	10/10/2016	No revisions



## 2.2 NONRESIDENTIAL: HVAC

### 2.2.1 Air Conditioner or Heat Pump Tune-up Measure Overview

**TRM Measure ID:** To be determined

**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<sup>22</sup>**

- 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
- 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.

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<sup>22</sup> Based on ENERGY STAR® HVAC Maintenance Checklist.  
[www.energystar.gov/index.cfm?c=heat\\_cool.pr\\_maintenance](http://www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance)

- Clean 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<sup>23</sup>**

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

## High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above, 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<sup>24</sup> HSPF, and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER<sup>25</sup> using the conversion developed by Lawrence Berkeley Lab and US DOE:  $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ . A 3.2 and 3.1 COP is equivalent to approximately 10.9 and 10.6 HSPF respectively using the conversion of  $HSPF = 3.412 \times COP$ .

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of five percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.<sup>26</sup>

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

<sup>24</sup> Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

<sup>25</sup> Code specified 13 SEER from federal standard effective January 23, 2006 through January 1, 2015, converted to EER using  $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ . National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. <http://www.nrel.gov/docs/fy11osti/49246.pdf>.

<sup>26</sup> Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of

## Energy Savings Algorithms

Heating energy savings are only applicable to heat pumps.

$$\text{Energy Savings [kWh}_{\text{savings}}] = \text{kWh}_{\text{savings,C}} + \text{kWh}_{\text{savings,H}}$$

**Equation 9**

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

**Equation 10**

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

**Equation 11**

Where:

- Capacity* = Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)
- EER<sub>pre</sub>* = Cooling efficiency of the equipment pre-tune-up using Equation 10 [Btuh/W]
- EER<sub>post</sub>* = Cooling efficiency of the equipment after the tune-up [Btuh/W]
- HSPF<sub>pre</sub>* = Heating efficiency of the equipment pre-tune-up using Equation 11 [Btuh/W]
- HSPF<sub>post</sub>* = Heating efficiency of the equipment after the tune-up [Btuh/W]
- EFLH<sub>C/H</sub>* = Cooling/heating equivalent full-load hours for appropriate climate zone [hours]. See Table 2-21 through 2-25 in Section 2.

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

**Equation 12**

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

**Equation 13**

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Recent Field Research.”

## **Demand Savings Algorithms**

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

Where:

$DF_C$  = Cooling Demand factor. See Table 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.<sup>27</sup>

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is 3 years<sup>28</sup>, and the estimated useful life of refrigerant charge adjustment is 10 years.<sup>29</sup> The other parts of the tune-up checklist

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<sup>27</sup> GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

<sup>28</sup> 2014 California Database for Energy Efficiency Resources.  
[http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update\\_2014-02-05.xlsx](http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx).

<sup>29</sup> *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**

### **Petitions and Rulings**

This section is not applicable.

### **Document Revision History**

**Table 2-12: Nonresidential HVAC Single-Zone AC-HP History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v4.0	10/10/2016	TRM v4.0 origin

## 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 that is at least five years old 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 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.<sup>30</sup> 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. These tables will be updated every few years so that systems greater than five years old will be eligible for early retirement. When the system age is unknown, assume an age of 17 years.<sup>31</sup>

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.

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<sup>30</sup> The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

<sup>31</sup> As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, taking into account increments in efficiency standards that took place in the historical period.



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

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER] <sup>32</sup>	Package System < 5.4 tons [EER] <sup>33</sup>	All Systems 5.4 to < 11.3 tons [EER]	All Systems 11.3 to < 20 tons [EER]	All Systems 20 to < 63.3 tons [EER]	All Systems ≥ 63.3 tons [EER]
≤ 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 – 2012	11.2	11.2	11.0	10.8	9.8	9.5

**Table 2-14: ER Baseline Part-Load Efficiency for ACs<sup>34</sup>**

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]	All Systems 11.3 to < 20 tons [IEER]	All Systems 20 to < 63.3 tons [IEER]	All Systems ≥ 63.3 tons [IEER]
≤ 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 – 2012	13.0	13.0	11.2	11.0	9.9	9.6

<sup>32</sup> 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>

<sup>33</sup> Ibid.

<sup>34</sup> IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

**Table 2-15: ER Baseline Full-Load Cooling Efficiency for HPs**

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER] <sup>35</sup>	Package System < 5.4 tons [EER] <sup>36</sup>	All Systems 5.4 to < 11.3 tons [EER]	All Systems 11.3 to < 20 tons [EER]	All Systems 20 to < 63.3 tons [EER]	All Systems ≥ 63.3 tons [EER]
≤ 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	9.9	9.1	8.8	8.8
2006 – 2009	11.2	11.2	9.9	9.1	8.8	8.8
2010 – 2012	11.2	11.2	10.8	10.4	9.3	9.3

**Table 2-16: ER Baseline Part-Load Cooling Efficiency for HPs<sup>37</sup>**

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]	All Systems 11.3 to < 20 tons [IEER]	All Systems 20 to < 63.3 tons [IEER]	All Systems ≥ 63.3 tons [IEER]
≤ 1991	10.0	9.7	9.1	8.1	8.1	7.9
1992 – 2001	10.0	9.7	9.1	8.4	8.4	8.6
2002 – 2005	10.0	9.7	10.1	9.2	8.9	8.9
2006 – 2009	13.0	13.0	10.1	9.2	8.9	8.9
2010 – 2012	13.0	13.0	11.0	10.5	9.4	9.4

**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

<sup>35</sup> 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>.

<sup>36</sup> Ibid.

<sup>37</sup> IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

2010 – 2012	7.7	7.7	3.3	3.2
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**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 ASHRAE 90.1-2010.

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

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source <sup>38</sup>
Air Conditioner	< 5.4	All	11.8 EER <sup>39</sup> 13.0 SEER (3-phase) 14.0 SEER (1-phase)	DOE Standards/ ASHRAE 90.1-2010
	5.4 to < 11.3	None or Electric Resistance	11.2 EER 11.4 IEER	
		All Other	11.0 EER 11.2 IEER	
	11.3 to < 20	None or Electric Resistance	11.0 EER 11.2 IEER	
		All Other	10.8 EER 11.0 IEER	
	20 to < 63.3	None or Electric Resistance	10.0 EER 10.1 IEER	
		All Other	9.8 EER 9.9 IEER	
	≥ 63.3	None or Electric Resistance	9.7 EER 9.8 IEER	
		All Other	9.5 EER 9.6 IEER	

<sup>38</sup> These baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 431.97. <http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf>.

<sup>39</sup> 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>.

System Type	Capacity [Tons]	Heating Section Type	Baseline Efficiencies	Source <sup>38</sup>
Heat Pump (cooling) <sup>40</sup>	< 5.4	Heat Pump	11.8 EER <sup>41</sup> 14.0 SEER	DOE Standards/ ASHRAE 90.1-2010
	5.4 to < 11.3		11.0 EER 11.2 IEER	
	11.3 to < 20		10.6 EER 10.7 IEER	
	≥ 20		9.5 EER 9.6 IEER	
Heat Pump (heating) <sup>42</sup>	< 5.4	Heat Pump	8.2 HSPF (split) 8.0 HSPF (packaged)	DOE Standards
	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<sup>43</sup>:

- 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).

<sup>40</sup> ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type “No Heating or Electric Resistance Heating”, excluding systems with “All Other Types of Heating”.

<sup>41</sup> There is no code specified EER for this size category. The code specified SEER value converted to EER using  $EER = -0.02 \times SEER^2 + 1.12 \times SEER$  for systems < 5.4 tons. National Renewable Energy Laboratory (NREL). “Building America House Simulation Protocols.” U.S. Department of Energy. Revised October 2010. <http://www.nrel.gov/docs/fy11osti/49246.pdf>.

<sup>42</sup> Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

<sup>43</sup> From PUCT Docket #41070.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

$$\text{Energy Savings [kWh}_{\text{savings}}] = \text{kWh}_{\text{savings,C}} + \text{kWh}_{\text{savings,H}}$$

Equation 14

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

Equation 15

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

Equation 16

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

Equation 17

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

Equation 18

Where:

$\text{Cap}_{\text{C/H,pre}}$	=	<i>Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh</i>
$\text{Cap}_{\text{C/H,post}}$	=	<i>Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh</i>
$\eta_{\text{baseline,C}}$	=	<i>Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]</i>
$\eta_{\text{installed,C}}$	=	<i>Rated cooling efficiency of the newly installed equipment (kW/Ton) - (Must exceed ROB/NC baseline efficiency standards in Table 2-18) [Btuh/W]</i>
$\eta_{\text{baseline,H}}$	=	<i>Heating efficiency of existing equipment (ER) or standard equipment (ROB/NC) [COP]</i>
$\eta_{\text{installed,H}}$	=	<i>Rated heating efficiency of the newly installed equipment (Must exceed baseline efficiency standards in Table 2-18) [COP]</i>

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

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

Equation 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 D.

### **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.<sup>44</sup>

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.

<sup>44</sup> The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those *buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type - Large Multifamily – included.*

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

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

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples <sup>45</sup>
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.

<sup>45</sup> Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.



Building Type	Principal Building Activity	Definition	Detailed Business Type Examples <sup>45</sup>
Lodging	Large Hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	1) Motel or Inn 2) Hotel 3) Dormitory, Fraternity, or Sorority 4) Retirement Home, Nursing Home, Assisted Living, or other Residential Care 5) Convent or Monastery
	Nursing Home		
	Small Hotel/Motel		
Mercantile	Stand-Alone Retail	Buildings used for the sale and display of goods other than food.	1) Retail Store 2) Beer, Wine, or Liquor Store 3) Rental Center 4) Dealership or Showroom for Vehicles or Boats 5) Studio or Gallery
	Strip Mall	Shopping malls comprised of multiple connected establishments.	1) Strip Shopping Center 2) Enclosed Malls
Office	Large Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	1) Administrative or Professional Office 2) Government Office 3) Mixed-Use Office 4) Bank or Other Financial Institution 5) Medical Office 6) Sales Office 7) Contractor's Office (e.g. Construction, Plumbing, HVAC) 8) Non-Profit or Social Services 9) Research and Development 10) City Hall or City Center 11) Religious Office 12) Call Center
	Medium Office		
	Small Office		

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples <sup>45</sup>
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 <sup>45</sup>
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	<ul style="list-style-type: none"> <li>1) Vehicle Service or Vehicle Repair Shop</li> <li>2) Vehicle Storage/Maintenance</li> <li>3) Repair Shop</li> <li>4) Dry Cleaner or Laundromat</li> <li>5) Post Office or Postal Center</li> <li>6) Car Wash</li> <li>7) Gas Station with no Convenience Store</li> <li>8) Photo Processing Shop</li> <li>9) Beauty Parlor or Barber Shop</li> <li>10) Tanning Salon</li> <li>11) Copy Center or Printing Shop</li> <li>12) Kennel</li> </ul>
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	<ul style="list-style-type: none"> <li>1) Refrigerated Warehouse</li> <li>2) Non-refrigerated warehouse</li> <li>3) Distribution or Shipping Center</li> </ul>
Other	Other	For building types not explicitited 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<sup>46</sup>**

Building Type	Principal Building Activity	Average Floor Area (ft <sup>2</sup> )	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

<sup>46</sup> Building prototype information from DOE Commercial Reference Buildings, “Not specified” means that a building prototype is not defined for that building type. <http://energy.gov/eere/buildings/commercial-reference-buildings>, 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	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>	DF <sub>H</sub>	EFLH <sub>H</sub>
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
	Quick-Service Restaurant	0.73	765	0.73	765	0.48	1,029
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
	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 Fort Worth (Climate Zone 2)**

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>	DF <sub>H</sub>	EFLH <sub>H</sub>
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
	Quick-Service Restaurant	1.08	1,588	1.08	1,588	0.61	631
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
	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	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>	DF <sub>H</sub>	EFLH <sub>H</sub>
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
	Quick-Service Restaurant	1.03	1,853	1.03	1,853	0.51	372
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
	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 Brownsville (Climate Zone 4)**

Building Type	Principal Building Activity	Package and Split DX					
		Air Conditioner		Heat Pump			
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>	DF <sub>H</sub>	EFLH <sub>H</sub>
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
	Quick-Service Restaurant	0.94	2,172	0.94	2,172	0.34	232
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
	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	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>	DF <sub>H</sub>	EFLH <sub>H</sub>
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
	Quick-Service Restaurant	0.76	1,082	0.76	1,082	0.26	522
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
	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.<sup>47</sup>

### **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 D.

**Table 2-26: Remaining Useful Life Early Retirement Systems<sup>48</sup>**

Age of Replaced System (years)	Split/Packaged AC/HP Systems RUL (years)	Age of Replaced System (years)	Split/Packaged AC/HP Systems RUL (years)
5	10	15	2.8
6	9.1	16	2.5
7	8.2	17	2.2
8	7.3	18	1.9
9	6.5	19	1.7
10	5.7	20	1.5
11	5.0	21	1.3
12	4.4	22	1.1
13	3.8	23	1.0
14	3.3		

<sup>47</sup> The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

<sup>48</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

## **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 D.

## 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.
- 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](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	Modified Early Retirement savings calculations and added references to Appendix D which details those calculations. Added heat pump minimum required heating efficiencies for reference. Revised baseline efficiency standards based on updates to federal standards.
v2.1	01/30/2015	Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	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	Update the building type definitions and descriptions. Added “Other” building type for when building type is not explicitly listed.
v4.0	10/10/2016	Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for split and packaged units less than 5.4 tons to be consistent with updated federal standards.

## 2.2.3 HVAC Chillers Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 2-35 through Table 2-39.

**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.

Applicable efficient measure types include<sup>49</sup>:

- Compressor Types: Centrifugal or Positive-displacement (Screw, Scroll, or Reciprocating)
- Condenser/Heat Rejection Type: Air-cooled or Water-cooled System Type Conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. 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

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<sup>49</sup> 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

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.<sup>50</sup>
- The building falls into one of the categories listed in Table 2-35 through Table 2-39. 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 that is at least five years old 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.

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 2-33 according to the capacity, chiller type, and age (based on year of manufacture) of the replaced system.<sup>51</sup> 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 2-33 should be used. These tables will be updated every few years so that systems greater than 5 years old will be eligible for early retirement. 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, coinciding with the ASHRAE 90.1-2010 code increase (Path A).

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<sup>50</sup> 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).

<sup>51</sup> The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010), efficiencies were given in COP and have been converted to EER and kW/ton in the tables below using  $EER = COP \times 3.412$  and  $kW/ton = 3.516 \div COP$ . Values in the “ $\leq 2001$ ” and “2002-2009” rows of Table 2-28, Table 2-30, Table 2-32 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  $\leq 2001$  rather than 1990-2001.

**Table 2-28: ER Baseline Full-Load Efficiency of All Air-Cooled Chillers<sup>52</sup>**

Year Installed (Replaced System)	< 75 tons [EER]	$\geq 75$ to 150 tons [EER]	$\geq 150$ to 300 tons [EER]	$\geq 300$ to 600 tons [EER]	$\geq 600$ tons [EER]
$\leq 2001$	<i>9.212</i>	<i>9.212</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
2002 - 2009	<i>9.554</i>	<i>9.554</i>	<i>9.554</i>	<i>9.554</i>	<i>9.554</i>
2010 - 2012	9.562	9.562	9.562	9.562	9.562

**Table 2-29: ER Baseline Part-Load Efficiency of All Air-Cooled Chillers**

Year Installed (Replaced System)	< 75 tons [IPLV]	$\geq 75$ to 150 tons [IPLV]	$\geq 150$ to 300 tons [IPLV]	$\geq 300$ to 600 tons [IPLV]	$\geq 600$ tons [IPLV]
$\leq 2001$	<i>9.554</i>	<i>9.554</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
2002 - 2009	<i>10.407</i>	<i>10.407</i>	<i>10.407</i>	<i>10.407</i>	<i>10.407</i>
2010 - 2012	12.750	12.750	12.750	12.750	12.750

ER Baseline: Centrifugal Water-Cooled Chillers

**Table 2-30: ER Baseline Full-Load Efficiency of Centrifugal Water-Cooled Chillers<sup>53</sup>**

Year Installed (Replaced System)	< 75 tons [kW/ton]	$\geq 75$ to 150 tons [kW/ton]	$\geq 150$ to 300 tons [kW/ton]	$\geq 300$ to 600 tons [kW/ton]	$\geq 600$ tons [kW/ton]
$\leq 2001$	<i>0.925</i>	<i>0.925</i>	<i>0.837</i>	<i>0.748</i>	<i>0.748</i>
2002 - 2009	<i>0.703</i>	<i>0.703</i>	<i>0.634</i>	<i>0.576</i>	<i>0.576</i>
2010 - 2012	0.634	0.634	0.634	0.576	0.570

<sup>52</sup> Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to EER using  $EER = COP \times 3.412$ . Values in the “ $\leq 2001$ ” and “2002-2009” rows have been converted and are expressed in italics.

<sup>53</sup> Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to kW/ton using  $kW/ton = 3.516 \div COP$ . Values in the “ $\leq 2001$ ” and “2002-2009” rows have been converted and are expressed in italics.

**Table 2-31: ER Baseline Part-Load Efficiency of Centrifugal Water-Cooled Chillers**

Year Installed (Replaced System)	< 75 tons [IPLV]	≥ 75 to 150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	<i>0.902</i>	<i>0.902</i>	<i>0.781</i>	<i>0.733</i>	<i>0.733</i>
2002 - 2009	<i>0.670</i>	<i>0.670</i>	<i>0.596</i>	<i>0.549</i>	<i>0.549</i>
2010 - 2012	0.596	0.596	0.596	0.549	0.539

**ER Baseline: Positive-Displacement Water-Cooled Chillers****Table 2-32: ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Water-Cooled Chillers<sup>54</sup>**

Year Installed (Replaced System)	< 75 tons [kW/ton]	≥ 75 to 150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	<i>0.925</i>	<i>0.925</i>	<i>0.837</i>	<i>0.748</i>	<i>0.748</i>
2002 - 2009	<i>0.790</i>	<i>0.790</i>	<i>0.718</i>	<i>0.639</i>	<i>0.639</i>
2010 - 2012	0.780	0.775	0.680	0.620	0.620

**Table 2-33: ER Baseline Part-Load Efficiency of Screw/Scroll/Recip. Water-Cooled Chillers**

Year Installed (Replaced System)	< 75 tons [IPLV]	≥ 75 to 150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	<i>0.902</i>	<i>0.902</i>	<i>0.781</i>	<i>0.733</i>	<i>0.733</i>
2002 - 2009	<i>0.676</i>	<i>0.676</i>	<i>0.628</i>	<i>0.572</i>	<i>0.572</i>
2010 - 2012	0.630	0.615	0.580	0.540	0.540

**Replace-on-Burnout and New Construction**

New baseline efficiency levels for chillers are provided in Table 2-34, 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, however Path A is the method chosen for consistency with the full-load efficiency conditions used in the savings algorithms.<sup>55</sup> Path B chillers are eligible to claim savings using the Path A chiller baseline efficiencies and demand and energy coefficients defined in this measure.

<sup>54</sup> Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to kW/ton using  $\text{kW/ton} = 3.516 \div \text{COP}$ . Values in the “≤ 2001” and “2002-2009” rows have been converted and are expressed in italics.

<sup>55</sup> According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for water-cooled chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller).



**Table 2-34: Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers<sup>56</sup>**

System Type [Efficiency Units]		Efficiency Type	Capacity [Tons]	Path A	
				Full-Load	IPLV
Air-Cooled Chiller		EER	< 150	≥ 9.562	≥ 12.750
			≥ 150	≥ 9.562	≥ 12.750
Water-Cooled Chiller	Electrically-Operated, Positive Displacement (Screw/Scroll/Reciprocating)	kW/ton	<75	≤ 0.780	≤ 0.630
			≥ 75 and < 150	≤ 0.775	≤ 0.615
			≥ 150 and < 300	≤ 0.680	≤ 0.580
	≥ 300		≤ 0.620	≤ 0.540	
	Electrically-Operated, Centrifugal		< 300	≤ 0.634	≤ 0.596
			≥ 300 and < 600	≤ 0.576	≤ 0.549
≥ 600		≤ 0.570	≤ 0.539		

## High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 2-34. Additional conditions for replace-on-burnout, early retirement and new construction are as follows:

### **New Construction and Replace on Burnout**

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

### **Early Retirement**

The high-efficiency retrofits must meet the following criteria<sup>57</sup>:

- 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).

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

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

Equation 20

<sup>56</sup> For ASHRAE 90.1-2010, a 2013 Supplement Addenda ch was filed which is effective January 1<sup>st</sup>, 2015. This Addenda contains revised full-load and part-load baseline efficiency standards for both Path A and Path B chillers, but the revisions are not reflected in these tables.

<sup>57</sup> From PUCT Docket #41070.

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

**Equation 21**

Where:

$\text{Cap}_{C,\text{pre}}$	=	Rated equipment cooling capacity of the existing equipment at AHRI standard conditions [Tons]
$\text{Cap}_{C,\text{post}}$	=	Rated equipment cooling capacity of the newly installed equipment at AHRI standard conditions [Tons]
$\eta_{\text{baseline}}$	=	Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/Ton]
$\eta_{\text{installed}}$	=	Rated efficiency of the newly installed equipment [kW/Ton] - (Must exceed efficiency standards, shown in Table 2-34)

Note: Use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. Table 2-28 through Table 2-33 provide efficiency ratings for baseline equipment and the efficiency ratings are given in terms of EER, kW/ton, or IPLV. 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:

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

**Equation 22**

$DF$  = Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-35 through Table 2-39)

$\text{EFLH}_C$  = Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 2-35 through Table 2-39)

### **Air-to Water-Cooled Replacement: Adjustments for Auxiliary Equipment<sup>58</sup>:**

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

$$\text{kW} = (\text{HP}_{\text{CW pump}} + \text{HP}_{\text{CT fan}}) \times \frac{0.746}{0.86} \times 0.80$$

**Equation 23**

<sup>58</sup> This extra adjustment is noted in PUCT Docket No. 41070.

$$kWh = kW \times 8,760$$

Equation 24

Where:

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

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

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

Equation 25

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

Equation 26

### **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 D.

Table 2-35 through Table 2-39 present the demand and energy coefficients. 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 2-35 through Table 2-39. 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 use the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

**Table 2-35: DF and EFLH for Amarillo (Climate Zone 1)**

Building Type	Principal Building Activity	Chiller <sup>59</sup>			
		Air Cooled		Water Cooled	
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>
Education	College	0.87	1,115	0.68	1,243
	Primary School	0.44	576	0.53	971
	Secondary School	0.62	802	0.58	1,772
Healthcare	Hospital	0.70	2,006	0.65	2,711
Large Multifamily	Midrise Apartment	0.41	421	0.50	1,098
Lodging	Large Hotel	0.58	1,283	0.59	1,553
	Nursing Home	0.41	428	0.50	1,115
Mercantile	Stand-Alone Retail	0.52	489	0.54	719
Office	Large Office	0.70	1,208	0.61	1,506
Public Assembly	Public Assembly	0.44	774	0.53	1,306
Religious Worship	Religious Worship	0.52	294	0.54	433
Other	Other	0.41	294	0.50	433

<sup>59</sup> Coefficient values are derived from the petitions filed in Docket 40885 and Docket 30331. Coefficients were updated with Docket 40885, but not all building types (herein “principal building activities,” or PBAs) that were originally available in Docket 30331 were updated in Docket 40885. Coefficient values for those PBAs that were not updated in Docket 40885 remain valid.

**Table 2-36: DF and EFLH for Fort Worth (Climate Zone 2)**

Building Type	Principal Building Activity	Chiller <sup>60</sup>			
		Air Cooled		Water Cooled	
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>
Education	College	0.89	1,587	0.81	1,761
	Primary School	0.48	726	0.60	1,412
	Secondary School	0.77	1,170	0.54	2,234
Healthcare	Hospital	0.90	2,784	0.81	3,683
Large Multifamily	Midrise Apartment	0.68	1,060	0.66	2,053
Lodging	Large Hotel	0.80	2,086	0.71	2,627
	Nursing Home	0.68	1,077	0.66	2,085
Mercantile	Stand-Alone Retail	0.79	936	0.72	1,328
Office	Large Office	0.92	1,711	0.70	2,062
Public Assembly	Public Assembly	0.48	976	0.60	1,898
Religious Worship	Religious Worship	0.79	563	0.72	799
Other	Other	0.48	563	0.54	799

**Table 2-37: DF and EFLH for Houston (Climate Zone 3)**

Building Type	Principal Building Activity	Chiller			
		Air Cooled		Water Cooled	
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>
Education	College	0.80	1,858	0.84	2,099
	Primary School	0.45	818	0.60	1,627
	Secondary School	0.73	1,306	0.55	2,404
Healthcare	Hospital	0.85	3,116	0.79	4,171
Large Multifamily	Midrise Apartment	0.65	1,295	0.66	2,467
Lodging	Large Hotel	0.71	2,499	0.73	3,201
	Nursing Home	0.65	1,315	0.66	2,506
Mercantile	Stand-Alone Retail	0.83	1,224	0.78	1,712
Office	Large Office	0.92	1,820	0.71	2,312
Public Assembly	Public Assembly	0.45	1,100	0.60	2,188
Religious Worship	Religious Worship	0.83	737	0.78	1,031
Other	Other	0.45	737	0.55	1,031

<sup>60</sup> Ibid.

**Table 2-38: DF and EFLH for Brownsville (Climate Zone 4)**

Building Type	Principal Building Activity	Chiller <sup>61</sup>			
		Air Cooled		Water Cooled	
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>
Education	College	0.80	2,340	0.87	2,583
	Primary School	0.45	937	0.61	1,845
	Secondary School	0.70	1,503	0.55	2,577
Healthcare	Hospital	0.79	3,455	0.82	4,637
Large Multifamily	Midrise Apartment	0.61	1,534	0.67	2,840
Lodging	Large Hotel	0.74	2,908	0.73	3,713
	Nursing Home	0.61	1,558	0.67	2,884
Mercantile	Stand-Alone Retail	0.75	1,394	0.76	1,953
Office	Large Office	0.82	2,027	0.72	2,570
Public Assembly	Public Assembly	0.45	1,260	0.61	2,481
Religious Worship	Religious Worship	0.75	839	0.76	1,176
Other	Other	0.45	839	0.55	1,176

**Table 2-39: DF and EFLH for El Paso (Climate Zone 5)**

Building Type	Principal Building Activity	Chiller <sup>62</sup>			
		Air Cooled		Water Cooled	
		DF	EFLH <sub>c</sub>	DF	EFLH <sub>c</sub>
Education	College	0.93	1,278	0.96	1,458
	Primary School	0.61	751	0.53	1,113
	Secondary School	0.78	1,039	0.54	2,196
Healthcare	Hospital	0.71	2,355	0.59	2,992
Large Multifamily	Midrise Apartment	0.56	841	0.52	1,553
Lodging	Large Hotel	0.63	1,815	0.58	2,038
	Nursing Home	0.56	854	0.52	1,577
Mercantile	Stand-Alone Retail	0.64	722	0.55	948
Office	Large Office	0.77	1,442	0.60	1,683
Public Assembly	Public Assembly	0.61	1,010	0.53	1,496
Religious Worship	Religious Worship	0.64	435	0.55	571
Other	Other	0.56	435	0.52	571

<sup>61</sup> Ibid.

<sup>62</sup> Coefficient values are derived from the petitions filed in Docket 41070, 40885, and 30331. The only coefficients that were developed specific to Climate Zone 5 are those filed in Docket 41070; however, the petition in that docket did not include coefficients for all building types (herein “principal building activities,” or PBAs). Prior to filing of Docket 41070, deemed savings for what is now Climate Zone 5 were the Climate Zone 2 deemed savings. As such, chiller deemed savings for those PBAs not addressed in docket 41070 (Nursing Home and Religious Worship) are derived from Climate Zone 2 values from the prior petitions. Coefficient values for those PBAs that were not updated in either of Docket 41070 or 40885 remain valid.

## Measure Life and Lifetime Savings

### Effective Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw / Scroll / Reciprocating Chillers – 20 years<sup>63</sup>
- Centrifugal Chillers – 25 years<sup>64</sup>

### Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 2-40. 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 D.

**Table 2-40: Remaining Useful Life of Early Retirement Systems<sup>65</sup>**

Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)	Age of Replaced System (years)	Non-Centrifugal Chillers RUL (years)	Centrifugal Chillers RUL (years)
5	14.7	19.9	21	3.2	6.6
6	13.7	18.9	22	2.9	6.3
7	12.7	17.9	23	2.6	5.9
8	11.8	16.9	24	2.4	5.6
9	10.9	15.9	25	2.1	5.4
10	10.0	14.9	26	1.9	5.1
11	9.1	13.9	27	1.8	4.9
12	8.3	12.9	28	1.6	4.7
13	7.5	11.9	29	1.5	4.5 <sup>66</sup>
14	6.8	10.9	30	1.3	4.3
15	6.2	10.1	31	1.2	4.1
16	5.5	9.3	32	N/A	4
17	5.0	8.7	33	N/A	3.8
18	4.5	8.1	34	N/A	3.7
19	4.0	7.5	35	N/A	3.6
20	3.6	7.1	36	N/A	3.5

<sup>63</sup> PUCT Docket No. 36779. The original source was DEER 2008, but DEER 2014 provides the same value of 20 years for “High Efficiency Chillers”. DEER does not differentiate between centrifugal and non-centrifugal chillers.

<sup>64</sup> PUCT Docket No. 40885, review of multiple studies looking at the lifetime of Centrifugal Chillers as detailed in petition workpapers.

<sup>65</sup> PUCT Docket No. 40085, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>66</sup> The correct value is listed in this table, and differs from Table 5 of PUC Petition 40885 due to a typographical error in the petition.

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

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

- Decision/Action Type: ER, ROB, NC, Conversion
- Building Type
- Climate Zone
- Baseline Equipment Type (Compressor/Condenser Type)
- Baseline Equipment Rated Capacity
- Baseline Number of Units
- For ER ONLY: Baseline Age of System and Method of Determination (e.g. nameplate, blueprints, customer reported, not available)
- Installed Equipment Type (Compressor/Condenser Type)
- 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 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 D.

## 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 90.1-2010. Energy Standard for Buildings except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.

## Document Revision History

**Table 2-41: Nonresidential HVAC-Chillers History**

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	Modified savings calculations surrounding Early Retirement programs, and revised details surrounding RUL and Measure Life. Added references to Appendix D for EUL and RUL discussion, and Net Present Value (NPV) equations.
v2.1	01/30/2015	Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	Update of savings method to allow for part-load efficiency calculations.
v3.1	11/05/2015	Updated table references to clarify building types and RUL references. Added "Other" building type for when building type is not explicitly listed. Added Religious Worship building type to Climate Zone 5 for consistency with other zones.
v4.0	10/10/2016	Used modeling approach to update DF and EFLH for applicable building types and climate zones.

## 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:** Large Hotel and Small Hotel/Motel

**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<sup>2</sup>. *Non-Standard Size* refers to equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide and a cross sectional area less than 670 in<sup>2</sup>.

**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.<sup>67</sup>
- The climate zone is determined from the county-to-climate-zone mapping table.
- For PTAC/PTHP and RAC equipment types, the eligible building types are “Large Hotel” and “Small Hotel/Motel”<sup>68</sup>. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system that is at least five years old 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.<sup>69</sup> When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-42, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. When the system age is unknown, assume 17 years.<sup>70</sup>

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<sup>67</sup> 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).

<sup>68</sup> The original petition did not include the “Large Hotel” business type. This application was added in TRMv2 as a short-term, conservative savings estimate, but more accurate savings estimates should be developed for a future TRM.

<sup>69</sup> The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

<sup>70</sup> As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, taking into account increments in efficiency standards that took place in the historical period.

**Table 2-42: ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units<sup>71</sup>**

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 × Cap/1000)	--
	>15,000	9.3	--
PTHP	<7,000	10.8	3.0
	7,000-15,000	12.3 – (0.213 × Cap/1000)	3.2 – (0.026 × Cap/1000)
	>15,000	9.1	2.8

**Replace-on-Burnout and New Construction**

Table 2-43 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 2-43: Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units**

Equipment	Category	Cooling Capacity [Btuh]	Minimum Cooling Efficiency [EER]	Minimum Heating Efficiency [COP]
PTAC	Standard Size	<7,000	11.7	--
		7,000-15,000	13.8 – (0.300 × Cap/1000)	--
		>15,000	9.3	--
	Non-Standard Size	<7,000	9.4	--
		7,000-15,000	10.9 – (0.213 × Cap/1000)	--
		>15,000	7.7	--
PTHP	Standard Size	<7,000	11.9	3.3
		7,000-15,000	14.0 – (0.300 × Cap/1000)	3.7 – (0.052 × 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 × Cap/1000)	2.9 – (0.026 × Cap/1000)
		>15,000	7.6	2.5

<sup>71</sup> ER only applies to Standard Size units because the minimum efficiency requirements for Non-Standard systems have never changed, making the ER baseline efficiency the same as for ROB.

<sup>72</sup> Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

Table 2-44 reflects the standards for Room Air Conditioners, specified in 10 CFR 430.32(b).

**Table 2-44: Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units<sup>73</sup>**

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

## High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 2-43 and Table 2-44.

The high-efficiency retrofits must also meet the following criteria<sup>74</sup>:

- 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).

<sup>73</sup> Direct final rule for new Room Air conditioner Standards was published on April 21<sup>st</sup>, 2011 (76 FR 22454), effective August 19<sup>th</sup>, 2011, and are required starting June 1<sup>st</sup>, 2014. These are found in 10 CFR Part 430.

<sup>74</sup> 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 27

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

Equation 28

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

Equation 29

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

Equation 30

Where:

- $Cap_{C/H,pre}$  = Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [BTUH]; 1 ton = 12,000 Btu/h
- $Cap_{C/H,post}$  = Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btu/h]; 1 ton = 12,000 Btu/h
- $\eta_{baseline,C}$  = Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 2-42 through Table 2-44)
- $\eta_{baseline,H}$  = Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 2-42 and Table 2-43)
- $\eta_{installed,C}$  = Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] - (Must exceed minimum federal standards found in Table 2-43 and Table 2-44)
- $\eta_{installed,H}$  = Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 2-43)
- $DF$  = 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 2-45 and Table 2-46.

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 D.

## 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 2-45 and Table 2-46 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 2-45: PTAC/PTHP Equipment: DF and EFLH Values by Climate Zone for Hotel – Small and Hotel – Large Building Types<sup>75</sup>**

Climate Zone	Packaged Terminal Unit				
	Air Conditioner		Heat Pump		
	DF	EFLH <sub>C</sub>	DF	EFLH <sub>C</sub>	EFLH <sub>H</sub>
Amarillo (Climate Zone 1)	0.51	1,359	0.51	1,359	361
Fort Worth (Climate Zone 2)	0.61	1,834	0.61	1,834	208
Houston (Climate Zone 3)	0.55	1,992	0.55	1,992	43
Brownsville (Climate Zone 4)	0.49	2,223	0.49	2,223	50
El Paso (Climate Zone 5) <sup>76</sup>	0.61	1,834	0.61	1,834	208

<sup>75</sup> Docket No. 40885 provides demand and energy savings by building type and cooling equipment for the four different climate zones. This original petition was dated 10/29/2012. An amended petition, dated 11/13/2012 was approved, which provides the original energy and demand coefficients (Table 2 18: CF and EFLH Values for Amarillo (Climate Zone 1) through Table 2-16, but also amended Tables (B3a through B3d and B4a through B4d).

<sup>76</sup> No values have been published for this measure for El Paso, Climate Zone 5, but per a comment received from Frontier, Climate Zone 5 has historically used the Fort Worth (Climate Zone 2) weather values

**Table 2-46: RAC Equipment: DF and EFLH Values<sup>77</sup>**

Climate Zone	Room/Window Air Conditioner	
	DF	EFLH <sub>c</sub>
Amarillo (Climate Zone 1)	0.51	1,359
Fort Worth (Climate Zone 2)	0.61	1,834
Houston (Climate Zone 3)	0.55	1,992
Brownsville (Climate Zone 4)	0.49	2,223
El Paso (Climate Zone 5)	0.61	1,834

## 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.<sup>78</sup>

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

The RUL of ER replaced systems is provided according to system age in Table 2-47.

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 D.

<sup>77</sup> PUCT Docket 40885 did not explicitly specify energy and demand coefficients for RAC units. PTAC/PTHP units are the most similar available equipment type. Therefore, RAC units will use the PTAC/PTHP coefficients. RAC-specific coefficients should be developed in a future TRM.

<sup>78</sup> The updates were made in Federal Register, 76 FR 22582-22584, but the reference to the EUL is found here: <http://www.regulations.gov/contentStreamer?objectId=0900006480c34c55&disposition=attachment&contentType=pdf>. Accessed 04/02/2014. This value is listed as 10.5 years, and has been rounded up to 11.



**Table 2-47: Remaining Useful Life of ER PTAC/PTHP Systems<sup>79</sup>**

Age of Replaced System (Years)	PTAC/PTHP RUL (Years)	Age of Replaced System (Years)	PTAC/PTHP RUL (Years)
5	10.0	15	2.8
6	9.1	16	2.5
7	8.2	17	2.2
8	7.3	18	1.9
9	6.5	19	1.7
10	5.7	20	1.5
11	5.0	21	1.3
12	4.4	22	1.1
13	3.8	23	1.0
14	3.3		

## **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

<sup>79</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

- 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](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](http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41)

## Document Revision History

**Table 2-48: 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	Updated EUL value for DX units, based on PUCT Docket No. 36779. Updated the minimum baseline efficiencies for Standard PTAC and PTHP based on new federal standards, 10 CFR 431.97, and updated the minimum efficiencies for Room AC units and added specifications for new Casement-only and Casement-slider equipment. Expanded application to "Hotel – Large" business type for PTAC/PTHP equipment, and changed the RAC energy and demand coefficients to reference those for DX systems, rather than those for PTAC/PTHP systems.
v2.1	01/30/2015	Corrections to energy and demand coefficients for heat pumps in Climate Zone 3 (Houston).
v3.0	04/10/2015	Added energy and demand coefficients for RAC units. Included text to allow for Early Retirement changes. For PTHPs: Added heating efficiencies and split EFLH into cooling and heating components.
v3.1	11/05/2015	Added updated building type definitions and descriptions, minor updates to text for clarification and consistency.
v4.0	10/10/2016	No revisions

## 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 2-50

**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 ASHRAE 90.1-2004. 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,  $\beta^0$ ;

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

Equation 31

Where:

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

Equation 32

Step 2 – Calculate the %power<sup>81</sup> 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 33

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

Equation 34

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

Equation 35

### VFD Technology

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

Equation 36

Step 3 – Calculate kW<sub>full</sub> 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:

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<sup>80</sup> A 60% minimum setpoint strategy is assumed, so any results below 60% are set to 60%.

<sup>81</sup> [https://focusonenergy.com/sites/default/files/Focus%20on%20Energy\\_TRM\\_January2015.pdf](https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf), page 225.

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

Equation 37

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

Equation 38

Step 4 – Calculate the kW savings for each hour within the 510-hr summer peak period, sum the kW savings from the 510 individual hourly calculations, divide by 510 to get the average peak demand impact, and then calculate the total peak demand saved by adding peak demand interactive effects:

### Hourly Savings Calculations

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

Equation 39

Average Peak Demand Saved Calculation, excluding interactive effects

$$kW_{AVG,Saved} = \sum_{i=1}^{510} (kW_i)_{Saved} \div 510$$

Equation 40

Total Peak Demand Saved Calculation, including interactive effects

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

Equation 41

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 42

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

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

Equation 43

Where:

$\%CFM_i$	=	Part-load fan airflow at the $i^{\text{th}}$ hour of the year
$t_i$	=	Dry bulb air temperature at $i^{\text{th}}$ hour taken from TMY3 hourly weather data
$t_{dbd}$	=	ASHRAE 0.4% Cooling Dry Bulb Design Temperature for the reference city from 1997 ASHRAE Handbook – Fundamentals, Table 26.1B
$\%power_i$	=	Percentage of full load power at the $i^{\text{th}}$ hour calculated by an equation based on the control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD) <sup>82</sup>
$kW_{full}$	=	Fan motor power demand operating at the fan design 100% CFM
$kW_i$	=	Fan real-time power at the $i^{\text{th}}$ 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
$\eta$	=	Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2004
0.746	=	HP to kW conversion factor
schedule	=	1 when building is occupied, 0.2 when building is unoccupied, see Table 2-49
Cooling <sub>SEER</sub>	=	Air conditioner cooling efficiency, assumed at 11.2, based on ASHRAE Standard 90.1 – 2004 minimum efficiency of a unitary AC system between 5 and 10 tons
510	=	Total number of hours during the utility defined summer peak period (Weekdays from 1-7 PM during months of June, July August and September) <sup>83</sup>
8760	=	Total number of hours in a year

<sup>82</sup> Fan curves by control type are provided in the BPA ASD Calculator, <http://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls>.

<sup>83</sup> The day of the week is not determined by a specific year, but by the Month and Year for the particular location based on the TMY3 weather data file.

## Deemed Energy and Demand Savings Tables

Table 2-49: Yearly Motor Operation Hours by Building Type<sup>84</sup>

Building Type	Weekday Schedule	Weekend Schedule	Annual Building Occupied Hours	Annual Motor Operation Hours*
Office – Large	8am–8pm	8am–10am	3,340	4,424
Office – Small	8am-6pm	8am-10am	2,818	4,007
Hospitals & Healthcare	24 hr	24 hr	8,760	8,760
Education – K-12	7am-5pm	8am-12pm	2,630	3,856
Education – College & University	8am-8pm	8am-12pm	3,548	4,591
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 2-50: Deemed Energy and Demand Savings Values for Outlet Damper Part-Load Fan Control by Climate Region

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.105	1,240	0.126	1,278	0.097	1,167	0.090	1,120	0.117	1,273
2	0.207	2,436	0.248	2,510	0.191	2,292	0.176	2,200	0.229	2,500
3	0.301	3,549	0.361	3,656	0.278	3,339	0.256	3,205	0.334	3,642
5	0.497	5,847	0.595	6,023	0.458	5,502	0.422	5,280	0.550	6,001
7.5	0.736	8,671	0.882	8,933	0.679	8,159	0.626	7,831	0.816	8,900
10	0.971	11,432	1.163	11,777	0.895	10,757	0.826	10,325	1.076	11,734
15	1.433	16,866	1.716	17,374	1.321	15,870	1.218	15,232	1.587	17,311
20	1.910	22,488	2.288	23,166	1.761	21,160	1.624	20,309	2.116	23,081
25	2.369	27,895	2.838	28,736	2.184	26,248	2.015	25,193	2.625	28,631
30	2.822	33,221	3.380	34,222	2.601	31,259	2.399	30,002	3.126	34,097
40	3.738	44,009	4.477	45,335	3.446	41,410	3.178	39,745	4.141	45,170
50	4.672	55,011	5.596	56,669	4.308	51,762	3.973	49,681	5.177	56,462
60	5.571	65,590	6.673	67,567	5.136	61,716	4.737	59,236	6.172	67,320
75	6.927	81,552	8.296	84,010	6.386	76,735	5.890	73,651	7.674	83,703
100	9.235	108,736	11.062	112,014	8.515	102,314	7.853	98,201	10.232	111,605

<sup>84</sup> 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	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Large										
1	0.105	601	0.126	622	0.097	557	0.090	530	0.117	618
2	0.207	1,181	0.248	1,222	0.191	1,095	0.176	1,041	0.229	1,214
3	0.301	1,720	0.361	1,781	0.278	1,595	0.256	1,516	0.334	1,768
5	0.497	2,834	0.595	2,934	0.458	2,627	0.422	2,498	0.550	2,913
7.5	0.736	4,203	0.882	4,351	0.679	3,897	0.626	3,705	0.816	4,321
10	0.971	5,542	1.163	5,736	0.895	5,138	0.826	4,885	1.076	5,697
15	1.433	8,176	1.716	8,463	1.321	7,579	1.218	7,207	1.587	8,404
20	1.910	10,901	2.288	11,284	1.761	10,106	1.624	9,609	2.116	11,206
25	2.369	13,523	2.838	13,997	2.184	12,536	2.015	11,920	2.625	13,900
30	2.822	16,104	3.380	16,669	2.601	14,929	2.399	14,196	3.126	16,554
40	3.738	21,334	4.477	22,082	3.446	19,777	3.178	18,805	4.141	21,929
50	4.672	26,667	5.596	27,603	4.308	24,721	3.973	23,507	5.177	27,411
60	5.571	31,796	6.673	32,911	5.136	29,475	4.737	28,027	6.172	32,683
75	6.927	39,533	8.296	40,920	6.386	36,648	5.890	34,848	7.674	40,637
100	9.235	52,711	11.062	54,560	8.515	48,864	7.853	46,464	10.232	54,182
Office - Small										
1	0.088	544	0.107	563	0.080	501	0.073	476	0.098	559
2	0.173	1,068	0.209	1,106	0.156	984	0.144	935	0.193	1,098
3	0.252	1,555	0.305	1,611	0.228	1,433	0.209	1,361	0.281	1,599
5	0.415	2,563	0.502	2,654	0.375	2,362	0.345	2,243	0.462	2,634
7.5	0.616	3,800	0.745	3,937	0.556	3,502	0.512	3,327	0.686	3,907
10	0.812	5,011	0.982	5,190	0.734	4,618	0.675	4,386	0.904	5,151
15	1.198	7,392	1.448	7,657	1.082	6,812	0.996	6,470	1.334	7,599
20	1.598	9,856	1.931	10,209	1.443	9,083	1.328	8,627	1.779	10,132
25	1.982	12,226	2.396	12,664	1.790	11,267	1.647	10,702	2.206	12,569
30	2.360	14,560	2.853	15,082	2.132	13,418	1.961	12,745	2.627	14,968
40	3.127	19,288	3.779	19,979	2.824	17,776	2.598	16,883	3.481	19,829
50	3.909	24,110	4.724	24,974	3.530	22,220	3.248	21,104	4.351	24,786
60	4.660	28,746	5.633	29,777	4.208	26,493	3.872	25,163	5.188	29,553
75	5.794	35,742	7.003	37,023	5.233	32,940	4.814	31,286	6.450	36,745
100	7.726	47,656	9.338	49,364	6.977	43,920	6.419	41,715	8.600	48,993
Education - K-12										
1	0.036	545	0.044	561	0.030	501	0.030	477	0.041	559
2	0.070	1,070	0.086	1,101	0.059	984	0.058	938	0.081	1,097
3	0.103	1,559	0.125	1,604	0.086	1,433	0.084	1,366	0.118	1,598
5	0.169	2,569	0.206	2,642	0.141	2,360	0.139	2,251	0.194	2,633
7.5	0.251	3,809	0.306	3,919	0.209	3,501	0.206	3,338	0.287	3,905
10	0.330	5,022	0.403	5,167	0.276	4,615	0.272	4,401	0.379	5,148
15	0.488	7,409	0.595	7,623	0.407	6,809	0.401	6,493	0.559	7,595
20	0.650	9,879	0.793	10,163	0.542	9,079	0.535	8,657	0.745	10,127
25	0.806	12,255	0.984	12,607	0.673	11,262	0.664	10,739	0.924	12,562
30	0.960	14,594	1.171	15,014	0.801	13,412	0.790	12,789	1.100	14,960
40	1.272	19,333	1.552	19,890	1.061	17,767	1.047	16,942	1.458	19,818
50	1.590	24,167	1.940	24,862	1.327	22,209	1.309	21,177	1.822	24,772
60	1.896	28,814	2.313	29,643	1.582	26,480	1.560	25,250	2.173	29,536
75	2.357	35,827	2.876	36,857	1.967	32,924	1.940	31,395	2.701	36,724
100	3.143	47,769	3.834	49,143	2.622	43,898	2.587	41,860	3.602	48,966

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh

Education - College & University

1	0.105	624	0.126	646	0.097	577	0.090	548	0.117	641
2	0.207	1,225	0.248	1,268	0.191	1,133	0.176	1,077	0.229	1,260
3	0.301	1,785	0.361	1,848	0.278	1,651	0.256	1,569	0.334	1,835
5	0.497	2,941	0.595	3,044	0.458	2,720	0.422	2,585	0.550	3,023
7.5	0.736	4,362	0.882	4,515	0.679	4,034	0.626	3,834	0.816	4,483
10	0.971	5,750	1.163	5,953	0.895	5,318	0.826	5,055	1.076	5,911
15	1.433	8,483	1.716	8,782	1.321	7,845	1.218	7,458	1.587	8,720
20	1.910	11,311	2.288	11,709	1.761	10,461	1.624	9,944	2.116	11,626
25	2.369	14,031	2.838	14,525	2.184	12,976	2.015	12,335	2.625	14,422
30	2.822	16,710	3.380	17,298	2.601	15,453	2.399	14,690	3.126	17,175
40	3.738	22,136	4.477	22,915	3.446	20,471	3.178	19,461	4.141	22,753
50	4.672	27,670	5.596	28,643	4.308	25,589	3.973	24,326	5.177	28,441
60	5.571	32,991	6.673	34,152	5.136	30,510	4.737	29,004	6.172	33,910
75	6.927	41,020	8.296	42,463	6.386	37,935	5.890	36,062	7.674	42,163
100	9.235	54,693	11.062	56,617	8.515	50,580	7.853	48,083	10.232	56,217

Retail

1	0.105	753	0.126	779	0.097	699	0.090	668	0.117	774
2	0.207	1,479	0.248	1,530	0.191	1,373	0.176	1,312	0.229	1,521
3	0.301	2,154	0.361	2,228	0.278	2,000	0.256	1,911	0.334	2,216
5	0.497	3,549	0.595	3,671	0.458	3,295	0.422	3,149	0.550	3,651
7.5	0.736	5,263	0.882	5,445	0.679	4,887	0.626	4,670	0.816	5,414
10	0.971	6,939	1.163	7,179	0.895	6,443	0.826	6,157	1.076	7,138
15	1.433	10,237	1.716	10,590	1.321	9,505	1.218	9,083	1.587	10,531
20	1.910	13,650	2.288	14,120	1.761	12,674	1.624	12,110	2.116	14,042
25	2.369	16,932	2.838	17,516	2.184	15,721	2.015	15,022	2.625	17,418
30	2.822	20,164	3.380	20,860	2.601	18,723	2.399	17,890	3.126	20,743
40	3.738	26,712	4.477	27,634	3.446	24,802	3.178	23,700	4.141	27,479
50	4.672	33,390	5.596	34,542	4.308	31,003	3.973	29,625	5.177	34,349
60	5.571	39,812	6.673	41,185	5.136	36,965	4.737	35,322	6.172	40,955
75	6.927	49,500	8.296	51,207	6.386	45,961	5.890	43,918	7.674	50,921
100	9.235	66,000	11.062	68,277	8.515	61,281	7.853	58,557	10.232	67,895

Restaurant - Fast Food

1	0.105	928	0.126	958	0.097	864	0.090	827	0.117	954
2	0.207	1,822	0.248	1,882	0.191	1,698	0.176	1,624	0.229	1,874
3	0.301	2,654	0.361	2,742	0.278	2,473	0.256	2,365	0.334	2,729
5	0.497	4,373	0.595	4,517	0.458	4,074	0.422	3,896	0.550	4,497
7.5	0.736	6,486	0.882	6,699	0.679	6,042	0.626	5,779	0.816	6,669
10	0.971	8,551	1.163	8,832	0.895	7,967	0.826	7,619	1.076	8,792
15	1.433	12,615	1.716	13,030	1.321	11,753	1.218	11,240	1.587	12,971
20	1.910	16,820	2.288	17,374	1.761	15,670	1.624	14,986	2.116	17,295
25	2.369	20,864	2.838	21,551	2.184	19,438	2.015	18,590	2.625	21,454
30	2.822	24,847	3.380	25,666	2.601	23,149	2.399	22,139	3.126	25,549
40	3.738	32,916	4.477	34,000	3.446	30,667	3.178	29,328	4.141	33,846
50	4.672	41,145	5.596	42,500	4.308	38,333	3.973	36,660	5.177	42,308
60	5.571	49,058	6.673	50,673	5.136	45,705	4.737	43,710	6.172	50,444
75	6.927	60,996	8.296	63,005	6.386	56,828	5.890	54,347	7.674	62,719
100	9.235	81,328	11.062	84,007	8.515	75,771	7.853	72,463	10.232	83,626

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Restaurant - Sit down										
1	0.105	715	0.126	739	0.097	864	0.090	641	0.117	735
2	0.207	1,404	0.248	1,451	0.191	1,698	0.176	1,259	0.229	1,444
3	0.301	2,045	0.361	2,114	0.278	2,473	0.256	1,834	0.334	2,104
5	0.497	3,370	0.595	3,483	0.458	4,074	0.422	3,022	0.550	3,466
7.5	0.736	4,998	0.882	5,166	0.679	6,042	0.626	4,481	0.816	5,140
10	0.971	6,589	1.163	6,811	0.895	7,967	0.826	5,909	1.076	6,777
15	1.433	9,721	1.716	10,047	1.321	11,753	1.218	8,717	1.587	9,998
20	1.910	12,961	2.288	13,397	1.761	15,670	1.624	11,622	2.116	13,330
25	2.369	16,077	2.838	16,618	2.184	19,438	2.015	14,417	2.625	16,535
30	2.822	19,147	3.380	19,790	2.601	23,149	2.399	17,169	3.126	19,692
40	3.738	25,364	4.477	26,217	3.446	30,667	3.178	22,745	4.141	26,087
50	4.672	31,706	5.596	32,771	4.308	38,333	3.973	28,431	5.177	32,608
60	5.571	37,803	6.673	39,073	5.136	45,705	4.737	33,898	6.172	38,879
75	6.927	47,002	8.296	48,582	6.386	56,828	5.890	42,148	7.674	48,341
100	9.235	62,670	11.062	64,776	8.515	75,771	7.853	56,197	10.232	64,455

**Table 2-51: Deemed Energy and Demand Savings Values for Inlet Damper Part-Load Fan Control by Climate Region**

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.125	1,905	0.158	1,991	0.115	1,729	0.103	1,619	0.150	1,995
2	0.246	3,742	0.311	3,911	0.225	3,397	0.202	3,180	0.295	3,919
3	0.359	5,451	0.452	5,697	0.328	4,948	0.294	4,632	0.430	5,708
5	0.591	8,981	0.745	9,387	0.541	8,153	0.484	7,632	0.709	9,405
7.5	0.876	13,319	1.106	13,922	0.803	12,092	0.719	11,318	1.051	13,948
10	1.155	17,561	1.458	18,355	1.058	15,942	0.947	14,923	1.386	18,390
15	1.704	25,907	2.150	27,078	1.561	23,519	1.398	22,015	2.045	27,130
20	2.272	34,542	2.867	36,104	2.081	31,358	1.863	29,353	2.727	36,174
25	2.819	42,848	3.557	44,786	2.582	38,899	2.311	36,411	3.382	44,872
30	3.357	51,029	4.236	53,336	3.075	46,325	2.753	43,362	4.028	53,438
40	4.447	67,599	5.611	70,656	4.073	61,368	3.647	57,444	5.336	70,791
50	5.558	84,499	7.014	88,320	5.091	76,710	4.558	71,805	6.670	88,489
60	6.627	100,749	8.363	105,304	6.070	91,461	5.435	85,613	7.953	105,506
75	8.240	125,267	10.398	130,931	7.548	113,719	6.758	106,448	9.888	131,182
100	10.987	167,022	13.864	174,575	10.063	151,626	9.010	141,930	13.184	174,909
Office - Large										
1	0.125	909	0.158	953	0.115	809	0.103	750	0.150	953
2	0.246	1,786	0.311	1,871	0.225	1,590	0.202	1,474	0.295	1,872
3	0.359	2,602	0.452	2,725	0.328	2,316	0.294	2,147	0.430	2,727
5	0.591	4,286	0.745	4,490	0.541	3,816	0.484	3,537	0.709	4,492
7.5	0.876	6,357	1.106	6,659	0.803	5,659	0.719	5,245	1.051	6,662
10	1.155	8,381	1.458	8,780	1.058	7,461	0.947	6,915	1.386	8,784
15	1.704	12,365	2.150	12,953	1.561	11,006	1.398	10,202	2.045	12,959
20	2.272	16,486	2.867	17,271	2.081	14,675	1.863	13,603	2.727	17,278
25	2.819	20,451	3.557	21,424	2.582	18,204	2.311	16,874	3.382	21,433
30	3.357	24,355	4.236	25,514	3.075	21,679	2.753	20,095	4.028	25,525
40	4.447	32,264	5.611	33,799	4.073	28,719	3.647	26,621	5.336	33,813
50	5.558	40,330	7.014	42,248	5.091	35,899	4.558	33,276	6.670	42,267
60	6.627	48,085	8.363	50,373	6.070	42,803	5.435	39,675	7.953	50,395
75	8.240	59,787	10.398	62,632	7.548	53,219	6.758	49,330	9.888	62,659
100	10.987	79,716	13.864	83,509	10.063	70,959	9.010	65,773	13.184	83,545

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Small										
1	0.104	822	0.132	862	0.094	727	0.084	673	0.126	862
2	0.204	1,615	0.260	1,693	0.184	1,427	0.164	1,322	0.247	1,693
3	0.298	2,352	0.378	2,467	0.268	2,079	0.239	1,925	0.360	2,466
5	0.491	3,876	0.623	4,064	0.441	3,426	0.394	3,172	0.594	4,063
7.5	0.728	5,748	0.925	6,027	0.654	5,080	0.584	4,704	0.880	6,026
10	0.960	7,578	1.219	7,946	0.863	6,698	0.770	6,201	1.161	7,945
15	1.416	11,180	1.798	11,723	1.273	9,882	1.136	9,149	1.712	11,722
20	1.888	14,906	2.398	15,631	1.697	13,176	1.515	12,198	2.283	15,629
25	2.341	18,491	2.974	19,389	2.105	16,344	1.879	15,132	2.832	19,387
30	2.788	22,021	3.542	23,091	2.507	19,464	2.238	18,021	3.373	23,088
40	3.694	29,172	4.693	30,589	3.322	25,785	2.964	23,872	4.468	30,585
50	4.617	36,464	5.866	38,236	4.152	32,231	3.705	29,840	5.585	38,232
60	5.505	43,477	6.994	45,590	4.951	38,429	4.418	35,579	6.659	45,584
75	6.845	54,057	8.696	56,684	6.155	47,781	5.493	44,237	8.280	56,677
100	9.127	72,076	11.594	75,579	8.207	63,708	7.324	58,983	11.040	75,569
Education - K-12										
1	0.043	834	0.055	868	0.035	734	0.034	681	0.054	871
2	0.084	1,638	0.109	1,706	0.069	1,441	0.066	1,338	0.107	1,711
3	0.122	2,386	0.158	2,485	0.100	2,099	0.096	1,949	0.155	2,492
5	0.201	3,931	0.261	4,094	0.165	3,458	0.159	3,212	0.256	4,106
7.5	0.298	5,829	0.387	6,071	0.244	5,128	0.235	4,763	0.380	6,090
10	0.393	7,686	0.510	8,005	0.322	6,761	0.310	6,280	0.501	8,029
15	0.579	11,339	0.752	11,809	0.475	9,975	0.457	9,265	0.739	11,845
20	0.772	15,118	1.003	15,746	0.634	13,300	0.610	12,354	0.985	15,793
25	0.958	18,754	1.244	19,532	0.786	16,498	0.756	15,324	1.222	19,591
30	1.141	22,334	1.482	23,261	0.937	19,648	0.901	18,250	1.455	23,331
40	1.512	29,586	1.963	30,814	1.241	26,028	1.193	24,176	1.927	30,907
50	1.890	36,983	2.454	38,518	1.551	32,535	1.491	30,220	2.409	38,634
60	2.253	44,095	2.926	45,925	1.849	38,792	1.778	36,031	2.873	46,064
75	2.801	54,826	3.638	57,102	2.299	48,232	2.211	44,800	3.572	57,274
100	3.735	73,101	4.850	76,136	3.065	64,309	2.948	59,733	4.762	76,365
Education - College & University										
1	0.125	943	0.158	988	0.115	837	0.103	776	0.150	989
2	0.246	1,853	0.311	1,941	0.225	1,644	0.202	1,524	0.295	1,942
3	0.359	2,699	0.452	2,827	0.328	2,395	0.294	2,220	0.430	2,829
5	0.591	4,447	0.745	4,658	0.541	3,947	0.484	3,657	0.709	4,661
7.5	0.876	6,595	1.106	6,908	0.803	5,853	0.719	5,424	1.051	6,913
10	1.155	8,695	1.458	9,107	1.058	7,717	0.947	7,151	1.386	9,114
15	1.704	12,828	2.150	13,436	1.561	11,385	1.398	10,550	2.045	13,445
20	2.272	17,103	2.867	17,915	2.081	15,180	1.863	14,066	2.727	17,927
25	2.819	21,216	3.557	22,222	2.582	18,830	2.311	17,449	3.382	22,238
30	3.357	25,266	4.236	26,465	3.075	22,424	2.753	20,780	4.028	26,483
40	4.447	33,471	5.611	35,059	4.073	29,706	3.647	27,528	5.336	35,083
50	5.558	41,839	7.014	43,823	5.091	37,133	4.558	34,410	6.670	43,854
60	6.627	49,885	8.363	52,251	6.070	44,274	5.435	41,027	7.953	52,287
75	8.240	62,025	10.398	64,967	7.548	55,048	6.758	51,011	9.888	65,011
100	10.987	82,700	13.864	86,622	10.063	73,397	9.010	68,015	13.184	86,682
Retail										

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
1	0.125	1,137	0.158	1,190	0.115	1,016	0.103	947	0.150	1,194
2	0.246	2,234	0.311	2,337	0.225	1,996	0.202	1,859	0.295	2,345
3	0.359	3,254	0.452	3,404	0.328	2,907	0.294	2,708	0.430	3,416
5	0.591	5,362	0.745	5,609	0.541	4,790	0.484	4,462	0.709	5,628
7.5	0.876	7,952	1.106	8,318	0.803	7,104	0.719	6,618	1.051	8,347
10	1.155	10,484	1.458	10,967	1.058	9,366	0.947	8,726	1.386	11,005
15	1.704	15,467	2.150	16,179	1.561	13,817	1.398	12,873	2.045	16,235
20	2.272	20,623	2.867	21,572	2.081	18,423	1.863	17,163	2.727	21,647
25	2.819	25,582	3.557	26,759	2.582	22,853	2.311	21,291	3.382	26,852
30	3.357	30,466	4.236	31,868	3.075	27,216	2.753	25,355	4.028	31,978
40	4.447	40,359	5.611	42,216	4.073	36,053	3.647	33,589	5.336	42,362
50	5.558	50,449	7.014	52,770	5.091	45,067	4.558	41,986	6.670	52,953
60	6.627	60,150	8.363	62,918	6.070	53,733	5.435	50,060	7.953	63,136
75	8.240	74,789	10.398	78,230	7.548	66,810	6.758	62,243	9.888	78,500
100	10.987	99,718	13.864	104,306	10.063	89,079	9.010	82,990	13.184	104,667
Restaurant - Fast Food										
1	0.125	1,410	0.158	1,475	0.115	1,265	0.103	1,179	0.150	1,480
2	0.246	2,771	0.311	2,897	0.225	2,484	0.202	2,316	0.295	2,907
3	0.359	4,036	0.452	4,220	0.328	3,619	0.294	3,374	0.430	4,234
5	0.591	6,649	0.745	6,954	0.541	5,962	0.484	5,558	0.709	6,977
7.5	0.876	9,861	1.106	10,313	0.803	8,842	0.719	8,243	1.051	10,347
10	1.155	13,002	1.458	13,597	1.058	11,658	0.947	10,868	1.386	13,642
15	1.704	19,181	2.150	20,059	1.561	17,198	1.398	16,034	2.045	20,125
20	2.272	25,575	2.867	26,745	2.081	22,931	1.863	21,378	2.727	26,834
25	2.819	31,724	3.557	33,176	2.582	28,445	2.311	26,519	3.382	33,286
30	3.357	37,781	4.236	39,510	3.075	33,876	2.753	31,582	4.028	39,641
40	4.447	50,049	5.611	52,340	4.073	44,876	3.647	41,837	5.336	52,513
50	5.558	62,562	7.014	65,425	5.091	56,095	4.558	52,297	6.670	65,641
60	6.627	74,593	8.363	78,007	6.070	66,883	5.435	62,354	7.953	78,265
75	8.240	92,745	10.398	96,990	7.548	83,159	6.758	77,528	9.888	97,311
100	10.987	123,660	13.864	129,321	10.063	110,879	9.010	103,371	13.184	129,748
Restaurant - Sit Down										
1	0.125	1,082	0.158	1,131	0.115	1,265	0.103	912	0.150	1,135
2	0.246	2,124	0.311	2,221	0.225	2,484	0.202	1,792	0.295	2,230
3	0.359	3,095	0.452	3,235	0.328	3,619	0.294	2,610	0.430	3,248
5	0.591	5,099	0.745	5,331	0.541	5,962	0.484	4,300	0.709	5,352
7.5	0.876	7,561	1.106	7,906	0.803	8,842	0.719	6,377	1.051	7,938
10	1.155	9,969	1.458	10,423	1.058	11,658	0.947	8,408	1.386	10,465
15	1.704	14,707	2.150	15,377	1.561	17,198	1.398	12,404	2.045	15,439
20	2.272	19,610	2.867	20,503	2.081	22,931	1.863	16,539	2.727	20,586
25	2.819	24,325	3.557	25,433	2.582	28,445	2.311	20,516	3.382	25,536
30	3.357	28,969	4.236	30,289	3.075	33,876	2.753	24,432	4.028	30,411
40	4.447	38,377	5.611	40,124	4.073	44,876	3.647	32,366	5.336	40,286
50	5.558	47,971	7.014	50,156	5.091	56,095	4.558	40,458	6.670	50,357
60	6.627	57,196	8.363	59,801	6.070	66,883	5.435	48,238	7.953	60,041
75	8.240	71,115	10.398	74,354	7.548	83,159	6.758	59,978	9.888	74,653
100	10.987	94,820	13.864	99,138	10.063	110,879	9.010	79,970	13.184	99,537

**Table 2-52: Deemed Energy and Demand Savings Values for Inlet Guide Vane Part-Load Fan Control by Climate Region**

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Hospital & Healthcare										
1	0.021	397	0.027	420	0.019	350	0.017	320	0.027	423
2	0.041	780	0.053	825	0.038	687	0.033	629	0.053	832
3	0.059	1,137	0.078	1,202	0.055	1,001	0.048	916	0.078	1,211
5	0.098	1,873	0.128	1,981	0.090	1,649	0.079	1,509	0.128	1,996
7.5	0.145	2,778	0.190	2,938	0.134	2,445	0.117	2,238	0.190	2,960
10	0.191	3,663	0.251	3,873	0.177	3,224	0.155	2,950	0.251	3,902
15	0.282	5,403	0.370	5,714	0.261	4,756	0.228	4,352	0.370	5,757
20	0.376	7,204	0.494	7,619	0.348	6,342	0.304	5,803	0.493	7,676
25	0.466	8,937	0.612	9,451	0.431	7,867	0.377	7,199	0.612	9,521
30	0.555	10,643	0.729	11,255	0.513	9,368	0.449	8,573	0.729	11,339
40	0.736	14,099	0.966	14,910	0.680	12,410	0.595	11,357	0.966	15,021
50	0.920	17,624	1.207	18,637	0.850	15,513	0.744	14,196	1.207	18,777
60	1.097	21,013	1.440	22,221	1.014	18,496	0.887	16,926	1.439	22,387
75	1.363	26,127	1.790	27,629	1.260	22,998	1.102	21,045	1.789	27,836
100	1.818	34,836	2.387	36,839	1.680	30,664	1.470	28,060	2.386	37,114
Office - Large										
1	0.021	187	0.027	198	0.019	161	0.017	146	0.027	200
2	0.041	368	0.053	389	0.038	316	0.033	287	0.053	392
3	0.059	536	0.078	567	0.055	461	0.048	418	0.078	571
5	0.098	883	0.128	934	0.090	759	0.079	688	0.128	941
7.5	0.145	1,310	0.190	1,385	0.134	1,126	0.117	1,020	0.190	1,396
10	0.191	1,727	0.251	1,826	0.177	1,485	0.155	1,345	0.251	1,841
15	0.282	2,548	0.370	2,694	0.261	2,190	0.228	1,985	0.370	2,716
20	0.376	3,398	0.494	3,592	0.348	2,920	0.304	2,646	0.493	3,621
25	0.466	4,215	0.612	4,455	0.431	3,623	0.377	3,283	0.612	4,492
30	0.555	5,019	0.729	5,306	0.513	4,314	0.449	3,909	0.729	5,349
40	0.736	6,649	0.966	7,029	0.680	5,715	0.595	5,179	0.966	7,086
50	0.920	8,311	1.207	8,786	0.850	7,144	0.744	6,474	1.207	8,858
60	1.097	9,910	1.440	10,475	1.014	8,518	0.887	7,719	1.439	10,561
75	1.363	12,321	1.790	13,024	1.260	10,591	1.102	9,597	1.789	13,131
100	1.818	16,428	2.387	17,366	1.680	14,121	1.470	12,796	2.386	17,508

HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Office - Small										
1	0.017	169	0.023	179	0.016	145	0.014	131	0.023	181
2	0.034	333	0.044	352	0.031	284	0.027	257	0.045	355
3	0.049	485	0.065	513	0.045	414	0.039	374	0.065	517
5	0.081	799	0.106	845	0.074	681	0.065	617	0.107	852
7.5	0.120	1,185	0.158	1,254	0.110	1,011	0.096	915	0.159	1,263
10	0.158	1,562	0.208	1,653	0.145	1,332	0.127	1,206	0.210	1,666
15	0.234	2,304	0.307	2,439	0.214	1,966	0.187	1,779	0.310	2,458
20	0.312	3,073	0.409	3,252	0.285	2,621	0.249	2,372	0.413	3,277
25	0.386	3,811	0.508	4,034	0.354	3,251	0.309	2,943	0.513	4,065
30	0.460	4,539	0.605	4,804	0.422	3,872	0.368	3,505	0.611	4,841
40	0.610	6,013	0.801	6,363	0.559	5,129	0.488	4,643	0.809	6,412
50	0.762	7,516	1.001	7,954	0.698	6,411	0.609	5,803	1.011	8,016
60	0.909	8,962	1.194	9,484	0.833	7,644	0.727	6,919	1.206	9,557
75	1.130	11,143	1.484	11,792	1.035	9,504	0.903	8,603	1.499	11,883
100	1.507	14,857	1.979	15,723	1.380	12,672	1.205	11,471	1.999	15,844
Education - K-12										
1	0.007	173	0.010	182	0.006	147	0.005	133	0.010	184
2	0.014	340	0.019	358	0.011	289	0.011	262	0.020	361
3	0.020	496	0.027	521	0.017	420	0.015	381	0.029	527
5	0.033	817	0.045	859	0.027	693	0.026	628	0.047	868
7.5	0.049	1,212	0.067	1,274	0.041	1,027	0.038	932	0.070	1,287
10	0.064	1,597	0.088	1,680	0.054	1,354	0.050	1,228	0.092	1,696
15	0.095	2,357	0.130	2,479	0.079	1,998	0.074	1,812	0.136	2,502
20	0.126	3,142	0.173	3,305	0.106	2,664	0.098	2,416	0.182	3,337
25	0.157	3,898	0.215	4,099	0.131	3,304	0.122	2,997	0.226	4,139
30	0.187	4,642	0.256	4,882	0.156	3,935	0.145	3,570	0.269	4,929
40	0.247	6,149	0.339	6,467	0.207	5,213	0.192	4,729	0.356	6,530
50	0.309	7,687	0.423	8,084	0.258	6,516	0.240	5,911	0.445	8,162
60	0.369	9,165	0.505	9,639	0.308	7,769	0.286	7,048	0.530	9,732
75	0.458	11,395	0.628	11,984	0.383	9,660	0.356	8,763	0.659	12,100
100	0.611	15,193	0.837	15,979	0.511	12,880	0.474	11,684	0.879	16,133
Education - College & University										
1	0.021	194	0.027	205	0.019	167	0.017	151	0.027	207
2	0.041	382	0.053	403	0.038	327	0.033	296	0.053	407
3	0.059	556	0.078	588	0.055	476	0.048	432	0.078	593
5	0.098	916	0.128	968	0.090	785	0.079	711	0.128	977
7.5	0.145	1,359	0.190	1,436	0.134	1,164	0.117	1,055	0.190	1,449
10	0.191	1,792	0.251	1,893	0.177	1,535	0.155	1,390	0.251	1,910
15	0.282	2,643	0.370	2,793	0.261	2,264	0.228	2,051	0.370	2,818
20	0.376	3,524	0.494	3,724	0.348	3,019	0.304	2,735	0.493	3,757
25	0.466	4,372	0.612	4,619	0.431	3,745	0.377	3,393	0.612	4,660
30	0.555	5,206	0.729	5,501	0.513	4,460	0.449	4,040	0.729	5,550
40	0.736	6,897	0.966	7,288	0.680	5,908	0.595	5,352	0.966	7,352
50	0.920	8,621	1.207	9,110	0.850	7,385	0.744	6,690	1.207	9,190
60	1.097	10,279	1.440	10,861	1.014	8,806	0.887	7,977	1.439	10,957
75	1.363	12,780	1.790	13,505	1.260	10,949	1.102	9,918	1.789	13,624
100	1.818	17,040	2.387	18,006	1.680	14,598	1.470	13,225	2.386	18,165
Retail										



HP	Dallas		El Paso		Houston		Corpus Christi		Amarillo	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
1	0.021	234	0.027	247	0.019	202	0.017	184	0.027	250
2	0.041	460	0.053	485	0.038	398	0.033	362	0.053	491
3	0.059	670	0.078	707	0.055	579	0.048	527	0.078	716
5	0.098	1,104	0.128	1,164	0.090	954	0.079	869	0.128	1,179
7.5	0.145	1,637	0.190	1,727	0.134	1,415	0.117	1,289	0.190	1,749
10	0.191	2,159	0.251	2,277	0.177	1,866	0.155	1,699	0.251	2,306
15	0.282	3,185	0.370	3,359	0.261	2,752	0.228	2,506	0.370	3,402
20	0.376	4,247	0.494	4,478	0.348	3,670	0.304	3,342	0.493	4,536
25	0.466	5,268	0.612	5,555	0.431	4,552	0.377	4,145	0.612	5,626
30	0.555	6,273	0.729	6,616	0.513	5,422	0.449	4,937	0.729	6,700
40	0.736	8,311	0.966	8,764	0.680	7,182	0.595	6,540	0.966	8,876
50	0.920	10,388	1.207	10,955	0.850	8,978	0.744	8,175	1.207	11,095
60	1.097	12,386	1.440	13,062	1.014	10,704	0.887	9,747	1.439	13,229
75	1.363	15,400	1.790	16,241	1.260	13,309	1.102	12,118	1.789	16,449
100	1.818	20,533	2.387	21,655	1.680	17,745	1.470	16,158	2.386	21,931
Restaurant - Fast Food										
1	0.021	292	0.027	308	0.019	253	0.017	231	0.027	312
2	0.041	573	0.053	605	0.038	497	0.033	453	0.053	612
3	0.059	835	0.078	882	0.055	725	0.048	660	0.078	892
5	0.098	1,376	0.128	1,453	0.090	1,194	0.079	1,088	0.128	1,469
7.5	0.145	2,040	0.190	2,154	0.134	1,770	0.117	1,613	0.190	2,178
10	0.191	2,690	0.251	2,840	0.177	2,334	0.155	2,126	0.251	2,872
15	0.282	3,969	0.370	4,190	0.261	3,443	0.228	3,137	0.370	4,237
20	0.376	5,292	0.494	5,587	0.348	4,591	0.304	4,183	0.493	5,650
25	0.466	6,564	0.612	6,930	0.431	5,695	0.377	5,189	0.612	7,008
30	0.555	7,817	0.729	8,253	0.513	6,782	0.449	6,179	0.729	8,346
40	0.736	10,356	0.966	10,933	0.680	8,985	0.595	8,186	0.966	11,056
50	0.920	12,945	1.207	13,667	0.850	11,231	0.744	10,232	1.207	13,820
60	1.097	15,434	1.440	16,295	1.014	13,391	0.887	12,200	1.439	16,478
75	1.363	19,190	1.790	20,260	1.260	16,650	1.102	15,169	1.789	20,488
100	1.818	25,587	2.387	27,014	1.680	22,200	1.470	20,225	2.386	27,317
Restaurant - Sit down										
1	0.021	223	0.027	235	0.019	253	0.017	178	0.027	238
2	0.041	438	0.053	462	0.038	497	0.033	350	0.053	468
3	0.059	638	0.078	673	0.055	725	0.048	510	0.078	682
5	0.098	1,051	0.128	1,109	0.090	1,194	0.079	840	0.128	1,123
7.5	0.145	1,559	0.190	1,644	0.134	1,770	0.117	1,246	0.190	1,666
10	0.191	2,055	0.251	2,168	0.177	2,334	0.155	1,642	0.251	2,196
15	0.282	3,032	0.370	3,198	0.261	3,443	0.228	2,423	0.370	3,240
20	0.376	4,043	0.494	4,264	0.348	4,591	0.304	3,230	0.493	4,320
25	0.466	5,015	0.612	5,289	0.431	5,695	0.377	4,007	0.612	5,359
30	0.555	5,972	0.729	6,299	0.513	6,782	0.449	4,772	0.729	6,382
40	0.736	7,912	0.966	8,344	0.680	8,985	0.595	6,321	0.966	8,454
50	0.920	9,890	1.207	10,430	0.850	11,231	0.744	7,902	1.207	10,568
60	1.097	11,792	1.440	12,436	1.014	13,391	0.887	9,421	1.439	12,600
75	1.363	14,661	1.790	15,462	1.260	16,650	1.102	11,714	1.789	15,666
100	1.818	19,548	2.387	20,616	1.680	22,200	1.470	15,619	2.386	20,888

## **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
- 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/](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 2-53: Nonresidential HVAC-VFD History**

TRM version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	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	Added reference for % power and corrected signs for variables in Equation 36.

## 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<sup>85</sup>

**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<sup>86</sup>.
- 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.

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<sup>85</sup> 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.

<sup>86</sup> As defined in proposed ASTM 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.<sup>87</sup>

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 2-56 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<sup>88</sup> 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 2-55.

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 2-54. 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		8.9 EER
	11.25 to 20		8.3 EER
	20 to 63.33		8.3 EER
	≥ 63.3		8.0 EER
Unitary Heat Pump (cooling)	< 5.42	Split	10.0 SEER
		Packaged	9.7 SEER
	5.42 to 11.25		8.9 EER
	11.25 to 20		8.3 EER
	20 to 63.33		8.3 EER

<sup>87</sup> ENERGY STAR® Certified Roofs. <http://www.energystar.gov/productfinder/product/certified-roof-products/>. Accessed 08/15/2016.

<sup>88</sup> 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
	$\geq 63.3$		8.5 EER
Unitary Heat Pump (heating)	$< 5.42$	Split	6.8 HSPF
		Packaged	6.6 HSPF
	5.4 to 11.25		3.0 COP
Air Cooled Chiller	$\geq 11.25$		2.9 COP
	$\leq 150$	Including Condenser	2.7 COP
	$\geq 150$	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	$\leq 0.5$	With Louvered Sides	8.0 EER
	<u>0.5 to 0.67</u>		8.5 EER
	<u>0.67 to 1.17</u>		9.0 EER
	<u>1.17 to 1.66</u>		8.8 EER
	$\geq 1.67$		8.2 EER
	$\leq 0.5$	Without Louvered Sides	8.0 EER
	<u>0.5 to 1.67</u>		8.5 EER
	$\geq 1.67$		8.2 EER

System Type	Capacity [Tons]	Other Qualifier	Efficiencies
Room Heat Pump (Cooling)	$\leq 1.67$	With Louvered Sides	8.5 EER
	$\geq 1.67$		8.5 EER
	$\leq 1.17$	Without Louvered Sides	8.0 EER
	$\geq 1.17$		8.0 EER
Room Heat Pump (Heating)	$\leq 1.67$	With Louvered Sides	8.5 HSPF
	$\geq 1.67$		8.5 HSPF
	$\leq 1.17$	Without Louvered Sides	8.0 HSPF
	$\geq 1.17$		8.0 HSPF
Packaged Terminal Air Conditioner	$\leq 2.00$		10.9 – 0.213 * CAP EER
Packaged Terminal Heat Pump (Cooling)	$\leq 2.00$		10.8 – 0.213 * CAP EER
Packaged Terminal Heat Pump (Heating)	$\leq 2.00$		2.9 – 0.026 * CAP COP
Electric Resistance Heat	<u>All</u>		1 COP
Gas Heat	<u>All</u>		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.

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

Equation 44

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

Equation 45

Where:

- A = Roof Area [ft<sup>2</sup>]
- h<sub>o</sub> = coefficient of heat transfer by long-wave radiation and convection at outer surface [Btu/hr-°F-ft<sup>2</sup>], 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-°F-ft<sup>2</sup>/Btu]. See Table 2-56.



$h_{in,air}$	=	The heat transfer coefficient for indoor air [Btu/hr-°F-ft <sup>2</sup> ], assumed to be 1.68.
$\rho$	=	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-ft <sup>2</sup> ]. See Table 2-57.
$\Sigma E_{t,l}$	=	The sum of the hourly solar radiation incident during a cooling period [Btu/hr-ft <sup>2</sup> ]. See Table 2-57.
$n$	=	The number of total cooling hours when solar radiation exist = 636 <sup>89</sup>
$\varepsilon$	=	Emittance of surface for solar radiation
$\Delta R$	=	Difference between long-wave radiation incident on surface from sky and radiation emitted by blackbody at outdoor air temperature [Btu/hr-ft <sup>2</sup> ], assumed to be 20.
$t_o$	=	Outdoor air temperature
$t_{in}$	=	Indoor air temperature, assumed to be 75°F

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.

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

**Equation 46**

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

**Equation 47**

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

**Equation 48**

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

**Equation 49**

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<sup>89</sup> Peak hours are set as the months of May to September, 1pm to 7pm weekdays.

Where:

$A$	=	Roof Area [ft <sup>2</sup> ]
$\Delta U$	=	Difference in pre- and post-retrofit overall coefficient of heat transfer
$\Delta Q$	=	Heat transfer [Btu/hr]
$\Delta T$	=	Temperature difference [°F]
$R_1$	=	Thermal resistance pre-retrofit
$R_2$	=	Thermal resistance post-retrofit
$\alpha$	=	Absorptance of surface for solar radiation <sup>90</sup>
$h_o$	=	Coefficient of heat transfer by long-wave radiation and convection at outer surface <sup>90</sup>
$I_{DT}$	=	Hourly solar radiation incident on surface <sup>90</sup> , deemed at 1,122
$\epsilon$	=	Hemispherical emittance of the surface, assumed to be 1.0
$T_{oa}$	=	Outdoor air temperature [°F]
$T_{sol}$	=	Sol-air temperature [°F] <sup>91</sup>
$T_{space}$	=	Indoor temperature [°F]
$\Delta R$	=	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:

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<sup>90</sup>  $I_{DT} = \frac{\alpha}{h_o} \times 1.15$ . 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 32° north latitude as described in 1993 ASHRAE Fundamentals, Chapter 27, Tables 14.

<sup>91</sup> 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.

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

**Equation 50**

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

**Equation 51**

$$\text{Total Energy Savings}^{92} = \text{Cooling Energy Savings} - \text{Heating Energy Penalty}$$

**Equation 52**

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

**Equation 53**

Where:

<i>EER</i>	=	Energy efficiency ratio of the buildings air conditioner [Btu/W-hr]
<i>E<sub>t,cooling</sub></i>	=	Total solar radiation incident on the surface throughout the time when a building is in cooling mode [Btu/ft <sup>2</sup> ]
<i>ρ<sub>new</sub></i>	=	Reflectance (at three years) of the new roof membrane
<i>ρ<sub>old</sub></i>	=	Reflectance of the original roof membrane
<i>R<sub>ins</sub></i>	=	R-value of the roof insulation [h-ft <sup>2</sup> -°F/Btu]
<i>R<sub>cons</sub></i>	=	R-value of the roof construction [h-ft <sup>2</sup> -°F/Btu]
<i>R<sub>airfilm</sub></i>	=	R-value of the air film [h-ft <sup>2</sup> -°F/Btu]
<i>h<sub>o</sub></i>	=	Coefficient of heat transfer by long-wave radiation and convection at outer surface
0.001	=	Conversion kWh per Watt-Hr
<i>COP</i>	=	Coefficient of performance of building's electric heating system
<i>E<sub>t,heating</sub></i>	=	Total solar radiation incident on the surface throughout the time when a building is in heating mode [Btu/ft <sup>2</sup> ]
3412	=	Conversion Btu per kWh

<sup>92</sup> For buildings with electric resistance heating.

$$I_t = \text{Total solar radiation incident on the surface during the summer peak hour [Btu/ft}^2\text{-hr]}$$

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

**Table 2-55: Reflectance and Emissivity of Surfaces**

Roofing Type	New Reflectance	Aged Reflectance <sup>93</sup>	Emissivity
Black EPDM <sup>94</sup>	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 <sup>95</sup>	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

<sup>93</sup> Calculated based on Aged Reflectance=0.2+β (New Reflectance – 0.20), where β=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>

<sup>94</sup> 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/>

<sup>95</sup> Last 3 in list from Lawrence Berkley National Laboratory. <http://energy.lbl.gov/coolroof/membrane.htm#membrane>

**Table 2-56: R-Values of Different Material [hr-ft<sup>2</sup>-°F/Btu]<sup>96</sup>**

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
		Polystyrene Bead Board	3.57
		Polystyrene Composite Board	3.32
Ceiling Material	R-Value	Rock Wool	3.10
Acoustic Tile	0.06	Vermiculite	2.13
Drywall Finish	0.45	Cork	3.57
Plaster Finish	0.45		
Plenum	R-Value		
Yes	0.61		
No	0.00		

**Table 2-57: TMY2 Solar Data**

Climate Zone	Peak Total Solar Radiation Incident [Btu/hr-ft <sup>2</sup> ]	Total Solar Radiation Incident [Btu/ft <sup>2</sup> ]
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

<sup>96</sup> 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 2-58: Deemed Values used in Algorithm for El Paso Electric<sup>97</sup>**

Variable	Assumed Value
EER	8.5 <sup>98</sup>
COP	1.0 <sup>99</sup>
$\rho_{\text{new}}$	0.7 <sup>100</sup>
$\rho_{\text{old}}$	0.062 <sup>101</sup>
$E_{t,\text{cooling}}$	469,199 <sup>102</sup>
$E_{t,\text{heating}}$	185,347 <sup>102</sup>
$I_t$	217 <sup>103</sup>
$R_{\text{ins}}$	16 <sup>104</sup>
$R_{\text{cons}}$	2 <sup>105</sup>
$R_{\text{airfilm}}$	0.92 <sup>106</sup>
$h_o$	3 <sup>107</sup>

## Deemed Energy and Demand Savings Tables

The resulting deemed energy and demand savings values are presented in Table 2-59. 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 2-59: Cool Roof Deemed Savings for El Paso Electric**

Region	Electric A/C and Gas Heat [kWh/ft <sup>2</sup> ]	Electric A/C and Electric Resistance Heat [kWh/ft <sup>2</sup> ]	Summer Peak (Electric A/C) [kW/ft <sup>2</sup> ]	Winter Peak (Electric Resistance Heat) [kW/ft <sup>2</sup> ]
West	0.6205	0.0099	0.0003	0.00

<sup>97</sup> All values and their sources were found in Docket No. 41070.

<sup>98</sup> Federal minimum for split and packaged systems, 11.25-20 tons from January 1<sup>st</sup>, 1994 through December 31<sup>st</sup>, 2009.

<sup>99</sup> Value for electric resistance heat.

<sup>100</sup> Minimum required by EPE Cool Roof Program.

<sup>101</sup> 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.

<sup>102</sup> Total global horizontal irradiance when temperature is over 65°F (typical building's thermal balance point) per El Paso TMY3 file.

<sup>103</sup> Total global horizontal irradiance during summer peak hour per El Paso TMY3 file.

<sup>104</sup> IECC 2000 Table 802.2(17).

<sup>105</sup> Typical value.

<sup>106</sup> ASHRAE Fundamentals 2006 27.2.

<sup>107</sup> 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](http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf). Accessed 09/10/2013
- DEER 2014 EUL update

### Document Revision History

**Table 2-60: Nonresidential Cool Roof History**

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	Clarified that reflectance is three years basis. Table 2-56 through Table 2-59: Rounded off values, too many insignificant digits.
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials to Table 2-56. Added new high performance roof calculator for use in determining ENERGY STAR® roof savings.



## 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 2-61 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.*<sup>108</sup> 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

$$\begin{aligned} \text{Demand Savings}_o \text{ [kW]} \\ = \frac{A_{film,o} \times SHGF_o \times (SC_{pre,o} - SC_{post,o})}{3413 \times COP} \end{aligned} \quad \text{Equation 54}$$

$$\text{Peak Demand Savings [kW]} = \text{Demand Savings}_{o,max} \quad \text{Equation 55}$$

$$\begin{aligned} \text{Energy Savings}_o \text{ [kWh]} \\ = \frac{A_{film,o} \times SHG_o \times (SC_{pre,o} - SC_{post,o})}{3413 \times COP} \end{aligned} \quad \text{Equation 56}$$

$$\text{Energy Savings [kWh]} = \sum \text{Energy Savings}_o \quad \text{Equation 57}$$

Where:

<i>Demand Savings</i>	=	<i>Peak demand savings per window orientation</i>
<i>Energy Savings</i>	=	<i>Energy savings per window orientation</i>
<i>A<sub>film,o</sub></i>	=	<i>Area of window film applied to orientation [ft<sup>2</sup>]</i>
<i>SHGF<sub>o</sub></i>	=	<i>Peak solar heat gain factor for orientation of interest [Btu/hr-ft<sup>2</sup>-year]. See Table 2-61.</i>
<i>SHG<sub>o</sub></i>	=	<i>Solar heat gain for orientation of interest [Btu/ ft<sup>2</sup>-year]. See Table 2-61.</i>
<i>SC<sub>pre</sub></i>	=	<i>Shading coefficient for existing glass/interior-shading device. See Table 2-62.</i>
<i>SC<sub>post</sub></i>	=	<i>Shading coefficient for new film/interior-shading device, from manufacturer specs</i>

<sup>108</sup> 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](http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf)

*COP* = Cooling equipment COP based on Table 2-63 or actual COP equipment, whichever is greater

3413 = Conversion factor [Btu/kW]

**Table 2-61: Solar Heat Gain Factors<sup>109</sup>**

Orientation	Solar Heat Gain {SHG} [Btu/ft <sup>2</sup> -year]	Peak Hour Solar Heat Gain (SHGF) [Btu/hr-ft <sup>2</sup> -year]				
		Zone 1 <sup>110</sup>	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

<sup>109</sup> Values are taken from the 1997 ASHRAE Fundamentals, Chapter 29 Table 17, based on the amount of solar radiation transmitted through single-pane clear glass for a cloudless day at 32°N Latitude for the 21<sup>st</sup> day of each month by hour of day and solar orientation. The SHG values listed above have been aggregated into daily totals for weekdays during the months of April through October.

<sup>110</sup> 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.

**Table 2-62: Recommended Shading Coefficient (SC) for Different Pre-Existing Shade Types**

Shading Type	Shading Coefficient	Source <sup>111</sup>
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

**Table 2-63: Recommended COP for Different HVAC System Types**

HVAC Type	COP	Source <sup>112</sup>
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 w/o 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 w/ 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

<sup>111</sup> Table numbers and shading coefficients provided are from 1997 ASHRAE Fundamentals Handbook, Chapter 29.

<sup>112</sup> Table numbers and COP provided are from ASHRAE 90.1-1999.

## 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
- DEER 2014 EUL update

### Document Revision History

Table 2-64: Nonresidential Window Treatment History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	Eliminated east-facing windows from consideration for energy savings.
v3.0	04/10/2015	References to EPE-specific deemed savings removed (EPE to adopt methods used by the other utilities). Demand savings: Frontier updated to incorporate new peak demand definition. Provided deemed values for shading coefficients and HVAC efficiencies. SHGF: Used CZ2 savings for CZ1 until better values can be developed.
v4.0	10/10/2016	No 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  $\geq 5$  and  $\leq 20113$ .

- 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.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.<sup>114</sup>

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<sup>113</sup> 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 26<sup>th</sup>, 2015.

<sup>114</sup> 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](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:

- 2/3-sized combination ovens,
- Dual-fuel heat source combination ovens,
- Gas combination ovens, and
- Electric combination ovens with a pan capacity < 5 and >20.

## Baseline Condition

Eligible baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity  $\geq 5$  and  $\leq 20$ .

## 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 2-65 below.

**Table 2-65: Cooking Energy-Efficiency and Idle Energy Rate Requirements<sup>115</sup>**

Operation	Idle Rate (kW)	Cooking Energy Efficiency (%)
Steam Mode	$\leq 0.133P + 0.6400$	$\geq 55$
Convection Mode	$\leq 0.080P + 0.4989$	$\geq 76$

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

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

$$\text{Energy Savings [kWh]} = kWh_{base} - kWh_{post} \quad \text{Equation 58}$$

$$\text{Peak Demand [kW]} = \frac{\Delta kWh}{t_{hrs} \times t_{days}} \times CF \quad \text{Equation 59}$$

$$kWh_{base} = kWh_{conv} + kWh_{st} \quad \text{Equation 60}$$

$$kWh_{post} = kWh_{conv} + kWh_{st} \quad \text{Equation 61}$$

<sup>115</sup> ENERGY STAR®. Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment. Calculator: [http://www.energystar.gov/buildings/sites/default/uploads/files/commercial\\_kitchen\\_equipment\\_calculator.xlsx](http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx)

$kWh_{conv}$  and  $kWh_{st}$  are each calculated the same for both the base (baseline) and post (ENERGY STAR®) cases, as shown in Equation 62, except they require their respective  $\eta$  (Cooking Efficiencies),  $E_{idle}$  (Idle Energy Rates) and  $C_{cao}$  (Production Capacity) relative to Convection and Steam Modes as seen in Table 2-66.

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

**Equation 62**

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 2-66)
$E_{idle}$	=	Idle energy rate [W]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66)
$\eta_{cooking}$	=	Cooking energy efficiency [%]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66)
$CCap$	=	Production capacity per pan [lb/hr]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66)
1000	=	Wh to kWh conversion



**Table 2-66: Deemed Variables for Energy and Demand Savings Calculations**

Parameter	Convection-Mode		Steam-Mode	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
kWh <sub>base</sub>	See Table 2-67			
kWh <sub>post</sub>				
W <sub>food</sub>	200			
t <sub>hours</sub>	12			
t <sub>Days</sub>	365			
N <sub>pans</sub>	10			
CF <sub>116</sub>	0.92			
E <sub>food</sub>	73.2		30.8	
η <sub>cooking</sub>	72%	76%	49%	55%
Idle <sub>B</sub>	1,320	1,299	5,260	1,970
CC <sub>Cap</sub>	79	119	126	177

## Deemed Energy and Demand Savings Tables

The energy and demand savings of High Efficiency Combination Ovens in Table 2-67 are calculated in the Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment using the default parameters shown above in Table 2-66.

**Table 2-67: Deemed Energy and Demand Savings Values<sup>117</sup>**

kWh <sub>base</sub>	kWh <sub>post</sub>	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).

<sup>116</sup> California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed July 12, 2012, <http://capabilities.theEM&Vteam.com/CeusWeb/Chart.aspx>.

<sup>117</sup> ENERGY STAR®. Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment Calculator: [http://www.energystar.gov/buildings/sites/default/uploads/files/commercial\\_kitchen\\_equipment\\_calculator.xlsx](http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx). 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**

N/A

### **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 2-68: Nonresidential High-Efficiency Combination Oven History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	Updated previous method based upon the Food Service Technology Center (FSTC) assumptions to an approach using the newly developed ENERGY STAR® Commercial Ovens Program Requirements Version 2.1, which added combination ovens under this version. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	Updated title to reflect ENERGY STAR® measure.
v4.0	10/10/2016	No 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®118.

- **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.<sup>119</sup>

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

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<sup>118</sup> ENERGY STAR® Program Requirements for Commercial Ovens.[https://www.energystar.gov/sites/default/files/specs/private/Commercial\\_Ovens\\_Program\\_Requirements\\_V2\\_1.pdf](https://www.energystar.gov/sites/default/files/specs/private/Commercial_Ovens_Program_Requirements_V2_1.pdf). Accessed January 26<sup>th</sup>, 2015.

<sup>119</sup> 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](http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf). Accessed 04/30/2015.

## 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 2-69 below:

**Table 2-69: 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:

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

Equation 63

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

Equation 64

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

Equation 65

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

Equation 66

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 2-70: Deemed Variables for Energy and Demand Savings Calculations<sup>120</sup>**

Variable	Full-Size	Half-Size
LB <sup>122</sup>	100	
Days	365	
CF <sup>121</sup>	0.92	
$E_{food}$ <sup>122</sup>	73.2	
$EFF_{base}$ <sup>122</sup>	65%	68%
$EFF_{HE}$ <sup>122</sup>	71%	
$IDLE_{base}$ <sup>122</sup>	2,000	1,030
$IDLE_{HE}$ <sup>122</sup>	1,600	1,000
$T_{on}$	12	
$PC_{base}$ <sup>122</sup>	90	45
$PC_{HE}$ <sup>122</sup>	90	50

<sup>120</sup> 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.

<sup>121</sup> 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>.

<sup>122</sup> 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 2-71: 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® research122 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

N/A

## Relevant Standards and Reference Sources

- ENERGY STAR® requirements for Commercial Ovens.  
[http://www.energystar.gov/index.cfm?c=ovens.pr\\_crit\\_comm\\_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 2-72: 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	No revisions
v3.0	04/10/2015	Updated to newer ENERGY STAR® Commercial Ovens Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	Updated title to reflect En ENERGY STAR® Measure.
v4.0	10/10/2016	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 2-73:

- 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.<sup>123</sup>

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<sup>123</sup> 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](http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf).  
Accessed 04/30/2015.



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 2-73: 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 10 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.

## Baseline Condition

Baseline equipment is either a low-temperature<sup>124</sup> or high temperature<sup>125</sup> machine as defined by Table 2-73, 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.

<sup>124</sup> Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

<sup>125</sup> High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

## 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 2-74 below.

**Table 2-74: High-Efficiency Requirements for Commercial Dishwashers<sup>126</sup>**

Machine Type	Low Temperature Efficiency Requirements		High Temperature Efficiency Requirements	
	Idle Energy Rate [kW]	Water Consumption [gal/rack]	Idle Energy Rate [kW]	Water Consumption [gal/rack]
Under Counter	≤ 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 <sup>127</sup>	≤ 1.20	≤ 0.58 <sup>127</sup>

## 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]*

$$= (V_{waterB} - V_{waterP}) \times \left( \frac{\Delta T_{DHW} + \Delta T_{boost}}{\eta_{DHW}} \right) \times \rho_{water} \times C_p \times \frac{1 W}{3413 kBtu/h} + (Idle_{base} - Idle_{post})$$

$$\times \left( t_{days} \times t_{hours} - t_{days} \times N_{racks} \times \frac{WashTime}{60} \right)$$

**Equation 67**

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

**Equation 68**

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

**Equation 69**

<sup>126</sup> Table 2-74 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](https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Dishwasher_Program_Requirements.pdf).

<sup>127</sup> Water Consumption for Pot, Pan and Utensil is specified in gallons per square foot rather than gallons per rack.

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

Equation 70

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]
$\rho_{water}$	=	Density of water [lbs/gallon]
$C_p$	=	Specific heat of water [Btu/lb °F]
$\Delta T_{DHW}$	=	Inlet water temperature increase for building water heater [°F]
$\eta_{DHW}$	=	Building electric water heater and booster heater efficiency [%]
$\Delta T_{boost}$	=	Inlet water temperature for booster water heater [°F]
$IDLE_{base}$	=	Baseline Idle Energy Rate [kW]
$IDLE_{post}$	=	High Efficiency Idle Energy Rate [kW]
$WashTime$	=	Wash time per Rack

**Table 2-75: Deemed Variables for Energy and Demand Savings Calculations**

Inputs	Under Counter	Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
$t_{\text{days}}^{128}$	365				
$t_{\text{hours}}^5$	18				
CF	0.97				
$\rho_{\text{water}}$	8.208 [lbs/gallon]				
$C_p$	1.0 [Btu/lb °F]				
$\Delta T_{\text{DHW}}^4$	Gas Hot Water Heaters: 0°F Electric Hot Water Heaters: 70 °F				
$\eta_{\text{DHW}}$	98%				
$\Delta T_{\text{boost}}$	Gas Booster Heaters: 0 °F Electric Booster Heaters: 40 °F				
$\eta_{\text{boost}}$	98%				
<b>Low Temperature Units</b>					
$N_{\text{racks}}$	75	280	400	600	N/A
$V_{\text{galrackB}}$	1.73	2.10	1.31	1.04	N/A
$V_{\text{galrackP}}$	1.19	1.18	0.79	0.54	N/A
$\text{IDLE}_{\text{base}}$	0.50	0.60	1.60	2.00	N/A
$\text{IDLE}_{\text{post}}$	0.50	0.60	1.50	2.00	N/A
WashTime	2.0	1.5	0.3	0.3	N/A
<b>High Temperature Units</b>					
$N_{\text{racks}}$	75	280	400	600	280
$V_{\text{galrackB}}$	1.09	1.29	0.87	0.97	0.70
$V_{\text{galrackP}}$	0.86	0.89	0.70	0.54	0.58
$\text{IDLE}_{\text{base}}$	0.76	0.87	1.93	2.59	1.20
$\text{IDLE}_{\text{post}}$	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 2-76: 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 w/ 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 w/ 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

N/A

<sup>128</sup> ENERGY STAR®. "Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment." Accessed 12/16/2013.

<sup>129</sup> California End Use Survey (CEUS), Building workbooks with load shapes by end use. <http://capabilities.theEM&Vteam.com/CeusWeb/Chart.aspx>. Accessed 07/12/12.

## 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](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](http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx). Accessed 01/27/2015.

## Document Revision History

**Table 2-77: 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	Update savings based on newest version of ENERGY STAR® deemed input variables.
v2.1	01/30/2015	Corrections to Water Use per Rack in Table 2-74.
v3.0	04/30/2015	Aligned calculation approach with ENERGY STAR® Commercial Dishwashers Program Requirements Version 2.0. Simplified methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	Added high-efficiency requirements for pots, pans, and utensils.

## 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.<sup>130</sup> Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.<sup>131</sup>

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

- Dual function equipment,
- Heated transparent merchandising cabinets, and
- Drawer warmers

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<sup>130</sup> 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.

<sup>131</sup> 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](http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf). Accessed 04/30/2015.

## 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<sup>3</sup> for all equipment sizes.

## High-Efficiency Condition

Eligible equipment are set by ENERGY STAR® and based on the cabinet's interior volume. Table 2-78 summarizes Idle Energy Rates per ENERGY STAR® Version 2.0:

**Table 2-78: Maximum Idle Energy Rate Requirements ENERGY STAR® Qualification**

Product Category	Product Interior Volume [ft <sup>3</sup> ]	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 71

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

Equation 72

Where:

$E_{IdleB}$  = Baseline idle energy rate [W]. See Table 2-79

$E_{IdleP}$  = Idle energy rate after installation [W]. See Table 2-79

V = Product Interior Volume [ft<sup>3</sup>]

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

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

CF = Peak coincidence factor



**Table 2-79: Equipment Operating Hours per Day and Operating Days per Year**

Input Variable	Half-Size	Three-Quarter Size	Full-Size
Product Interior Volume [ft <sup>3</sup> ]	12	20	30
Baseline Equipment Idle Energy Rate [E <sub>idleB</sub> ]	480	800	1,200
Efficient Equipment Idle Energy Rate [E <sub>idleE</sub> ]	258	294	318
Operating Hours per Day [t <sub>hours</sub> ]	15		
Facility Operating Days per Year [t <sub>days</sub> ]	365		
Peak Coincidence Factor <sup>132</sup> [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 2-80: 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<sup>133</sup> 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
- Post-Retrofit Equipment Interior Cabinet Volume
- Post-Retrofit Equipment Size (Half, Three-Quarters, Full)

<sup>132</sup> California End Use Survey (CEUS), Building workbooks with load shapes by end use. <http://capabilities.theEM&Vteam.com/CeusWeb/Chart.aspx>. Accessed 07/12/12.

<sup>133</sup> 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.

## 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\\_HFH\\_C\\_Program\\_Requirements\\_2.0.pdf](https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_HFH_C_Program_Requirements_2.0.pdf). Accessed 01/21/2015
- DEER 2014 EUL update

### Document Revision History

**Table 2-81: 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	No revisions
v3.0	04/10/2015	Updated to newer ENERGY STAR® Hot Food Holding Cabinet Program Requirements Version 2.0. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	No 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®<sup>134</sup>.

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets<sup>135</sup>

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

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

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<sup>134</sup> 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](https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Fryers_Program_Requirements.pdf). Accessed 01/27/15.

<sup>135</sup> 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](http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf). Accessed 04/30/2015.

## Baseline Condition

Baseline fryers can be existing or new electric standard-size fryers  $\geq 12$  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  $\geq 12$  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 2-82.

**Table 2-82: High-Efficiency Requirements for Electric Fryers**

Inputs	Standard	Large-Vat
Cooking energy efficiency	$\geq 80\%$	$\geq 80\%$
Idle energy rate [W]	$\leq 1,000$	$\leq 1,100$

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

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

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

Equation 73

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

Equation 74

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

Equation 75

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

Equation 76

Where:

$kWh_{base}$	=	<i>Baseline annual energy consumption [kWh]</i>
$kWh_{post}$	=	<i>Post annual energy consumption [kWh]</i>
$W_{food}$	=	<i>Pounds of food cooked per day [lb/day]</i>
$E_{food}$	=	<i>ASTM energy to food [Wh/lb]</i>
$\eta_{cookingP}$	=	<i>Post measure cooking energy efficiency [%]</i>
$\eta_{cookingB}$	=	<i>Baseline cooking energy efficiency [%]</i>
$E_{IdleP}$	=	<i>Post measure idle energy rate [W]</i>
$E_{IdleB}$	=	<i>Baseline idle energy rate [W]</i>
$C_{CapP}$	=	<i>Post measure production capacity per pan [lb/hr]</i>
$C_{CapB}$	=	<i>Baseline production capacity per pan [lb/hr]</i>
$t_{Days}$	=	<i>Facility operating days per year [days/yr]</i>
$t_{OpHrs}$	=	<i>Average daily operating hours per day [hr]</i>
$\eta_{PC}$	=	<i>Percent of rated production capacity [%]</i>
$CF$	=	<i>Peak coincidence factor</i>

**Table 2-83: Deemed Variables for Energy and Demand Savings Calculations<sup>136</sup>**

Parameter	Standard-Sized Vat		Large-Vat	
	Baseline	Post Retrofit	Baseline	Post Retrofit
kWh <sub>base</sub>	See Table 2-79			
kWh <sub>post</sub>				
W <sub>food</sub>	150			
t <sub>OpHors</sub>	16		12	
t <sub>days</sub>	365			
CF <sup>137</sup>	0.92			
E <sub>food</sub>	167			
η <sub>cooking</sub>	75%	80%	70%	80%
E <sub>idle</sub>	1,050	1,000	1,350	1,110
C <sub>Cap</sub>	65	70	100	110

## Deemed Energy and Demand Savings Tables

The energy and demand savings of Electric Fryers are deemed values. Table 2-84 provides these deemed values.

**Table 2-84: Deemed Energy and Demand Savings Values by Fryer Type**

Fryer Type	kWh <sub>base</sub>	kWh <sub>post</sub>	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

<sup>136</sup> 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](http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx). Accessed 01/30/2015.

<sup>137</sup> California End Use Survey (CEUS), Building workbooks with load shapes by end use. <http://capabilities.theEM&Vteam.com/CeusWeb/Chart.aspx>. Accessed 07/12/12,

- 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](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 2-85: Nonresidential Electric Fryers History**

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	Updated to newer ENERGY STAR® Electric Fryers Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	No 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 2-87

**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.<sup>138</sup>

### 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.<sup>139</sup>

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<sup>138</sup> Federal standards, based on EPACT 2005 and ASTM F2324 test conditions require a base line of 1.6 GPM.

<sup>139</sup> FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-Rinse Spray Valves.



# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

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

Equation 77

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

Equation 78

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 (°F)
$T_C$	=	Average supply (cold) water temperature (°F)
Days	=	Annual facility operating days for the applications
$C_H$	=	Unit Conversion: 8.33 BTU/ (Gallons-°F)
$C_E$	=	Unit Conversion: 1 BTU = 0.00029308 kWh (1/3412)
$\text{Eff}_E$	=	Efficiency of Electric Water Heater
$P$	=	Hourly Peak Demand as percent of Daily Demand

**Table 2-86: Deemed Variables for Energy and Demand Savings Calculations**

Variable	Deemed Values
F <sub>B</sub>	1.6 <sup>138</sup>
F <sub>P</sub>	1.25 <sup>138,139</sup>
U <sub>B</sub> = U <sub>P</sub>	Fast Food Restaurant: 45 min/day/unit <sup>140</sup> Casual Dining Restaurant: 105 min/day/unit <sup>140</sup> Institutional: 210 min/day/unit <sup>140</sup> Dormitory: 210 min/day/unit <sup>140</sup> K-12 School: 105 min/day/unit <sup>141</sup>
T <sub>H</sub>	120 <sup>142</sup>
T <sub>C</sub>	69 <sup>143</sup>
Days <sup>144</sup>	Fast Food Restaurant: 360 Casual Dining Restaurant: 360 Institutional: 360 Dormitory: 270 K-12 School: 193
C <sub>H</sub>	8.33
C <sub>E</sub>	0.00029
Eff <sub>E</sub>	1.0
P <sup>145</sup>	Fast Food Restaurant: 6.81% Casual Dining Restaurant: 17.36% Institutional: 5.85% Dormitory: 17.36% K-12 School: 11.35%

<sup>140</sup> CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Valves.

<sup>141</sup> 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.

<sup>142</sup> 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.

<sup>143</sup> FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-Rinse Spray Valves. Average calculated input water temperature for five Texas climate zone cities.

<sup>144</sup> For facilities that operate year round: assume operating days of 360 days/year; For schools open weekdays except summer: 360 x (5/7) x (9/12) = 193; For dormitories with few occupants in the summer: 360 x (9/12) = 270.

<sup>145</sup> 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 2-87: 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.<sup>138,143</sup> 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](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

N/A

## Document Revision History

**Table 2-88: 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	Updated the baseline and post-retrofit minimum flow rate values, based on federal standards. Removed reference to a list of qualifying pre-rinse spray valves.
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	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.<sup>146</sup> Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets<sup>147</sup>

### 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 2-89.

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<sup>146</sup> ENERGY STAR® Qualified Commercial Steam Cookers. List Posted on May 15<sup>th</sup>, 2012.  
[http://www.energystar.gov/ia/products/prod\\_lists/Steamers\\_prod\\_list.pdf](http://www.energystar.gov/ia/products/prod_lists/Steamers_prod_list.pdf). Accessed 09/09/2013.

<sup>147</sup> 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](http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf).  
Accessed 04/30/2015.

**Table 2-89: ENERGY STAR® Energy Efficiency and Idle Rate Requirements for Electric Steam Cookers<sup>148</sup>**

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

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

Equation 79

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

Equation 80

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

Equation 81

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

Equation 82

Where:

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

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

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

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

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

<sup>148</sup> ENERGY STAR®. "Commercial Steam Cookers Key Product Criteria." [http://www.energystar.gov/index.cfm?c=steamcookerspr\\_crit\\_steamcookers](http://www.energystar.gov/index.cfm?c=steamcookerspr_crit_steamcookers). Accessed 9/26/11

$\eta_{base}$	=	Baseline Cooking energy efficiency (Differs for boiler-based or steam generator equipment)
$\eta_{post}$	=	Post-Retrofit Cooking energy efficiency
$\eta_{tSteam}$	=	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 2-90: Deemed Variables for Energy and Demand Savings Calculations<sup>149</sup>**

Parameter	Baseline Value	Post Retrofit Value
kWh <sub>base</sub>	See Table 2-91 Table 2-91	
kWh <sub>post</sub>		
W <sub>food</sub>	100	
E <sub>food</sub>	30.8	
$\eta$	Boiler-based Efficiency: 26% Steam-Generator Efficiency: 30%	50%
$\eta_{tSteam}$	40%	
E <sub>IdleRate</sub>	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 <sub>OpHours</sub>	12	
N <sub>OpDays</sub>	365	

<sup>149</sup> 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](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/commercial_kitchen_equipment_calculator.xls).

Parameter	Baseline Value	Post Retrofit Value
CF <sup>150</sup>	0.92	

**Table 2-91: Annual Energy Consumption and Daily Food Cooked<sup>151</sup>**

Steam Cooker Type	N <sub>pan</sub>	kWh <sub>base</sub>	kWh <sub>Post</sub>	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

<sup>150</sup> California End Use Survey (CEUS), Building workbooks with load shapes by end use. <http://capabilities.theEM&Vteam.com/CeusWeb/Chart.aspx>. Accessed 07/12/12.

<sup>151</sup> 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](http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx)



## **References and Efficiency Standards**

### **Petitions and Rulings**

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

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

- ENERGY STAR® specifications for Commercial Steam Cookers. [https://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/Commercial\\_Steam\\_Cookers\\_Program\\_Requirements.pdf](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 2-92: Nonresidential High-Efficiency Commercial Steam Cookers History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	Updated EUL based on ENERGY STAR® and DEER 2014.
v3.0	04/10/2015	Updated to newer ENERGY STAR® Steam Cooker Program Requirements Version 1.2. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	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

N/A

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

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

Equation 83

The baseline assumes door heaters 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 42.89°F DP and all on (duty cycle of 100%) at 52.87°F for a typical supermarket. Between these values, the door heaters' duty cycle changes proportionally:

**Door Heater ON%** =

$$\frac{t_{d-in} - \text{All OFF setpt (42.89°F)}}{\text{All ON setpt (52.87°F)} - \text{All OFF setpt (42.89°F)}}$$

Equation 84

The controller only changes the run-time of the heaters so the instantaneous door heater power ( $kW_{ASH}$ ) as a resistive load remains constant per linear foot of door heater at:

For medium temperature

$$kW_{Ash} = 0.109 \text{ per door or } 0.0436 \text{ per linear foot of door}^{152,153}$$

For low temperature

$$kW_{Ash} = 0.191 \text{ per door or } 0.0764 \text{ per linear foot of door}^{154,155}$$

Equation  
85

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<sup>152</sup> (Pennsylvania TRM) State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.

<sup>153</sup> 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.

<sup>154</sup> (Pennsylvania TRM) State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.

<sup>155</sup> 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:

$$kWh_{ASH-Hourly} = kW_{ASH} \times \text{Door Heater ON}\% \times 1\text{Hour}$$

**Equation 86**

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

**Equation 87**

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<sup>156</sup>, the cooling load contribution from door heaters can be given by:

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

**Equation 88**

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<sup>157</sup>.

For medium temperature compressors, the following equation is used to determine the EER<sub>MT</sub> [Btu/hr/watts]. These values are shown in Table 2-93.

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

**Equation 89**

Where:

$$a = 3.75346018700468$$

$$b = -0.049642253137389$$

<sup>156</sup> A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

<sup>157</sup> Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & Electric Company. May 29, 2009.

<i>c</i>	=	29.4589834935596
<i>d</i>	=	0.000342066982768282
<i>e</i>	=	-11.7705583766926
<i>f</i>	=	-0.212941092717051
<i>g</i>	=	-1.46606221890819 x 10 <sup>-6</sup>
<i>h</i>	=	6.80170133906075
<i>i</i>	=	-0.020187240339536
<i>j</i>	=	0.000657941213335828
<i>PLR</i>	=	1/1.15 = 0.87
<i>SCT</i>	=	ambient design temperature+ 15

For low temperature compressors, the following equation is used to determine the EER<sub>LT</sub> [Btu/hr/watts]:

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

Equation 90

Where:

<i>a</i>	=	9.86650982829017
<i>b</i>	=	-0.230356886617629
<i>c</i>	=	22.905553824974
<i>d</i>	=	0.00218892905109218
<i>e</i>	=	-2.48866737934442
<i>f</i>	=	-0.248051519588758
<i>g</i>	=	-7.57495453950879 x 10 <sup>-6</sup>
<i>h</i>	=	2.03606248623924
<i>i</i>	=	-0.0214774331896676
<i>j</i>	=	0.000938305518020252
<i>PLR</i>	=	1/1.15 = 0.876956521739

$$SCT = \text{ambient design temperature} + 10$$

**Table 2-93: Values Based on Climate Zone City**

Climate Zone	Summer Design Dry Bulb Temp <sup>158</sup>	SCT <sub>MT</sub>	SCT <sub>LT</sub>	EER <sub>MT</sub>	EER <sub>LT</sub>
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:

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER} \quad \text{Equation 91}$$

$$kWh_{refrig} = \sum kWh_{refrig-Hourly} \quad \text{Equation 92}$$

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of all hourly reading values:

$$kWh_{total} = kWh_{refrig} + kWh_{ASH} \quad \text{Equation 93}$$

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

$$\text{Annual Energy Savings [kWh]} = kWh_{total-baseline} - kWh_{total-post} \quad \text{Equation 94}$$

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:

$$\text{Peak Demand Savings} = \frac{kWh_{refrig-baseline} - kWh_{refrig-post}}{8760} \quad \text{Equation 95}$$

## **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.

<sup>158</sup> ASHRAE Climatic Region Data, 0.5% (°F).

**Table 2-94: 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](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](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 2-95: 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	In the energy savings equation used to determine the EER, rounded off the regression coefficients to 4 or 5 significant figures.
v2.1	01/30/2015	Correction to state that savings are on a per-linear foot of display case.
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	Update Deemed kW <sub>ash</sub> for Medium temperature cases and add kW <sub>ash</sub> for Low temperature cases. Added more significant digits to the input variables a-j for Equation 89 and Equation 90.



## 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 96

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

Equation 97

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

Equation 98

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

Equation 99

## Freezer

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

Equation 100

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

Equation 101

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

Equation 102

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

Equation 103

Where:

$N$	=	<i>Number of Motors replaced</i>
$W_{\text{base}}$	=	Input wattage of existing/baseline evaporator fan motor
$W_{\text{ee}}$	=	Input wattage of new energy efficient evaporator fan motor
LF	=	Load factor of evaporator fan motor
$DC_{\text{EvapCool}}$	=	Duty cycle of evaporator fan motor for cooler
$DC_{\text{EvapFreeze}}$	=	Duty cycle of evaporator fan motor for freezer
$COP_{\text{cooler}}$	=	Coefficient of performance of compressor in the cooler
$COP_{\text{freezer}}$	=	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, if the facility has evaporator fan controls %OFF = 46%.

**Table 2-96: Deemed Variables for Energy and Demand Savings Calculations**

Variable	Deemed Values
$W_{base}$	See Table 2-97
$W_{ee}$	See Table 2-97
$LF^{159}$	0.9
$DC_{EvapCool}^{160}$	100%
$DC_{EvapFreeze}^{161}$	94.4%
$COP_{cooler}$	See Table 2-98
$COP_{freezer}$	See Table 2-98
Hours <sup>162</sup>	8760 or 8273 <sup>163</sup>
%OFF	0 or 46%

**Table 2-97: Motor Sizes, Efficiencies and Input Watts<sup>164</sup>**

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

<sup>159</sup> "ActOnEnergy; Business Program-Program Year 2, June, 2009 through May, 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009

<sup>160</sup> "Efficiency Maine; Commercial Technical Reference User Manual No. 2007-1." Published 3/5/07.

<sup>161</sup> Ibid

<sup>162</sup> 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.

<sup>163</sup> 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](http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf)

<sup>164</sup> 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 2-98: Compressor Coefficient of Performance Based on Climate and Refrigeration Type  
(COP<sub>cooler</sub> or COP<sub>freezer</sub>)**

Representative Climate City	Summer Design Dry Bulb Temperature, ASHRAE Fundamentals 2009	COP <sub>cooler</sub>	COP <sub>freezer</sub>
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 & GrocWkIn-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 2-99: 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	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	Updated the methodology with cooler and freezer values.

## 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

N/A

### 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:

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

**Equation 104**

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

**Equation 105**

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

**Equation 106**

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

**Equation 107**

Where:

$\Delta kWh_{defrost}$  = Energy savings resulting from an increase in operating efficiency due to the addition of electronic defrost controls

$\Delta kWh_{heat}$  = 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 2-100: Deemed Variables for Energy and Demand Savings Calculations**

Variable	Deemed Values
DRF <sup>165</sup>	35%
Eff <sub>MT</sub> <sup>166</sup>	Amarillo: 1.86 Dallas-Ft. Worth: 1.98 El Paso: 2.02 Houston: 1.86 McAllen: 1.98
Eff <sub>LT</sub> <sup>166</sup>	Amarillo: 2.41 Dallas-Ft. Worth: 2.57 El Paso: 2.61 Houston: 2.41 McAllen: 2.57

## Deemed Energy and Demand Savings Tables

N/A

## Measure Life and Lifetime Savings

The EUL has been defined for this measure as 10 years.<sup>167</sup>

## 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)

<sup>165</sup> 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.

<sup>166</sup> Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPSCNRRN009 (rev.o.2007).

<sup>167</sup> Energy & Resource Solutions (2005). *Measure Life Study*. Prepared for The Massachusetts Joint Utilities.

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket No. 40669 provides energy and demand savings and measure specifications

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

N/A

### **Document Revision History**

**Table 2-101: Nonresidential Electronic Defrost Controls History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	No revisions

## 2.5.4 Evaporator Fan Controls Measure Overview

**TRM Measure ID:** NR-RF-FC

**Market Sector:** Commercial

**Measure Category:** Refrigeration

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

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculation

**Savings Methodology:** 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

N/A

### 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 108

**Peak Demand [kW] =**

$$\left( (kW_{evap} \times n_{fans}) - kW_{circ} \right) \times (1 - DC_{comp}) \times DC_{evap} \times BF$$

Equation 109

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

Variable	Deemed Values
$kW_{evap}^{168}$	0.123 kW
$kW_{circ}^{169}$	0.035 kW
$DC_{comp}^{170}$	50%
$DC_{evap}^{171}$	Cooler: 100% Freezer: 94%
$BF^{172}$	Low Temp: 1.5 Medium Temp: 1.3 High Temp: 1.2

## Deemed Energy and Demand Savings Tables

N/A

### 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 - GrocWIkIn-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

<sup>168</sup> Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts.

<sup>169</sup> Wattage of fan used by Freeaire and Cooltrol.

<sup>170</sup> 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.

<sup>171</sup> 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).

<sup>172</sup> 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.

## **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 2-103: Nonresidential Evaporator Fan Controls History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	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

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.<sup>173</sup>
- Infiltration accounts for approximately 24% of the total cooling load of open horizontal (coffin or tub style) display cases.<sup>173</sup>

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

- 8% on vertical cases<sup>173</sup>
- 50% on horizontal cases<sup>174</sup>

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 110

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)

For Medium Temperature (MT):  $SCT = DB_{adj} + 15$

Equation 111

<sup>173</sup> ASHRAE 2006. Refrigeration Handbook. Retail Food Store Refrigeration and Equipment. Atlanta, Georgia. p. 46.1, p. 46.5, p. 46.10.

<sup>174</sup> 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 Low Temperature (LT):  $SCT = DB_{adj} + 10$

Equation 112

Where:

$DB_{adj}$  = Design dry-bulb temperature (°F), based on climate zone, of ambient or space where the compressor/condensing units reside. Table 2-104 below lists design dry-bulb temperatures by climate zone.

**Table 2-104: Various Climate Zone Design Dry Bulb Temperatures and Representative Cities**

Representative Climate Zone	Summer Design Dry Bulb Temperature, ASHRAE Climatic Region Data, 0.5% (°F) <sup>175</sup>
Amarillo, TX	96
Dallas-Ft. Worth, TX	100
El Paso, TX	101
Houston, TX	96
McAllen, TX	100

- c. Determine the EER for both MT and LT applications
- d. 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.<sup>176</sup>
- e. 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 113

Where:

$PLR$  = Part Load Ratio

$Q_{cooling}$  = Cooling Load

<sup>175</sup> ASHRAE 2009 Handbook Fundamentals.

<sup>176</sup> Southern California Edison, Anti-Sweat Heat (ASH) Controls Work Paper WPSCNRRN009 (rev.0.2007).

$$Q_{capacity} = Total\ Compressor\ Capacity^{177}$$

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

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

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

- f. 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<sub>MT</sub> (Btu/hr/watts). The equation uses SCT (from step 2), and a PLR of 0.87 (from step 3b).

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

**Equation 114**

Where:

<i>a</i>	=	3.75346018700468
<i>b</i>	=	-0.049642253137389
<i>c</i>	=	29.4589834935596
<i>d</i>	=	0.000342066982768282
<i>e</i>	=	-11.7705583766926
<i>f</i>	=	-0.212941092717051
<i>g</i>	=	-1.46606221890819 × 10 <sup>-6</sup>
<i>h</i>	=	6.80170133906075
<i>i</i>	=	-0.020187240339536
<i>j</i>	=	0.000657941213335828

- g. For low temperature compressors, the following equation is used to determine the EER<sub>LT</sub> (Btu/hr/watts). The equation uses SCT (from step 2), and a PLR of 0.87 (from step 3b).

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<sup>177</sup> Compressor capacity is determined by multiplying baseline cooling load by a compressor over-sizing factor of 15%.

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

Equation 115

Where:

<i>a</i>	=	9.86650982829017
<i>b</i>	=	-0.230356886617629
<i>c</i>	=	22.905553824974
<i>d</i>	=	0.00218892905109218
<i>e</i>	=	-2.48866737934442
<i>f</i>	=	-0.248051519588758
<i>g</i>	=	-7.57495453950879 × 10 <sup>-6</sup>
<i>h</i>	=	2.03606248623924
<i>i</i>	=	-0.0214774331896676
<i>j</i>	=	0.00938305518020252

h. Convert EER to kW/ton

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

Equation 116

i. 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 117

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

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

Equation 118

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:

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

Equation 119

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

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

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

Equation 120

## 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.<sup>178</sup> The deemed energy and demand savings are shown below.

**Table 2-105: 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).

<sup>178</sup> PUCT Docket No. 40669, page A-2 states that Amarillo, Texas was chosen as a conservative climate zone due to little variation between climate zones. This statement has not been expanded upon.

## **Program Tracking Data & Evaluation Requirements**

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

- Display case type
- Refrigeration Temperature

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40669 provides energy and demand savings and measure specifications

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

- DEER 2014 EUL update

## **Document Revision History**

**Table 2-106: Nonresidential Night Covers for Open Refrigerated Display Cases History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	Removed all references to Peak Demand Savings as this measure is implemented outside of the peak demand period. Also rounded off savings to a reasonable number of significant digits.
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	Added more significant digits to the input variables a-j for Equation 114 and Equation 115.

## 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 2-108).

### 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 2-107.

**Table 2-107: Baseline Energy Consumption<sup>179,180</sup>**

Baseline Standards	Refrigerator Daily Consumption [kWh]	Freezer Daily Consumption [kWh]
Solid Door	$0.10V + 2.04$	$0.40V + 1.38$
Glass Door	$0.12V + 3.34$	$0.75V + 4.10$

## High-Efficiency Condition

Eligible high efficiency equipment for solid- or glass-door reach-in refrigerators and freezers must meet CEE or ENERGY STAR® minimum efficiency requirements, as shown in Table 2-108 below:

**Table 2-108: Efficient Energy Consumption<sup>181</sup>**

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

## 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 2-107 and Table 2-108, based on the volume of the units.

<sup>179</sup> 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.

<sup>180</sup>  $V$  = Interior volume [ft<sup>3</sup>] of a refrigerator or freezer (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).

<sup>181</sup> 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](http://www.energystar.gov/ia/partners/product_specs/program_reqs/commer_refrig_glass_prog_req.pdf)

The savings calculations are found below.

$$\text{Energy [kWh]} = (\text{kWh}_{\text{base}} - \text{kWh}_{\text{ee}}) \times 365 \quad \text{Equation 121}$$

$$\text{Peak Demand [kW]} = \frac{\Delta \text{kWh}}{8760} \times CF \quad \text{Equation 122}$$

Where:

$\text{kWh}_{\text{base}}$  = Baseline maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 2-107.

$\text{kWh}_{\text{ee}}$  = Efficient maximum daily energy consumption in kWh, based on volume (V) of unit, found in Table 2-108.

V = Chilled or frozen compartment volume [ft<sup>3</sup>] (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)<sup>182</sup>

## Deemed Energy and Demand Savings Tables.

N/A

## 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<sup>183</sup>.

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<sup>182</sup> 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.

<sup>183</sup> DEER 2008, December 2008 Final Report.



## **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
- 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](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 2-109: Nonresidential Solid and Glass Door Refrigerators and Freezers History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	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 2-110.

**Table 2-110: Deemed Energy and Demand Savings for Freezers and Coolers<sup>184</sup>**

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 - GrocWIkIn-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

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<sup>184</sup> Values based on analysis prepared by ADM for FirstEnergy utilities in Pennsylvania, provided by FirstEnergy on June 4<sup>th</sup>, 2010. Based on a review of deemed savings assumptions and methodologies from Oregon and California.

## Document Revision History

Table 2-111: 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	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	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 0°F.

### 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 °F). 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 ( $t_{d-in}$ ) can be calculated from outdoor dew point ( $t_{d-out}$ ) using the following equation:

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

**Equation 123**

The baseline assumes door heaters 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:

$$kWh_{ASH-Hourly} = kW_{ASH} \times \text{Door Heater ON\%} \times 1\text{Hour}$$

**Equation 124**

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

**Equation 125**

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system<sup>185</sup>, the cooling load contribution from door heaters can be given by:

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

**Equation 126**

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<sup>185</sup> A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data. The compressor analysis is limited to the cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

For medium temperature refrigerated cases, the saturated condensing temperature (SCT) is calculated as the design dry-bulb temperature plus 15 degrees. For low temperature refrigerated cases, the SCT is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity, and is assumed to be a constant 0.87<sup>186</sup>.

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

Table 2-93:

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

**Equation 127**

Where:

<i>a</i>	=	3.75346018700468
<i>b</i>	=	-0.049642253137389
<i>c</i>	=	29.4589834935596
<i>d</i>	=	0.000342066982768282
<i>e</i>	=	-11.7705583766926
<i>f</i>	=	-0.212941092717051
<i>g</i>	=	-1.46606221890819 x 10 <sup>-6</sup>
<i>h</i>	=	6.80170133906075
<i>i</i>	=	-0.020187240339536
<i>j</i>	=	0.000657941213335828
<i>PLR</i>	=	0.87
<i>SCT</i>	=	<i>ambient design temperature</i> + 15

<sup>186</sup> Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & Electric Company. May 29,2009.

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 128**

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
$SCT$	=	<i>ambient design temperature</i> +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 129**

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

**Equation 130**



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 131**

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

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

**Equation 132**

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:

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

**Equation 133**

**Table 2-112: Deemed Energy and Demand Savings Values by Location and Refrigeration Temperature in kWh per Linear Foot of Display Case**

Zero Energy Door	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	1132	0.129	2074	0.237
Dallas	1143	0.131	2101	0.240
El Paso	1147	0.131	2109	0.241
Houston	1132	0.129	2074	0.237
McAllen	1143	0.131	2101	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 2-113: Nonresidential Zero-Energy Refrigerated Case Doors History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	Updated savings methodology to be consistent with the door heater controls measure.

## 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

N/A

### 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

N/A

### 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 2-114: Deemed Energy and Demand Savings Values by Equipment Type**

Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW] <sup>187</sup>
Control for Refrigerated Cold Drink Unit cans or bottles	1,612 <sup>188</sup>	0.030
Control for Refrigerated Reach-in Unit any sealed beverage	1,086 <sup>189</sup>	0.035
Control for Non-Refrigerated Snack Unit with lighting (include. Warm beverage)	387 <sup>190</sup>	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

<sup>187</sup> Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56.

<sup>188</sup> Pacific Gas and Electric, Work Paper VMCold, Revision 3, August, 2009, Measure Code R97.

<sup>189</sup> Pacific Gas and Electric, Work Paper VMReach, Revision 3, August, 2009, Measure Code R143.

<sup>190</sup> 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](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](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 2-115: 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	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	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.<sup>191</sup> 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 5°F or 10°F 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).

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<sup>191</sup> The original petition also includes savings for HVAC-only control in master-metered multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is 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<sup>192</sup> and prototypical ASHRAE 90.1-1999 occupancy schedules were used in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system, which was compared to the baseline models.<sup>193</sup>

## **Savings Algorithms and Inputs**

A building simulation approach was used to produce savings estimates.

## **Deemed Energy and Demand Savings Tables**

Energy and demand savings are provided by region, for HVAC-Only and HVAC+Lighting control configurations, and for three facility types: Motel and Hotel guest rooms, and Dormitory rooms.

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<sup>192</sup> HVAC occupancy rates appear to be based on a single HVAC study of three hotels, but not dorms or multifamily buildings. For the lighting study, a typical guest room layout was used as the basis for the savings analysis. Hotel guest rooms are quite different from either dorms or multifamily units.

<sup>193</sup> A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

**Table 2-116: Deemed Energy and Demand Savings for Motel per Guest Room, by Region**

Representative City (Region) <sup>194</sup>	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & Lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-Degree Setup/Setback Offset</b>								
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
<b>10-Degree Setup/Setback Offset</b>								
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 2-117: 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
<b>5-Degree Setup/Setback Offset</b>								
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
<b>10-Degree Setup/Setback Offset</b>								
Amarillo (Panhandle)	0.102	426	0.121	568	0.102	557	0.121	684

<sup>194</sup> Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo (Panhandle) was “Panhandle”, Dallas-Ft Worth (North) was “North”, Houston (South) was “South Central”, El Paso (West) was “Big Bend”, and McAllen (Valley) was “Rio Grande Valley”.



Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & Lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
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

**Table 2-118: 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
<b>5-Degree Setup/Setback Offset</b>								
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
<b>10-Degree Setup/Setback Offset</b>								
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<sup>195</sup>. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

## Program Tracking Data & Evaluation Requirements

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

- HVAC System and Equipment Type
- Climate Zone/Region
- Temperature Offset category (5 or 10 degrees)

<sup>195</sup> 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.

- 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 2-119: Lodging Guest Room Occupancy Controls History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v2.0	04/18/2014	TRM v2.0 origin
v2.0	04/18/2014	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	No revisions

## 2.6.3 Pump-off Controller 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<sup>196</sup>” 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<sup>197</sup> prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive, and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a *conventional* well (above ground, 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.

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<sup>196</sup> Fluid pounding occurs when the downhole pump rate exceeds the production rate of the formation. The pump strikes the top of the fluid column on the downstroke causing extreme shock loading of the components which can result in premature equipment failure.

<sup>197</sup> The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.

## Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*<sup>198</sup> (SPE 16363), which identified a relationship between volumetric efficiency and pump run times, and the *2006-2008 Evaluation Report for PG&E Fabrication, Process, and Manufacturing Contract Group*<sup>199</sup>, which showed a reduction in savings from the SPE 16363 paper. These two methods were the basis of the current savings calculations and deemed inputs listed below. 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<sup>200</sup>.

### Savings Algorithms and Inputs

The energy and demand algorithms and associated input variables are listed below:

$$\text{Energy Savings [kWh]} = kW_{avg} * (\text{TimeClock}\%On - \text{POC}\%On) * 8760$$

Equation 134

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

Equation 135<sup>201</sup>

The inputs for the energy and peak coincident demand savings are listed below:

$$kW_{avg} = HP \times 0.746 \times \frac{LF}{\frac{ME}{SME}}$$

Equation 136

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

Equation 137<sup>202</sup>

<sup>198</sup> Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production*", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

<sup>199</sup> *2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group*. Calmac Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.

<sup>200</sup> The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

<sup>201</sup> The equations in the petition for peak demand simplify to the equation shown.

<sup>202</sup> This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is  $(\text{Run}_{constant} + \text{Run}_{coefficient} * \text{VolumetricEfficiency}\%)$  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 2-120
ME	=	Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 2-121
SME	=	Mechanical efficiency of sucker rod pump, see Table 2-120
TimeClock%On	=	Stipulated baseline timeclock setting, see Table 2-120
$Run_{constant}, Run_{coefficient}$	=	8.336, 0.956. Derived from SPE 16363 <sup>203</sup>
VolumetricEfficiency%	=	Average well gross production divided by theoretical production (provided on rebate application)

## Deemed Energy and Demand Savings Tables

Table 2-120: Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/ Deemed Values
LF (Load Factor)	25% <sup>204</sup>
ME (motor efficiency)	See Table 2-121
SME (pump mechanical efficiency)	95% <sup>205</sup>
Timeclock%On	65% <sup>206</sup>

<sup>203</sup> Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production*", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

<sup>204</sup> *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.

<sup>205</sup> Engineering estimate for standard gearbox efficiency.

<sup>206</sup> 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 2-121: NEMA Premium Efficiency Motor Efficiencies<sup>207</sup>**

Motor Horsepower	Nominal Full Load Efficiency					
	Open Motors (ODP)			Enclosed Motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%

## Claimed Peak Demand Savings

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8760 hours) is used, as shown in Equation 135.

## Measure Life and Lifetime Savings

The EUL for this measure is 15 years<sup>208</sup>.

## 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
- Rated Motor Horsepower
- Motor Type (TEFC or ODP)

<sup>207</sup> 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](http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50).

<sup>208</sup> CPUC 2006-2008 Industrial Impact Evaluation "SCIA\_06-08\_Final\_Report\_Appendix\_D-5": An EUL of 15 years was used for the ex-post savings, consistent with the SPC – Custom Measures and System Controls categories in the CPUC Energy Efficiency Policy Manual (Version 2) and with DEER values for an energy management control system.

- Rated Motor RPM
- Baseline control type and timeclock % on time (or actual on-time schedule)
- Volumetric Efficiency
- Field data on actual energy use and post-run times<sup>209</sup>

## **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 2-122: Pump-off Controller History**

<b>TRM Version</b>	<b>Date</b>	<b>Description of Change</b>
v2.1	01/30/2015	TRM v2.1 origin
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	No revisions

<sup>209</sup> Per PUCT Docket 42551, Southwestern Public Service Company (SPS)/Xcel Energy has agreed to collect field data in 2015 on post-run times for a sample of wells in order to improve the accuracy of POC saving estimates.



## APPENDIX C: 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 C-0-1: Operating Hours Building Type, By Utility<sup>210</sup>**

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146 <sup>211</sup>	LSF Calculators <sup>212</sup>	Oncor Calculator <sup>213</sup>
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

<sup>210</sup> Discrepancies from PUCT Docket No. 39146 are denoted by an asterisk (\*).

<sup>211</sup> These values were sourced from PUCT Docket No. 39146, Table 8.

<sup>212</sup> 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.

<sup>213</sup> Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146 <sup>211</sup>	LSF Calculators <sup>212</sup>	Oncor Calculator <sup>213</sup>
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
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

**Table C-0-2: Coincidence Factors Building Type, By Utility<sup>214</sup>**

Building Type Code	Building Type Description	Coincidence Factors		
		Docket 39146 <sup>215</sup>	LSF Calculators <sup>216</sup>	Oncor Calculator <sup>217</sup>
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%
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%

Building Type Code	Building Type Description	Coincidence Factors
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<sup>214</sup> 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.

<sup>215</sup> These values were sourced from PUCT Docket No. 39146, Table 8.

<sup>216</sup> 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.

<sup>217</sup> Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

		Docket 39146 <sup>218</sup>	LSF Calculators <sup>219</sup>	Oncor Calculator <sup>220</sup>
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%

<sup>218</sup> These values were sourced from PUCT Docket No. 39146, Table 8.

<sup>219</sup> 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.

<sup>220</sup> Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

**Table C-0-3: 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)

**Table C-3: (Cont.) Operating Hour and Coincidence Factor Sources from Petition 39146**

Building Type	Operating Hours	Operating Hour Sources	Coincidence Factor	Coincidence Factor Sources
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 of 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.cce1.org/sites/default/files/library/8828/CEE\\_Eval\\_CTCoincidenceFactorsC&ILightsHVAC\\_4Jan2007.PDF](http://webapps.cce1.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 C-0-4: Lighting Power Densities, By Building Type, By Utility<sup>221</sup>**

Building Type Code	Building Type Description	Lighting Power Density (LPD) or New Construction	
		Oncor Calculator <sup>222</sup>	LSF Calculators <sup>223</sup>
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

<sup>221</sup> Building Type Code has been pulled from PUCT Docket No. 39146 to show the variation between Building Type Codes used for HOU and CF, and Building Type Codes used for LPDs. Records where a Building Type Description has been listed, but no Building Type Code have been pulled from the calculator utilizing those specific LPDs. Building Types from the Lighting HOU and CF tables are denoted by an asterisk (\*).

<sup>222</sup> Oncor Calculator, 2013 N1 – Lighting (New Construction).

<sup>223</sup> 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	Lighting Power Density (LPD) or New Construction	
		Oncor Calculator <sup>222</sup>	LSF Calculators <sup>223</sup>
Museum	--	1.10	1.10
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)	--	--

Building Type Code	Building Type Description	Lighting Power Density (LPD) or New Construction	
		Oncor Calculator <sup>222</sup>	LSF Calculators <sup>223</sup>
Lodging, Common*	Lodging (Hotel/Motel/Dorm), Common Area	--	--
Lodging, Rooms*	Lodging (Hotel/Motel/Dorm), Rooms	--	--
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	--	--

Building Type Code	Building Type Description	Lighting Power Density (LPD) or New Construction	
		Oncor Calculator <sup>222</sup>	LSF Calculators <sup>223</sup>
--	Public Assembly - Sports Arena	--	--
--	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 C-0-5: Energy Adjustment Factors By Utility<sup>224</sup>**

Building Type Code	Control Codes	Energy Adjustment Factors			
		Docket 40668 <sup>225</sup>	LSF Calculators <sup>226</sup>	Oncor Calculator (Retrofit) <sup>227</sup>	Oncor Calculator (New Construction) <sup>228</sup>
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*	--

<sup>224</sup> Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (\*). The EAF is applicable to all building types.

<sup>225</sup> These values were sourced from PUCT Docket No. 40668, Page A-24.

<sup>226</sup> 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.

<sup>227</sup> Oncor Calculator, 2013 E1 – Lighting (Retrofit).

<sup>228</sup> Oncor Calculator, 2013 N1 – Lighting (New Construction).

**Table C-0-6: Demand Adjustment Factors By Utility<sup>229</sup>**

Building Type Code	Control Codes	Demand Adjustment Factors					
		Docket 40668 <sup>230</sup>		LSF Calculators <sup>231</sup>		Oncor Calculator <sup>232</sup>	
		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	--	--	--	--	--	--

<sup>229</sup> Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (\*).

<sup>230</sup> These values were sourced from PUCT Docket No. 40668, Page A-24.

<sup>231</sup> 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.

<sup>232</sup> Oncor Calculator, 2013 E1 – Lighting (Retrofit) and 2013 N1 – Lighting (New Construction).

## **APPENDIX D: MEASURE LIFE CALCULATIONS FOR EARLY RETIREMENT PROGRAMS**

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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:

$$\text{Early Retirement (ER) Period} = ML_{ER} = RUL \quad \text{Equation 138}$$

$$\text{Replace on Burnout (ROB) Period} = ML_{ROB} = EUL - RUL \quad \text{Equation 139}$$

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:

$$\Delta kW_{ER} = kW_{replaced} - kW_{installed} \quad \text{Equation 140}$$

$$\Delta kW_{RPB} = kW_{baseline} - kW_{installed} \quad \text{Equation 141}$$

$$\Delta kWh_{ER} = kWh_{replaced} - kWh_{installed} \quad \text{Equation 142}$$

$$\Delta kWh_{RPB} = kWh_{baseline} - kWh_{installed} \quad \text{Equation 143}$$

Where:

$\Delta kW_{ER}$  = Early retirement demand savings

$\Delta kW_{ROB}$  = Replace-on-burnout demand savings

$kW_{replaced}$  = Demand of the retired system<sup>233</sup>

$kW_{baseline}$  = Demand of the baseline ROB system<sup>234</sup>

$kW_{installed}$  = Demand of the replacement system<sup>235</sup>

$\Delta kWh_{ER}$  = Early retirement energy savings

$\Delta kWh_{ROB}$  = Replace-on-burnout energy savings

$kWh_{replaced}$  = Energy Usage of the retired system<sup>233</sup>

$kWh_{baseline}$  = Energy Usage of the baseline ROB system<sup>234</sup>

$kWh_{installed}$  = Energy Usage of the replacement system<sup>235</sup>

<sup>233</sup> Retired system refers to the existing equipment that was in use before the retrofit has occurred.

<sup>234</sup> Baseline used for a replace-on-bunout project of the same type and capacity as the system being installed in the early retirement project (as specified in the applicable measure)

<sup>235</sup> Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

**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 144

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

Equation 145

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

Equation 146

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

Equation 147

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 <sup>236</sup>
$d$	=	Discount rate weighted average cost of capital (per utility) <sup>236</sup>
$AC_{kW}$	=	Avoided cost per kW (\$/kW) <sup>236</sup>
$AC_{kWh}$	=	Avoided cost per kWh (\$/kWh) <sup>236</sup>
$ML_{ER}$	=	ER Measure Life (calculated in Equation 138)
$ML_{ROB}$	=	ROB measure life (calculated in Equation 139)

**Note:** Demand and energy savings ( $\Delta kW$  and  $\Delta kWh$ ) used to estimate NPV in **Equation 144** through **Equation 147** 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

<sup>236</sup> The exact values to be used each year for the escalation rate, discount rate, and avoided costs are established by the PUC in Substantive Rule §25.181 and updated annually, as applicable. Please note that the discount rates are based on a utility's weighted average cost of capital and, as such, will vary by utility and may change each year.



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 148**

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

**Equation 149**

Where:

$$NPV_{Total, kW} = \text{Total capacity contributions to NPV of both ER and ROB component}$$

$$NPV_{Total, kWh} = \text{Total energy contributions to NPV of both ER and ROB component}$$

**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 150**

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

**Equation 151**

Where:

$$NPV_{EUL, kW} = \text{Capacity contributions to NPV without weighting, using original EUL}$$

$$NPV_{EUL, kWh} = \text{Energy contributions to NPV without weighting, using original EUL}$$

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

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

**Equation 152**

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

**Equation 153**

Where:

<i>Weighted kW</i>	=	<i>Weighted lifetime demand savings</i>
<i>Weighted kWh</i>	=	<i>Weighted lifetime energy savings</i>
$NPV_{Total, kW}$	=	<i>Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 148</i>
$NPV_{Total, kWh}$	=	<i>Total energy contributions to NPV of both ER and ROB component, calculated in Equation 149</i>
$NPV_{EUL, kW}$	=	<i>Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 152</i>
$NPV_{EUL, kWh}$	=	<i>Energy contributions to NPV without weighting, using original EUL, calculated in Equation 153</i>