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 2-139.

Table 2-139: Deemed Energy and Demand Savings for Freezers and Coolers[204]

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

Measure Life and Lifetime Savings

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

Program Tracking Data & Evaluation Requirements

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

- Unit Temperature (Refrigerator or Freezer)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications
- PUCT Docket 36779 provides EUL estimates for Commercial Refrigerators and Freezers

Relevant Standards and Reference Sources

- DEER 2014 EUL update

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

Document Revision History

Table 2-140: Nonresidential Strip Curtains for Walk-In Refrigerated Storage Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

2.5.8 Zero Energy Doors for Refrigerated Cases Measure Overview

TRM Measure ID: NR-RF-ZE

Market Sector: Commercial

Measure Category: Refrigeration

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit or New Construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the deemed savings methodology for the installation of Zero Energy Doors for refrigerated cases. These new zero-energy door designs eliminate the need for anti-sweat heaters to prevent the formation of condensation on the glass surface by incorporating heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate glass panes, and/or non-metallic frames.

Eligibility Criteria

This measure cannot be used in conjunction with anti-sweat heat (ASH) controls. It is not eligible to be installed on cases above 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 ($t_{d\text{-}in}$) can be calculated from outdoor dew point ($t_{d\text{-}out}$) using the following equation:

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

Equation 137

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

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

For medium temperature:

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

For low temperature:

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

Door heater energy consumption for each hour of the year is a product of power and run-time:

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

Equation 138

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

Equation 139

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming that 35 percent of the anti-sweat heat becomes a load on the refrigeration system,[205] the cooling load contribution from door heaters can be given by:

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

Equation 140

[205] 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.[206]

For medium temperature compressors, the following equation is used to determine the EER_{MT} [Btu/hr/watts]. These values are shown in Table 2-122:

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

Equation 141

Where:

a	=	3.75346018700468
b	=	-0.049642253137389
c	=	29.4589834935596
d	=	0.000342066982768282
e	=	-11.7705583766926
f	=	-0.212941092717051
g	=	$-1.46606221890819 \times 10^{-6}$
h	=	6.80170133906075
I	=	-0.020187240339536
j	=	0.000657941213335828
PLR	=	0.87
SCT	=	*ambient design temperature+ 15*

For low temperature compressors, the following equation is used to determine the EER_{LT} [Btu/hr/watts]:

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

Equation 142

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

Where:

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

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER}$$

Equation 143

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

Equation 144

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 145

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

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

Equation 146

While there might be instantaneous demand savings because of the cycling of the door heaters, peak demand savings will only be due to the reduced refrigeration load. Peak demand savings is calculated by the following equation:

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

Equation 147

Table 2-141: Deemed Energy and Demand Savings Values by Location and Refrigeration Temperature in kWh per Linear Foot of Display Case

Climate Zone	Medium Temperature		Low Temperature	
	Annual Energy Savings [kWh/ft]	Peak Demand Savings [kW/ft]	Annual Energy Savings [kWh/ft]	Peak Demand Savings [kW/ft]
Amarillo	1,132	0.129	2,074	0.237
Dallas	1,143	0.131	2,101	0.240
El Paso	1,147	0.131	2,109	0.241
Houston	1,132	0.129	2,074	0.237
McAllen	1,143	0.131	2,101	0.240

Measure Life and Lifetime Savings

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

Program Tracking Data & Evaluation Requirements

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

- Refrigeration Temperature Range

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669 provides energy and demand savings and measure specifications
- PUCT Docket 36779 provides EUL values for Zero Energy Doors

Relevant Standards and Reference Sources

- DEER 2014 EUL update

Document Revision History

Table 2-142: Nonresidential Zero-Energy Doors for Refrigerated Cases Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. Updated savings methodology to be consistent with the door heater controls measure.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

2.5.9 Door Gaskets for Walk-in and Reach-in Coolers and Freezers

TRM Measure ID: NR-RF-DG

Market Sector: Commercial

Measure Category: Refrigeration

Applicable Building Types: Any Commercial retail facility such as supermarkets, convenience stores, restaurants, and refrigerated warehouses

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET)

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V, Engineering algorithms and estimates

Measure Description

This measure applies to the installation of door gaskets on walk-in and reach-in coolers and freezers to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated space. Additionally, the reduction in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time, reducing energy consumption and improving the overall effectiveness of heat removal from a refrigerated cabinet.

Eligibility Criteria

Door gaskets must be installed on walk-in and reach-in coolers or freezers. The most common applications for this measure are refrigerated coolers or freezers in supermarkets, convenience stores, restaurants, and refrigerated warehouses.

Baseline Condition

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets. An average baseline gasket efficacy[207] of 90 percent is assumed for this measure.

[207] Gasket efficacy is defined as the ratio of the gasket length that was removed by the installers to the gasket length that was replaced. A 90 percent gasket efficacy translates to an average of 10 percent of missing, badly damaged or ineffective gasket by length replaced.

High-Efficiency Condition

The efficient condition for this measure is a new, better-fitting gasket. Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, reducing the cooling load. A decrease in moisture entering the refrigerated space also prevents frost on cooling coils.

Energy and Demand Savings Methodology

The energy savings assumptions are based on DEER 2005 analysis performed by Southern California Edison (SCE) and an evaluation of a Pacific Gas and Electric (PG&E) Direct Install refrigeration measures for program year 2006-2008.[208,209] The results from the PG&E evaluation were used as the foundation for establishing the energy savings for the refrigeration gasket measures. The energy savings achievable for new gaskets replacing baseline gaskets were found during this study to be dependent almost entirely on the leakage through the baseline gaskets. Therefore, the energy savings attributable to door gaskets were derived for various scenarios regarding baseline gasket efficacies and are shown in Table 2-143 below.

Table 2-143: Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per linear foot of installed door gasket)

Refrigerator Type	Baseline 0% Efficacy (kWh/ft)	Baseline 50% Efficacy (kWh/ft)	Baseline 90% Efficacy (kWh/ft)	Baseline 100% Efficacy (kWh/ft)
Cooler	30	15	3	0
Freezer	228	114	23	0

As the PG&E analysis was performed in California with different climate zones as compared to those in Texas, an analysis was conducted to develop an adjustment factor to associate the savings in the table above to Texas anticipated results. The PG&E study could not be used to determine these affects, as insufficient climate zones were researched. Therefore, the SCE study was utilized as savings in this study were determined for each of the 16 climate zones in California and were similar[210] to those assessed within the PG&E results at 90 percent efficacy. A comparison was completed between the SCE energy savings and the typical meteorological year 3 (TMY3) data[211] to establish cooling degree day (CDD) correlations across the 16 California climate zones. Figure 2-1 provides a summary comparison for coolers and Figure 2-2 for freezers. The resulting correlations are strong with an R^2 of 0.85 for coolers and an R^2 of 0.88 for freezers, respectively.

208 Southern California Edison (SCE). WPSCNRRN0013—Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases & Solid Doors of Reach-in Coolers and Freezers. 2007.

209 Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010.

210 The SCE ex-ante savings as reported in the PG&E report were 10.2 and 21.7 kWh/linear foot for coolers and freezers respectively. Modeled savings as reported in the SEC report for climate zone 4 were approximately 6 and 15 kWh/linear foot for coolers and freezers respectively.

211 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/zip/alltmy3a.zip

Figure 2-1: Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 CA Climate Zones for Reach-In Display Cases (Coolers)

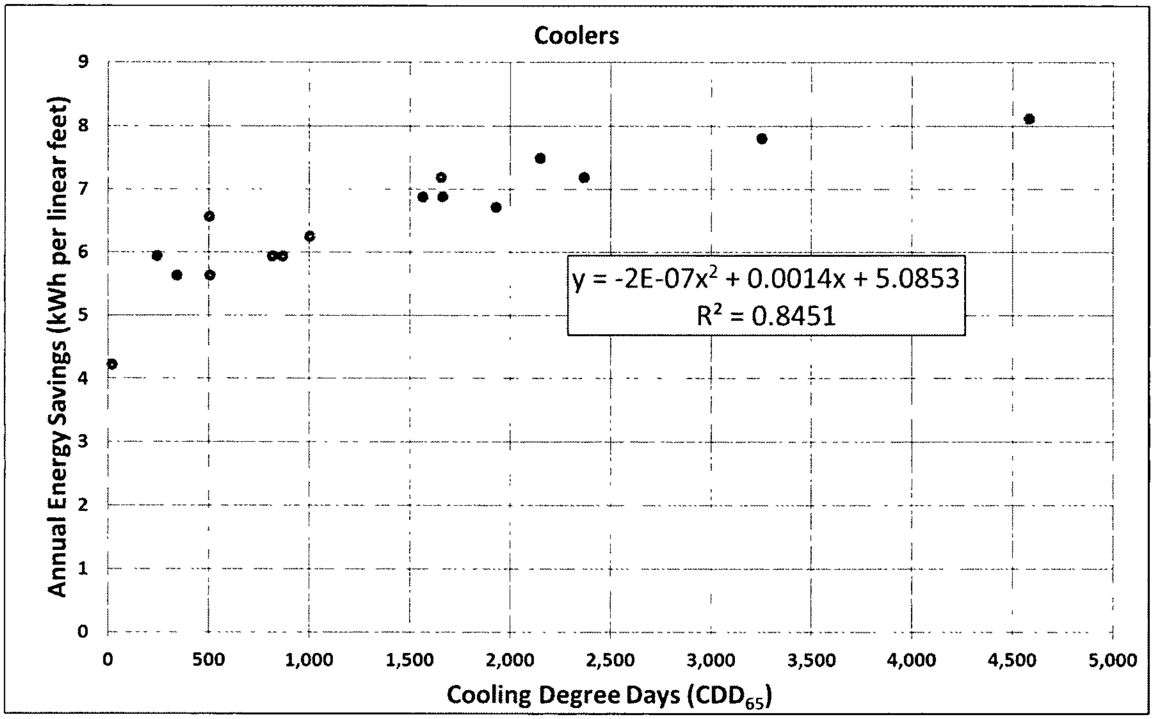
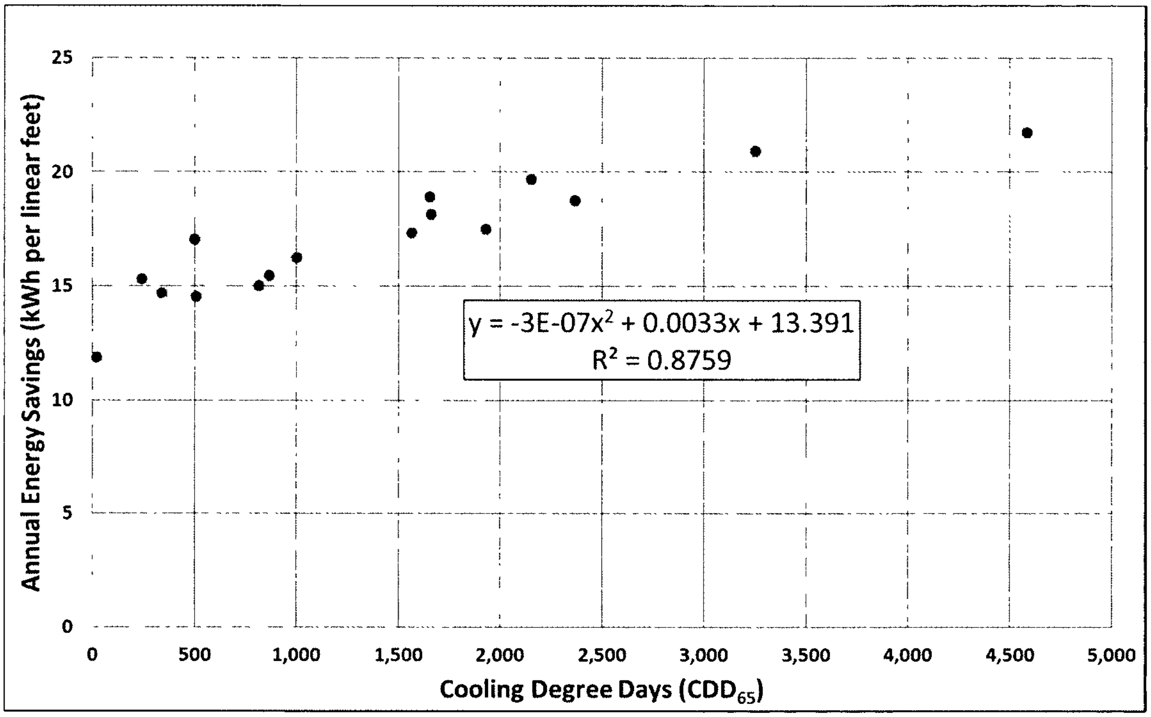


Figure 2-2: Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 CA Climate Zones for Reach-In Display Cases (Freezers)



These correlations were used to adjust the energy savings and TMY3 CDDs in California to TMY3 CDDs in Texas to determine an average energy savings of 7.4 and 20.0 kWh/linear feet for coolers and freezers in Texas. Comparing the average energy savings between California and Texas, the CDD adjustment results in a 113 percent adjustment factor for coolers and a 117 percent adjustment factor for freezers. For simplicity, an average adjustment factor of 115 percent was applied to the PG&E results at 90 percent efficacy (as shown in Table 2-143 above) resulting in Texas based annual energy savings values for coolers of 3.5 kWh/linear feet and freezers of 26.5 kWh/linear feet. These results are summarized in Table 2-144 below.

Table 2-144: Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per linear foot of installed door gasket)

Refrigerator Type	CA CZ1-CZ16 Average Savings (kWh/ft)	CA Average Savings Normalized to TX by CDD (kWh/ft)	TX vs CA Energy Savings	Average CDD Adjustment Factor	PG&E Baseline 90% Efficacy (kWh/ft)	TX Baseline 90% Efficacy (kWh/ft)
Cooler	6.5	7.4	113%	115%	3	3.5
Freezer	17.1	20.0	117%		23	26.5

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8760 hours).

Savings Algorithms and Input Variables

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

$$Energy\ Savings\ [kWh] = \frac{\Delta kWh}{ft} \times L$$

Equation 148

$$Demand\ Savings\ [kW] = \frac{kWh_{Savings}}{8760} \times L$$

Equation 149

Where:

$\Delta kWh/ft$ = *Annual energy savings per linear foot of gasket (see Table 2-145)*

L = *Total gasket length (ft)*

Deemed Energy and Demand Savings Tables

Table 2-145: Deemed Energy and Demand Savings per Linear Foot of Installed Door Gasket

Refrigerator Type	ΔkW/ft	ΔkWh/ft
Walk-in or Reach-in Cooler	0.0004	3.5
Walk-in or Reach-in Freezer	0.0030	26.5

Claimed Peak Demand Savings

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8760 hours).

Measure Life and Lifetime Savings

The EUL for this measure is 4 years according to the California Database of Energy Efficiency Resources (DEER 2014).[212]

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.

- Building type (convenience store, supermarket, restaurant, refrigerated warehouse)
- Refrigerator type (walk-in or reach-in cooler or freezer)
- Total length of installed gasket (ft)
- Presence of existing gasket (yes/no)
- Optional (if applicable): length of ineffective baseline gasket (feet), general description of baseline gasket condition (e.g., good, moderate, poor, non-existent), and primary reason for baseline gasket ineffectiveness (partial tear, torn & dislocated, rotted/dry, poor fit/shrink, missing, or other).

References and Efficiency Standards

Petitions and Rulings

- Docket No. 48265. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. PETITION TO APPROVE DEEMED SAVINGS FOR NEW NONRESIDENTIAL DOOR AIR INFILTRATION, NONRESIDENTIAL DOOR GASKETS, AND RESIDENTIAL ENERGY STAR CONNECTED THERMOSTATS. Public Utility Commission of Texas.

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

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 2-146: Door Gaskets for Walk-in and Reach-In Coolers and Freezers Revision History

TRM Version	Date	Description of Change
v6.0	10/2018	TRM v6.0 origin.

2.6 NONRESIDENTIAL: MISCELLANEOUS

2.6.1 Vending Machine Controls Measure Overview

TRM Measure ID: NR-MS-VC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All building types applicable

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: M&V

Measure Description

This section presents the deemed savings methodology for the installation of Vending Machine controls to reduce energy usage during periods of inactivity. These controls reduce energy usage by powering down the refrigeration and lighting systems when the control device signals that there is no human activity near the machine. If no activity or sale is detected over the manufacturer's programmed time duration, the device safely de-energizes the compressor, condenser fan, evaporator fan, and any lighting. For refrigerated machines, it will power up occasionally to maintain cooling to meet the machine's thermostat set point. When activity is detected, the system returns to full power. The energy and demand savings are determined on a per-vending machine basis.

Eligibility Criteria

Not applicable.

Baseline Condition

Eligible baseline equipment is a 120 volt single phase vending machine manufactured and purchased prior to August 31, 2012.

High-Efficiency Condition

Eligible equipment is a refrigerated vending machine or non-refrigerated snack machine (including warm beverage machines) without any controls. It is assumed that the display lighting has not been permanently disabled.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Not applicable.

Deemed Energy and Demand Savings Tables

Energy and demand savings 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 2-147: Deemed Energy and Demand Savings Values by Equipment Type

Size	Annual Energy Savings [kWh]	Peak Demand Savings [kW][213]
Control for Refrigerated Cold Drink Unit cans or bottles	1,612[214]	0.030
Control for Refrigerated Reach-in Unit any sealed beverage	1,086[215]	0.035
Control for Non-Refrigerated Snack Unit with lighting (including warm beverage)	387[216]	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

[213] 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.

[214] Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

[215] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

[216] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A: http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/40669_3_735684.PDF. Accessed 09/24/2013.
- PUCT Docket 36779—Provides EUL for Vending Machine Controls.

Relevant Standards and Reference Sources

- Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56. http://www.eceee.org/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper. Accessed 09/24/2013.
- DEER 2014 EUL update.

Document Revision History

Table 2-148: Nonresidential Vending Machine Controls Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

2.6.2 Lodging Guest Room Occupancy Sensor Controls Measure Overview

TRM Measure ID: NR-MS-LC

Market Sector: Commercial

Measure Category: HVAC, Indoor Lighting

Applicable Building Types: Hotel/Motel Guestrooms, Schools/Colleges (Dormitory)

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET)

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling

Measure Description

This measure 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.[217] 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 percent of all the lighting fixtures in a guest room—both hardwired and plug-load lighting—must be actively controlled.

Baseline Condition

The baseline condition is a guest room or dorm room without occupancy controls.

[217] The original petition also includes savings for HVAC-only control in master-metered Multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is quite different from the transitory occupation of hotel/motels, and even dormitories. This measure is not currently being implemented and is not likely to be used in the future, but it can be added to a future TRM if warranted.

High-Efficiency Condition

The high-efficiency condition is a hotel/motel guest room or dorm room with occupancy controls. The occupancy sensors can control either the HVAC equipment only, or the HVAC equipment and the interior lighting (including plug-in lighting).

The occupancy-based control system must include, but not be limited to, infrared sensors, ultrasonic sensors, door magnetic strip sensors, and/or card-key sensors. The controls must be able to either completely shut-off the HVAC equipment serving the space and/or place it into an unoccupied temperature setback/setup mode.

Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies[218] 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.[219]

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.

[218] 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.

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

Table 2-149: Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Representative City (Region)[220]	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & Lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.059	267	0.075	380	0.059	341	0.075	441
Dallas-Ft Worth (North)	0.076	315	0.091	443	0.076	365	0.091	485
Houston (South)	0.082	324	0.097	461	0.082	351	0.097	484
McAllen (Valley)	0.086	354	0.103	500	0.086	369	0.103	513
El Paso (West)	0.063	251	0.078	379	0.063	283	0.078	406
10-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.111	486	0.126	598	0.111	627	0.126	726
Dallas-Ft Worth (North)	0.146	559	0.161	686	0.146	640	0.161	761
Houston (South)	0.151	559	0.166	695	0.151	602	0.166	735
McAllen (Valley)	0.163	617	0.179	761	0.163	650	0.179	792
El Paso (West)	0.118	432	0.133	561	0.118	482	0.133	607

Table 2-150: Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & Lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.053	232	0.072	439	0.053	303	0.072	530
Dallas-Ft Worth (North)	0.073	258	0.093	452	0.073	303	0.093	505
Houston (South)	0.074	242	0.094	430	0.074	260	0.094	450
McAllen (Valley)	0.081	260	0.102	451	0.081	267	0.102	459
El Paso (West)	0.056	178	0.075	360	0.056	196	0.075	380
10-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.102	426	0.121	568	0.102	557	0.121	684
Dallas-Ft Worth (North)	0.134	452	0.154	617	0.134	517	0.154	676
Houston (South)	0.136	423	0.156	599	0.136	446	0.156	621
McAllen (Valley)	0.149	467	0.169	652	0.149	483	0.169	667
El Paso (West)	0.106	312	0.126	479	0.106	338	0.126	501

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

Table 2-151: Deemed Energy and Demand Savings for Dormitories per Room, by Region

Representative City (Region)	Heat Pump				Electric Heat			
	HVAC-Only		HVAC & Lighting		HVAC-Only		HVAC & Lighting	
	kW	kWh	kW	kWh	kW	kwh	kW	kWh
5-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.034	136	0.061	319	0.034	152	0.061	316
Dallas-Ft Worth (North)	0.048	214	0.076	425	0.048	223	0.076	428
Houston (South)	0.051	242	0.078	461	0.051	244	0.078	462
McAllen (Valley)	0.053	265	0.081	492	0.053	266	0.081	492
El Paso (West)	0.031	110	0.059	327	0.031	110	0.059	326
10-Degree Setup/Setback Offset								
Amarillo (Panhandle)	0.073	261	0.084	404	0.073	289	0.084	417
Dallas-Ft Worth (North)	0.078	293	0.105	505	0.078	304	0.105	511
Houston (South)	0.081	326	0.108	543	0.081	328	0.108	545
McAllen (Valley)	0.088	368	0.114	591	0.088	370	0.114	593
El Paso (West)	0.045	151	0.060	448	0.045	153	0.060	450

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

Estimated Useful Life is 10 years based on the value for Retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study[221]. 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)

[221] 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 2-152: Lodging Guest Room Occupancy Sensor Controls Revision History

TRM Version	Date	Description of Change
v2.0	04/18/2014	TRM v2.0 origin.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

2.6.3 Pump-off Controllers Measure Overview

TRM Measure ID: NR-MS-PC

Market Sector: Commercial

Measure Category: Controls

Applicable Building Types: Industrial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Field study, Engineering algorithms and estimates

Measure Description

Pump-off Controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions, 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"[222] 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[223] 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.

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[222] 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.

[223] The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*[224] (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,*[225] 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.[226]

Savings Algorithms and Inputs

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

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

Equation 150

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

Equation 151[227]

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

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

Equation 152

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

Equation 153[228]

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[224] 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).

[225] *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.

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

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

[228] This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is ($Run_{contstant}$ + $Run_{coefficient}$ * VolumetricEfficiency%) with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25%).

Where:

kW_{avg}	=	*The demand used by each rod pump*
HP	=	*Rated pump motor horsepower*
0.746	=	*Conversion factor from HP to kW*
LF	=	*Motor load factor—ratio of average demand to maximum demand, see Table 2-153*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 2-154*
SME	=	*Mechanical efficiency of sucker rod pump, see Table 2-153*
TimeClock%On	=	*Stipulated baseline timeclock setting, see Table 2-153*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956. Derived from SPE 16363* [229]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

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

Deemed Energy and Demand Savings Tables

Table 2-153: Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/ Deemed Values
LF (Load Factor)	25%[230]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[231]
Timeclock%On	65%[232]

Table 2-154: NEMA Premium Efficiency Motor Efficiencies[233]

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

Claimed Peak Demand Savings

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8760 hours) is used, as shown Equation 151.

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

[231] Engineering estimate for standard gearbox efficiency.

[232] 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.

[233] DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-Load Efficiencies for General Purpose Electric Motors [Subtype I] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50.

Measure Life and Lifetime Savings

The EUL for this measure is 15 years.[234]

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)
- Rated Motor RPM
- Baseline control type and timeclock percent on time (or actual on-time schedule)
- Volumetric Efficiency
- Field data on actual energy use and post-run times[235]

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.

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234 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.

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

- Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011.

Document Revision History

Table 2-155: Pump-off Controllers Revision History

TRM Version	Date	Description of Change
v2.1	01/30/2015	TRM v2.1 origin.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.

2.6.4 ENERGY STAR® Pool Pumps Measure Overview

TRM Measure ID: NR-MS-PP

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable speed pool pump.

Eligibility Criteria

This measure applies to all Commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a Custom program. Motor-only Retrofits are not eligible.

Multi-speed pool pumps are not permitted. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[236] The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for Commercial pool operation as mandated by Texas Administrative Code.

Baseline Condition

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

[236] Hunt, A. & Easley, S., 2012, "*Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.*" Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator with Texas selected as the applicable location so Texas-specific assumptions were used.[237]

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

Equation 154

Where:

kWh_{conv} = Conventional single-speed pool pump energy (kWh)

kWh_{ES} = ENERGY STAR® variable speed pool pump energy (kWh)

Algorithms to calculate the above parameters are defined as:

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

Equation 155

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

Equation 156

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

Equation 157

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

Equation 158

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

Where:

kWh_{HS}	=	*ENERGY STAR® variable speed pool pump energy at high speed [kWh]*
kWh_{LS}	=	*ENERGY STAR® variable speed pool pump energy at low speed [kWh]*
$hours_{conv}$	=	*Conventional single-speed pump daily operating hours (Table 2-156)*
$hours_{HS}$	=	*ENERGY STAR® variable speed pump high speed daily operating hours (Table 2-157)*
$hours_{LS}$	=	*ENERGY STAR® variable speed pump low speed daily operating hours (Table 2-157)*
days	=	*Operating days per year = Year-Round Operation: 365 days; Seasonal Operation: 7 months x 30.4 days/month = 212.8 days (default)*
PFR_{conv}	=	*Conventional single-speed pump flow rate [gal/min] (Table 2-156)*
PFR_{HS}	=	*ENERGY STAR® variable speed pump high speed flow rate [gal/min] (Table 2-157)*
PFRconv	=	*ENERGY STAR® variable speed pump low speed flow rate [gal/min] (Table 2-157)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (Table 2-156)*
EF_{HS}	=	*ENERGY STAR® variable speed pump high speed energy factor [gal/W·hr] (Table 2-157)*
EF_{LS}	=	*ENERGY STAR® variable speed pump low speed energy factor [gal/W·hr] (Table 2-157)*
60	=	*Constant to convert between minutes and hours*
1,000	=	*Constant to convert from kilowatts to watts*

Table 2-156: Conventional Pool Pumps Assumptions[238]

New Rated Pump HP	$hours_{conv}$, limited hours[239]	$hours_{conv}$, 24/7 Operation	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
≤ 1.25	12	24	75.5000	2.5131
1.25 < hp ≤ 1.75			78.1429	2.2677
1.75 < hp ≤ 2.25			89.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ 3			102.6667	1.9987

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

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

Table 2-157: ENERGY STAR® Pool Pumps Assumptions[240]

New Rated Pump HP	$Hours_{HS}$ limited hours [241]	$Hours_{HS}$ 24/7 Operation	$Hours_{LS}$ limited hours	$Hours_{LS}$ 24/7 Operation	PFR_{HS} (gal/min)	EF_{HS} (gal/W·h)	PFR_{LS} (gal/min)	EF_{LS} (gal/W·h)
≤ 1.25	6	12	6	12	70.00	3.01	40.30	6.78
1.25 < hp ≤ 1.75					78.00	2.74	41.80	6.71
1.75 < hp ≤ 2.25					89.70	2.40	44.80	6.50
2.25 < hp ≤ 2.75					90.00	2.44	45.70	5.96
2.75 < hp ≤ 3					102.00	1.99	51.00	6.07

Demand Savings Algorithms

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \left(\frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right)\right] \times \frac{DF}{days}$$

Equation 159

Where:

kWh_{HS} = *ENERGY STAR® variable speed pool pump energy at high speed [kWh]*

kWh_{LS} = *ENERGY STAR® variable speed pool pump energy at low speed [kWh]*

$hours_{conv}$ = *Conventional single-speed pump daily operating hours (Table 2-156)*

$hours_{HS}$ = *ENERGY STAR® variable speed pump high speed daily operating hours (Table 2-157)*

$hours_{LS}$ = *ENERGY STAR® variable speed pump low speed daily operating hours (Table 2-157)*

$days$ = *Operating days per year = Year-Round Operation: 365 days; Seasonal Operation: 7 months x 30.4 days/month = 212.8 days (default)*

DF = *Demand Factor from Table 2-158*

Table 2-158: Demand Factors

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

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

[241] Total pump operating hours at high and low speed are assumed to match conventional pump operating hours. Number of hours spent at high speed and low speed are estimated to meet requirements of the Texas Administrative Code, Title 25, Part 1, Chapter 2655, Subchapter L, Rule §265.187 which requires pool volume turnover every 6 hours.

Deemed Energy Savings Tables

Table 2-159: ENERGY STAR® Variable Speed Pool Pump Energy Savings[242]

New Rated Pump HP	Year-Round Operation		Seasonal Operation (7 months)
	24/7 Operation	Limited Hours	
	kWh Savings	kWh Savings	kWh Savings
≤ 1.25	8,117	4,058	2,366
1.25 < hp ≤ 1.75	8,993	4,497	2,622
1.75 < hp ≤ 2.25	8,866	4,433	2,585
2.25 < hp ≤ 2.75	10,723	5,362	3,126
2.75 < hp ≤ 3	11,320	5,660	3,300

Deemed Summer Demand Savings Tables[243]

Table 2-160: ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings—For All Operating Profiles

New Rated Pump (HP)	Demand Savings (kW)
≤ 1.25	0.927
1.25 < hp ≤ 1.75	1.027
1.75 < hp ≤ 2.25	1.012
2.25 < hp ≤ 2.75	1.224
2.75 < hp ≤ 3	1.292

242 The results in this table may vary slightly from results produced by the ENERGY STAR® calculator because of rounding of default savings coefficients throughout the measure and pool volume.
243 Ibid.

Deemed Winter Demand Savings Tables

Table 2-161: ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings

New Rated Pump HP	Year-Round Operation. 24/7 Demand Savings (kW)	Year-Round and Seasonal Operation, Limited Hours Demand Savings (kW)
≤ 1.25	0.927	0.463
1.25 < hp ≤ 1.75	1.027	0.513
1.75 < hp ≤ 2.25	1.012	0.506
2.25 < hp ≤ 2.75	1.224	0.612
2.75 < hp ≤ 3	1.292	0.646

Claimed Peak Demand Savings

Table 2-162: ENERGY STAR® Variable Speed Pool Pump Claimed Demand Savings

New Rated Pump (HP)	Demand Savings (kW)
≤ 1.25	0.927
1.25 < hp ≤ 1.75	1.027
1.75 < hp ≤ 2.25	1.012
2.25 < hp ≤ 2.75	1.224
2.75 < hp ≤ 3	1.292

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

According to DEER 2014, the estimated useful life for this measure is 10 years.[244]

Program Tracking Data & Evaluation Requirements

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

- For All Projects
  - Pool pump rated horsepower
  - Climate zone

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

- Proof of purchase including quantity, make and model information

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 2-163: ENERGY STAR® Pool Pumps Revision History

TRM Version	Date	Description of Change
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revisions.

APPENDIX A: NONRESIDENTIAL LIGHTING FACTORS COMPARISON TABLES

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

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

Table A-1: Operating Hours Building Type, By Utility[245]

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[246]	LSF Calculators[247]	Oncor Calculator[248]
Educ. K-12, No Summer	Education (K-12 w/o Summer Session)	2,777	2,777	2,777
Education, Summer	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	3,577	3,577	3,577
Non-24-Hr Retail	Food Sales—Non-24-Hr Supermarket/Retail	4,706	4,706	4,706
24-Hr Retail	24-Hr Supermarket/Retail	6,900	6,900	6,900
Fast Food	Food Service—Fast Food	6,188	6,188	6,188
Sit-down Rest.	Food Service—Sit-down Restaurant	4,368	4,368	4,368
Health In	Health Care (In Patient)	5,730	5,730	5,730
Health Out	Health Care (Out Patient)	3,386	3,386	3,386
Lodging, Common	Lodging (Hotel/Motel/Dorm), Common Area	6,630	6,630	6,630
Lodging, Rooms	Lodging (Hotel/Motel/Dorm), Rooms	3,055	3,055	3,055
Manufacturing	Manufacturing	5,740	5,740	5,740
MF Common	Multi-family Housing, Common Areas	4,772	4,772	4,772
Nursing Home	Nursing and Residential Care	4,271	4,271	4,271
Office	Office	3,737	3,737	3,737
Outdoor	Outdoor Lighting Photo-Controlled	3,996	3,996	4,145*
Parking	Parking Structure	7,884	7,884	7,884
Public Assembly	Public Assembly	2,638	2,638	2,638

245 Discrepancies from PUCT Docket No. 39146 are denoted by an asterisk (*).
246 These values were sourced from PUCT Docket No. 39146, Table 8.
247 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.
248 Oncor Calculator, 2013 E1—Lighting (Retrofit) and 2013 N1–Lighting (New Construction).

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[246]	LSF Calculators[247]	Oncor Calculator[248]
Public Order	Public Order and Safety	3,472	3,472	3,472
Religious	Religious Worship	1,824	1,824	1,824
Retail Non-mall/strip	Retail (Excl. Mall and Strip Center)	3,668	3,668	3,668
Enclosed Mall	Retail (Enclosed Mall)	4,813	4,813	4,813
Strip/Non-enclosed Mall	Retail (Strip Center and Non-enclosed Mall)	3,965	3,965	3,965
Service (Non-food)	Service (Excl. Food)	3,406	3,406	3,406
Non-refrig. Warehouse	Warehouse (Non-refrigerated)	3,501	3,501	3,501
Refrig. Warehouse	Warehouse (Refrigerated)	3,798	3,798	3,798
Enclosed Mall	Retail (Enclosed Mall)	4,813	4,813	4,813

Table A-2: Coincidence Factors Building Type, By Utility[249]

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[250]	LSF Calculators[251]	Oncor Calculator[252]
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%

249 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.

250 These values were sourced from PUCT Docket No. 39146, Table 8.

251 LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01.

252 Oncor Calculator, 2013 E1—Lighting (Retrofit) and 2013 N1—Lighting (New Construction).

Building Type Code	Building Type Description	Operating Hours		
		Docket 39146[250]	LSF Calculators[251]	Oncor Calculator[252]
Sit-down Rest.	Food Service—Sit-down Restaurant	81%	81%	81%
Health In	Health Care (In Patient)	78%	78%	78%
Health Out	Health Care (Out Patient)	77%	77%	77%
Lodging, Common	Lodging (Hotel/Motel/Dorm), Common Area	82%	82%	82%
Lodging, Rooms	Lodging (Hotel/Motel/Dorm), Rooms	25%	25%	25%
Manufacturing	Manufacturing	73%	73%	73%
MF Common	Multi-family Housing, Common Areas	87%	87%	87%
Nursing Home	Nursing and Residential Care	78%	78%	78%
Office	Office	77%	77%	77%
Outdoor	Outdoor Lighting Photo-Controlled	0%	0% / 61%*	64%*
Parking	Parking Structure	100%	100%	100%
Public Assembly	Public Assembly	56%	56%	56%
Public Order	Public Order and Safety	75%	75%	75%
Religious	Religious Worship	53%	53%	53%
Retail Non-mall/strip	Retail (Excl. Mall and Strip Center)	90%	90%	90%
Enclosed Mall	Retail (Enclosed Mall)	93%	93%	93%
Strip/Non-enclosed Mall	Retail (Strip Center and Non-enclosed Mall)	90%	90%	90%
Service (Non-food)	Service (Excl. Food)	90%	90%	90%
Non-refrig. Warehouse	Warehouse (Non-refrigerated)	77%	77%	77%
Refrig. Warehouse	Warehouse (Refrigerated)	84%	84%	84%

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

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

Building Type	Operating Hours	Operating Hour Sources	Coincidence Factor	Coincidence Factor Sources
Education K-12, w/o Summer Session	2,777	Navigant (2002) Weighted-average Calculation	0.47	RLW (2007)
Education: College, University, Vocational, Day Care, and K-12 w/ summer session	3,577	SCE (2007), weighted average calculation	0.69	RLW (2007)
Food Sales - Non-24-Hour Supermarket Retail	4,706	CBECS (2003); Navigant (2002) weighted ave calculation	0.95	RLW (2007)
Food Sales - 24 Hour Supermarket Retail	6,900	Weighted Ave of Existing PUCT-Approved Value and Navigant (2002)	0.95	Existing PUCT-Approved Value
Food Service – fast food	6,183	SCE (2007)	0.81	RLW (2007), weighted-average calculation
Food Service – Sit-down Restaurant	4,368	SCE (2007)	0.81	RLW (2007), weighted-average calculation
Health Care (Out-patient)	3,386	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Health Care (In-patient)	5,730	Navigant (2002) Weighted-average Calculation	0.78	See Explanation below
Lodging (Hotel/Motel/Dorm) Common Areas	6,630	Navigant (2002) Weighted-average Calculation	0.82	RLW (2007)
Lodging (Hotel/Motel/Dorm), Rooms	3,055	Navigant (2002) Weighted-average Calculation	0.25	See Explanation below
Manufacturing	5,740	Frontier Estimate	0.73	RLW (2007)
Multi-family Housing, Common Areas	4,772	Existing PUCT-Approved Value	0.87	RLW (2007)
Nursing and Resident Care	4,271	Navigant (2002) Weighted-average Calculation	0.78	RLW (2007)
Office	3,737	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Outdoor (street & parking)	3996	Oncor Street Lighting Tariff Filing	0.00	Oncor Street Lighting Tariff Filing
Parking Structure	7,884	Existing PUCT-approved value	1.00	Existing PUCT-approved value
Public Assembly	2,638	Navigant (2002) Weighted-average Calculation	0.56	Conn (2007), Weighted by XENCAP Study
Public Order and Safety	3,472	Navigant (2002) Weighted-average Calculation	0.75	Conn (2007), Weighted by XENCAP Study
Religious	1,824	Navigant (2002) Weighted-average Calculation	0.53	Conn (2007), Weighted by XENCAP Study
Retail (Excluding Malls and Strip Centers)	3,668	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007)
Retail (Enclosed Mall)	4,813	Navigant (2002) Weighted-average Calculation	0.93	RLW (2007)
Retail (Strip shopping and non-enclosed mall)	3,965	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007)
Service (Excluding Food)	3,406	Navigant (2002) Weighted-average Calculation	0.90	RLW (2007) – assumed similar operations as Retail
Warehouse (Non-refrigerated)	3,591	Navigant (2002) Weighted-average Calculation	0.77	RLW (2007)
Warehouse (Refrigerated)	3,798	Navigant (2002) Weighted-average Calculation	0.84	RLW (2007)

Petition 39146, Table 8, References:

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

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

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

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

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

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

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

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

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[253]	LSF Calculators[254]
Automotive Facility	--	0.90	0.90
Convention Center	--	1.20	1.20
Court House	--	1.20	1.20
Dining: Bar Lounge/Leisure	--	1.30	1.30
Dining: Cafeteria/Fast Food	--	1.40	1.40
Dining: Family	--	1.60	1.60
Dormitory	--	1.00	1.00
Exercise Center	--	1.00	1.00
Gymnasium	--	1.10	1.10
Health Center	--	1.00	1.00
Hospital	--	1.20	1.20
Hotel	--	1.00	1.00
Library	--	1.30	1.30
Manufacturing Facility	--	1.30	1.30
Motel	--	1.00	1.00
Motion Picture Theater	--	1.20	1.20
Multi-family	--	0.70	0.70
Museum	--	1.10	1.10
Penitentiary	--	1.00	1.00

253 Oncor Calculator, 2013 N1—Lighting (New Construction).

254 LSF Calculators used by Xcel, Sharyland, AEP, EPE, and Entergy. 2013 Lighting Survey Form (LSF). Specified calculator versions are: Xcel v7.01, EPE v7.02, Sharyland, v8.01, TNMP v4.18.

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[253]	LSF Calculators[254]
Performing Arts Theater	--	1.60	1.60
Police/Fire Station	--	1.00	1.00
Post Office	--	1.10	1.10
Retail	--	1.50	1.50
School/University	--	1.20	1.20
Sports Arena	--	1.10	1.10
Town Hall	--	1.10	1.10
Transportation	--	1.00	1.00
Warehouse	--	0.80	0.80
Workshop	--	1.40	1.40
Educ. K-12, No Summer*	Education (K-12 w/o Summer Session)	--	--
Education, Summer*	Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	--	--
Non-24-Hr Retail*	Food Sales—Non-24-Hr Supermarket/Retail	--	--
24-Hr Retail*	24-Hr Supermarket/Retail	--	--
Fast Food*	Food Service—Fast Food	--	--
Sit-down Rest.*	Food Service—Sit-down Restaurant	--	--
--	Food Service—Sit-down Restaurant - Dining: Bar Lounge/Leisure	--	--
Health In*	Health Care (In Patient)	--	--
Health Out*	Health Care (Out Patient)	--	--
Lodging, Common*	Lodging (Hotel/Motel/Dorm), Common Area	--	--
Lodging, Rooms*	Lodging (Hotel/Motel/Dorm), Rooms	--	--
Manufacturing*	Manufacturing	--	--

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[253]	LSF Calculators[254]
MF Common*	Multi-family Housing, Common Areas	--	--
Nursing Home*	Nursing and Residential Care	--	--
Office*	Office	1.00	1.00
--	Outdoor - Outdoor Uncovered Parking Area: Zone 1	--	0.04
--	Outdoor - Outdoor Uncovered Parking Area: Zone 2	--	0.06
--	Outdoor - Outdoor Uncovered Parking Area: Zone 3	--	0.10
--	Outdoor - Outdoor Uncovered Parking Area: Zone 4	--	0.13
Outdoor*	Outdoor Lighting Photo-Controlled	--	--
Parking*	Parking Structure	0.30	0.30
Public Assembly*	Public Assembly	--	--
--	Public Assembly - Convention Center	--	--
--	Public Assembly - Exercise Center	--	--
--	Public Assembly - Gymnasium	--	--
--	Public Assembly - Hospital	--	--
--	Public Assembly - Library	--	--
--	Public Assembly - Motion Picture Theater	--	--
--	Public Assembly - Museum	--	--
--	Public Assembly - Performing Arts Theater	--	--
--	Public Assembly - Post Office	--	--
--	Public Assembly - Sports Arena	--	--
--	Public Assembly - Transportation	--	--

Building Type Code	Building Type Description	Operating Hours	
		Oncor Calculator[253]	LSF Calculators[254]
--	Public Order and Safety - Court House	--	--
--	Public Order and Safety - Penitentiary	--	--
--	Public Order and Safety - Police/Fire Station	--	--
Public Order*	Public Order and Safety	--	--
Religious*	Religious Worship	1.30	1.30
Retail Non-mall/strip*	Retail (Excl. Mall and Strip Center)	--	--
Enclosed Mall*	Retail (Enclosed Mall)	--	--
Strip/Non-enclosed Mall*	Retail (Strip Center and Non-enclosed Mall)	--	--
Service (Non-food)*	Service (Excl. Food)	--	--
Non-refrig. Warehouse*	Warehouse (Non-refrigerated)	--	--
Refrig. Warehouse*	Warehouse (Refrigerated)	--	--

Table A-5: Energy Adjustment Factors by Utility[255]

Building Type Code	Control Codes	Operating Hours			
		Docket 40668[256]	LSF Calculators[257]	Oncor Calculator (Retrofit)[258]	Oncor Calculator (New Construction)[259]
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 OSV—on/off	0.65	0.65	0.65	0.65
Photocontrol	Photo	--	--	1.00*	--

255 Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (*). The EAF is applicable to all building types.
256 These values were sourced from PUCT Docket No. 40668, Page A-24.
257 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.
258 Oncor Calculator, 2013 E1—Lighting (Retrofit).
259 Oncor Calculator, 2013 N1—Lighting (New Construction).

Table A-6: Demand Adjustment Factors by Utility[260]

Building Type Code	Control Codes	Demand Adjustment Factors					
		Docket 40668[261]		LSF Calculators[262]		Oncor Calculator [263]	
		K-12, No Summer	All Other Bldg Types	K-12, No Summer	All Other Bldg Types	K-12, No Summer	All Other Bldg 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	--	--	--	--	--	--

260 Discrepancies from PUCT Docket No. 40668 are denoted by an asterisk (*).
261 These values were sourced from PUCT Docket No. 40668, Page A-24.
262 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.
263 Oncor Calculator, 2013 E1—Lighting (Retrofit) and 2013 N1—Lighting (New Construction).

APPENDIX B: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

The following appendix describes the method of calculating savings for any dual baseline measure, including all Early Retirement measures. This supersedes the previous Measure Life Savings found in PUCT Dockets 40083 and 40885 and is revised to clarify the understanding of the Measure Life calculations and reduce any misrepresentation of Net Present Value (NPV) of Early Retirement projects.

Option 1 provides reduced savings claimed over the full EUL. Option 2 provides higher savings claimed over a reduced EUL. The lifetime savings are the same for both Option 1 and 2. The Option 1 calculations were originally provided in Docket [43681].

Option 1—Weighting Savings and Holding Measure Life Constant

Step 1: Determine the measure life for First-Tier (FT) and Second-Tier (ST) components of the calculated savings:

$$First\ Tier\ (FT)\ Period = ML_{FT} = RUL$$

Equation 160

$$Second\ Tier\ (ST)\ Period = ML_{ST} = EUL - RUL$$

Equation 161

Where:

RUL	=	*The useful life corresponding with the first tier-savings. For Early Retirement projects, RUL is the remaining useful life determined from lookup tables based on the age of the replaced unit (or default age when actual age is unknown)*
EUL	=	*The useful life corresponding with the second-tier savings. For Early Retirement projects, EUL is the estimated useful life as specified in applicable measure from Texas TRM (or approved petition)*

Step 2: Calculate the FT demand and energy savings and the ST demand and energy savings:

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

Equation 162

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

Equation 163

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

Equation 164

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

Equation 165

Where:

ΔkW_{FT}	=	*First-tier demand savings*
ΔkW_{ST}	=	*Second-tier demand savings*
$kW_{replaced}$	=	*Demand of the first-tier baseline system, usually the retired system*[264]
$kW_{baseline}$	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[265]
$kW_{installed}$	=	*Demand of the replacement system*[266]
ΔkWh_{FT}	=	*First-tier energy savings*
ΔkWh_{ST}	=	*Second-tier energy savings*
$kWh_{replaced}$	=	*Energy Usage of the first-tier baseline system, usually the retired system*[264]
$kWh_{baseline}$	=	*Energy Usage of the second-tier baseline system, usually the baseline ROB system*[265]
$kWh_{installed}$	=	*Energy Usage of the replacement system*[266]

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

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

Equation 166

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

Equation 167

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

Equation 168

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

Equation 169

Where:

$NPV_{FT,kW}$	=	*Net Present Value (kW) of first-tier projects*
$NPV_{ST,kW}$	=	*Net Present Value (kW) of second-tier projects*

264 Retired system refers to the existing equipment that was in use before the retrofit has occurred.
265 Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the Early Retirement project (as specified in the applicable measure).
266 Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

$NPV_{FT,kWh}$	=	*Net Present Value (kWh) of first-tier projects*
$NPV_{ST,kWh}$	=	*Net Present Value (kWh) of second-tier projects*
e	=	*Escalation Rate* [267]
d	=	*Discount rate weighted average cost of capital (per utility)* [267]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [267]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [267]
ML_{FT}	=	*First-tier Measure Life (calculated in Equation 160)*
ML_{ST}	=	*Second-tier measure life (calculated in Equation 161)*

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

$$NPV_{Total,kW} = NPV_{FT,kW} + NPV_{T,kW}$$

Equation 170

$$NPV_{Total,kWh} = NPV_{FT,kWh} + NPV_{ST,kWh}$$

Equation 171

Where:

$NPV_{Total,kW}$	=	*Total capacity contributions to NPV of both first-tier and second-tier component*
$NPV_{Total,kWh}$	=	*Total energy contributions to NPV of both first-tier and second-tier component*

Step 5: Calculate the capacity and energy cost contributions to the NPV without weighting by demand and energy savings for a scenario using the original EUL:

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

Equation 172

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

Equation 173

Where:

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

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

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

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

Equation 174

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

Equation 175

Where:

Weighted kW	=	*Weighted lifetime demand savings*
Weighted kWh	=	*Weighted lifetime energy savings*
$NPV_{Total,\ kW}$	=	*Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 170*
$NPV_{Total,\ kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 171*
$NPV_{EUL,\ kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 172*
$NPV_{EUL,\ kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 173*

Option 2—Weighting Measure Life and Holding First Year Savings Constant

Repeat Step 1 through Step 4 from Option 1.

Step 5: Reverse calculate the EUL for the capacity and energy contributions to the NPV for a scenario using the first-tier savings:

$$EUL_{kW} = \left. ln\left[\frac{NPV_{Total,kW} \times (d-e)}{\Delta kW_{FT} \times AC_{kW} \times (1+e)}\right] \middle/ ln\left[\frac{(1+e)}{(1+d)}\right] \right.$$

Equation 176

$$EUL_{kWh} = \left. ln\left[\frac{NPV_{Total,kWh} \times (d-e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1+e)}\right] \middle/ ln\left[\frac{(1+e)}{(1+d)}\right] \right.$$

Equation 177

Where:

EUL_{kW}	=	*EUL for capacity contribution to NPV using first tier savings*
EUL_{kWh}	=	*EUL for energy contribution to NPV using first tier savings*

Step 6: Confirm that capacity EUL and energy EUL are equivalent. First tier savings are claimed over this weighted EUL.

Public Utility Commission of Texas

Texas Technical Reference Manual

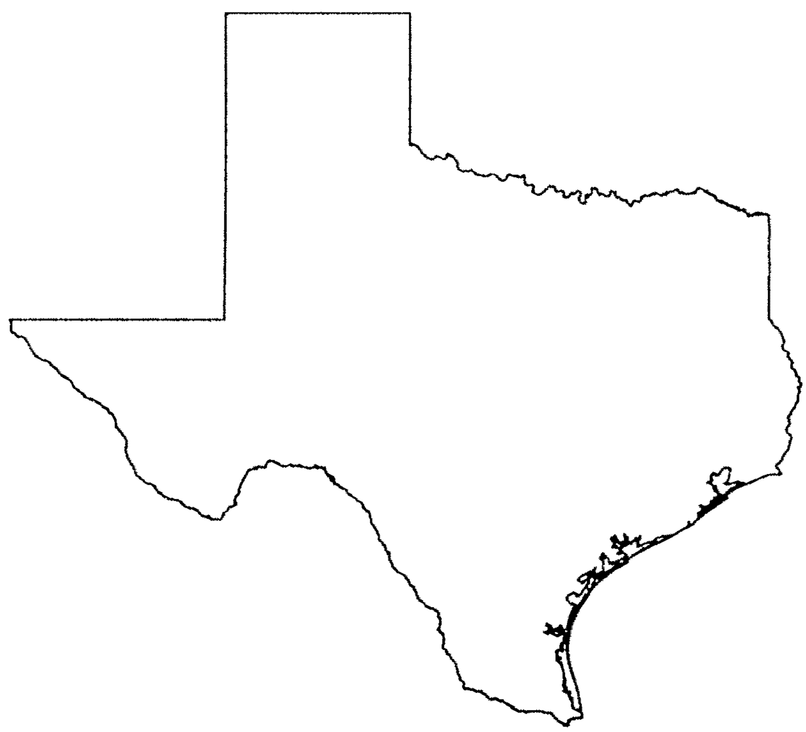
Version 6.0

Volume 4: Measurement & Verification Protocols

Program Year 2019

Last Revision Date:

November 2018



Public Utility Commission of Texas

Texas Technical Reference Manual

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Table of Contents

List of Figures

List of Tables

Acknowledgements

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

This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Associates (TXu 1-904-705), ICF, CLEAResult and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2016 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2018 by Frontier Energy. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as consistent structure and level of information.

TRM Technical Support

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

1. INTRODUCTION

This volume of the TRM contains Measurement and Verification (M&V) protocols for determining and/or verifying utility claimed energy and demand savings for particular measures or programs ((§ 25.181(q)(6)(A)). Table 1-1 provides an overview of the M&V measures contained within Volume 4 and the types of savings estimates available for each one.

M&V protocols are included for the following measures:

- HVAC: Air Conditioning Tune-Up
- HVAC: Ground Source Heat Pump
- HVAC: Variable Refrigerant Flow Systems
- Whole House: Residential New Construction
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors less than 75 hp
- Demand Response: Residential Load Curtailment
- Demand Response: Nonresidential Load Curtailment.

This is an update to TRM 3.1 that includes M&V protocols. Additional M&V protocols will be included in future versions of TRM Volume 4 as they are submitted, reviewed, and approved by the EM&V team and Commission staff.

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: Residential and Nonresidential M&V Savings by Measure Category

Sector	Measure Category	Measure Description	6.0 Update
Residential & Nonresidential	HVAC	Air Conditioning Tune-Up	No revisions.
Nonresidential	HVAC	Ground Source Heat Pump	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.
Residential & Nonresidential	HVAC	Variable Refrigerant Flow Systems	Minor formula corrections.
Residential	Whole-House	Residential New Construction	Added provision for Multi-Family New Construction, updated baseline to reflect adoption of IECC2015
Residential & Nonresidential	Renewables	Solar Photovoltaics	No revisions.
Residential & Nonresidential	Renewables	Solar Shingles	No revisions.
Nonresidential	Miscellaneous	Behavioral	No revisions.
Nonresidential	Miscellaneous	Air Compressors Less Than 75hp	No revisions.
Nonresidential	Miscellaneous	Commercial Retro-commissioning	TRM v6.0 origin.
Residential	Demand Response	Residential Load Curtailment	No revisions.
Nonresidential	Demand Response	Nonresidential Load Curtailment	No revisions.

2. M&V MEASURES

2.1 M&V: HVAC

2.1.1 Air Conditioning Tune-Ups Measure Overview

TRM Measure ID: R-HV-TU and NR-HV-TU

Market Sector: Residential and Commercial

Measure Category: HVAC

Applicable Building Types: Residential; Commercial

Fuels Affected: Electricity

Decision/Action Type(s): Operation & Maintenance (O&M)

Program Delivery Type(s): Custom

Deemed Savings Type: Deemed efficiency loss factors are applied to measured operating performance indictors to estimate energy saving impacts. The deemed efficiency loss factors estimate equipment improvements based on each unit's specific operating conditions.

Savings Methodology: Algorithms, EM&V, and deemed efficiency loss corresponding to whether refrigerant charge was adjusted

AC tune-ups promote a holistic approach to improving the operational efficiency of existing air conditioners by completing six tune-up service measures. This protocol is used to estimate savings for tune-up measures through an M&V approach that relies on test-out measurements of key AC performance indicators following completion of all tune-up service measures.

The M&V protocols included here are for air conditioner tune-ups (AC tune-up) for equipment where the six tune-up service measures are completed by professional air conditioning technicians. Tuned air conditioners are then performance tested under protocol conditions to ensure the AC system is under significant load and at steady-state conditions prior to recording measurements. Compliance with these M&V protocols ensures reliable performance measurements from which to estimate the energy savings impacts from the combined effects of all six tune-up service measures.

Measure Description

AC tune-ups must be professionally completed by qualified air conditioning service technicians using measurement tools and equipment. This protocol covers assumptions made for baseline equipment efficiencies based on previous M&V tune-ups in Texas from 2011-2014. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating AC tune-up unit. Following completion of the six service measures, the M&V methodology for tune-ups require in-field measurement and recording of AC performance parameters under protocol conditions to record *in situ*, post tune-up, performance to calculate estimated energy impacts.

The AC tune-up requires completion of 6 tune-up service measure tasks listed below.

- Clean condenser surfaces
- Clean evaporator surfaces
- Clean blower assembly (fan blades, plenum interior)
- Verify filter is clean: change or clean as needed
- Verify airflow within 15 percent of 400 cubic feet per minute per ton; adjust as needed
- Check refrigerant charge; adjust as needed

Applicable equipment types include:

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

Eligibility Criteria

This measure only applies to existing air conditioning equipment, which includes service, to split and packaged air conditioner and heat pump systems. For an AC tune-up to be eligible to use the deemed efficiency loss factors and savings approach, the AC tune-up must include completion of the six tune-up service measures and the following conditions must be met:

- Use of program specified measurement equipment and accuracies
- Tune-up completed by a qualified technician
- Document all service procedures completed during tune-up (e.g., clean AC components, verify airflow, and check/adjust refrigerant charge)

Baseline Condition

The baseline efficiency conditions are calculated (see Equation 7) based on the efficiency loss values determined by this protocol (see Table 2-1)

High-Efficiency Condition

The high-efficiency conditions are calculated based on measurements taken in the field after the tune-up has been performed. These test-out (TO) measurements are then adjusted to Air-Conditioning Refrigeration and Heating Institute (AHRI) standard operating conditions to develop an in-situ post tune-up high-efficiency condition. The equipment efficiency effects are used to estimate cooling and heating (heat pumps only) energy impacts as applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 1

$$Peak\ Demand\ Savings\ [kW_{Savings,C}] = Cap_{Rated} \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right) \times CF \times \frac{kW}{1000\ W}$$

Equation 2

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = Cap_{Rated} \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right) \times EFLH_C \times \frac{kW}{1000\ W}$$

Equation 3

$$Energy\ (Heating)\ [kWh_{Savings,H}] = Cap_{Rated} \times \left(\frac{1}{\eta_{pre,H}} - \frac{1}{\eta_{post,H}}\right) \times EFLH_H \times \frac{kW}{1000\ W}$$

Equation 4

$$\eta_{post,C} = \eta_{TO,C} \times EER\ Adjustment\ Factor$$

Equation 5

$$\eta_{pre,C} = (1 - efficiency\ loss) \times \eta_{post,C}$$

Equation 6

$$\eta^{(1)}_{post,H} = 0.3342 \times \eta^{(2)}{}_{post,C} + 3.9871$$

Equation 7

$$\eta_{pre,H} = (1 - efficiency\ loss) \times \eta_{post,H}$$

Equation 8

$$Test\ Out\ Efficiency\ [\eta_{TO,C}] = \frac{Cap_{post,C}}{Power_{TO,C}}$$

Equation 9

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[1] Developed by Cadmus: 2013 Portfolio Evaluation, Entergy Arkansas, Appendix A

[2] For this protocol, the cooling efficiency of the existing equipment measured after tune-up and adjusted to AHRI standard conditions (i.e., $\eta_{post,C}$) is used as a proxy for the post tune-up heating efficiency.

$$\boldsymbol{Cap_{post,C} = Cap_{TO,C} \times Capacity\ Adjustment\ Factor}$$

Equation 10

$$Cap_{TO,C} = \left(h_{Return\ Air} - h_{Supply\ Air}\right) \times (Mass\ Flow\ Rate)$$

Equation 11

$$Enthalpy\ of\ Moist\ Air\ (Return\ Air/Supply\ Air), [h] = C_p \times t_{db} + W \times (1061 + 0.444 \times t_{db})$$

Equation 12

$$Specific\ Heat\ of\ Moist\ Air, [C_p] = -2.0921943x10^{-14} \times t_{db}^4 + 2.5588383x10^{-11} \times t_{db}^3 + 1.2900877x10^{-8} \times t_{db}^2 + 5.8045267x10^{-6} \times t_{db} + 0.23955919$$

Equation 13

$$Humidity\ Ratio, [W] = \frac{(1093 - 0.556t_{wb})W_s - C_p(t_{db} - t_{wb})}{1093 + 0.444t - t_{wb}}$$

Equation 14

$$Saturation\ Humidity\ Ratio, [W_s] = (0.62198) \times \frac{p_{ws}}{p_{atm} - p_{ws}}$$

Equation 15

The Saturation Over Liquid Water equation is:

$$ln(P_{ws}) = \frac{C_8}{T} + C_9 + C_{10} \times T + C_{11} \times T^2 + C_{12} \times T^3 + C_{13} \times ln(T)$$

Equation 16

$$Saturation\ Pressure\ Over\ Liquid\ Water, [P_{ws}] = e^{\left[\frac{C_8}{T} + C_9 + C_{10} \times T + C_{11} \times T^2 + C_{12} \times T^3 + C_{13} \times ln(T)\right]}$$

Equation 17

$$P_{atm} = \frac{29.92}{2.036} \times (1 - 6.8753x10^{-6} \times Z)^{5.2559}$$

Equation 18

$$\boldsymbol{Mass\ Flow\ Rate = \frac{(CFM)}{(v_{Return\ Air})} \times \left(\frac{60\ minutes}{hour}\right)}$$

Equation 19

$$Specific\ Volume\ (Return\ Air), [v_{Return\ Air}] = \frac{0.7543 \times (t_{db} + 459.67) \times (1 + 1.6078 \times W)}{P}$$

Equation 20

Note that if CFM (air flow) in Equation 19 is determined using method 2 determination (measured air speed and duct grill dimensions), then the above CFM value is calculated using Equation 21.

$$Air\ Flow, Method\ 2, [CFM] = Length \times Width \times Air\ Speed \times \left(\frac{1\ sq.ft.}{144\ sq.inch}\right)$$

Equation 21

$$Total\ Input\ Power\ [Power_{TO}] = Power_{Blower}^{(3)} + Power_{Condenser}$$

Equation 22

$$Blower\ Single\ Phase\ Power\ [Power_{Blower}] = Volts \times Amps \times PF$$

Equation 23

$$Condenser\ Three\ Phase\ Power\ [Power_{Blower}] = \frac{V_1 + V_2 + V_3}{3} \times \frac{A_1 + A_2 + A_3}{3} \times \sqrt{3} \times PF$$

Equation 24

$$Condenser\ Single\ Phase\ Power\ [Power_{Condenser}] = Volts \times Amps \times PF$$

Equation 25

$$Condenser\ Three\ Phase\ Power\ [Power_{Condenser}] = \frac{V_1 + V_2 + V_3}{3} \times \frac{A_1 + A_2 + A_3}{3} \times \sqrt{3} \times PF$$

Equation 26

$$EER\ Adjustment\ Factor = D_1 + D_2 \times A + D_3 \times B + D_4 \times A^2 + D_5 \times B^2 + D_6 \times A \times B$$

Equation 27

$$\boldsymbol{Capacity\ Adjustment\ Factor = C_1 + C_2 \times A + C_3 \times B + C_4 \times A^2 + C_5 \times B^2 + C_6 \times A \times B}$$

Equation 28

$$A = 10°\text{F} - \left(Wet\ Bulb_{Return\ Air} - Wet\ Bulb_{Supply\ Air}\right)$$

Equation 29

$$B = (95°\text{F} - Dry\ Bulb_{Oudoor})$$

Equation 30

[3] Blower power is only added if the AC system is split. If packaged, total input power is measured condenser power only as a packaged unit already includes the blower.

Where:

Cap_{Rated} = Rated nominal equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh

$Cap_{TO,C}$ = Measured cooling capacity after tune-up [Btuh]; 1 ton = 12,000 Btuh

$\eta_{pre,C}$ = Cooling efficiency of existing equipment before tune-up [Btuh/W]

$\eta_{post,C}$ = Cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI standard conditions [Btuh/W]

$\eta_{TO,C}$ = Cooling efficiency of existing equipment measured after tune-up [Btuh/W]

$\eta_{pre,H}$ = Heating efficiency of existing equipment before tune-up [HSPF]

$\eta_{post,H}$ = Heating efficiency of existing equipment after tune-up and adjusted to AHRI standard conditions [Btuh/W]. For this protocol $\eta_{post,H}$ is a mathematical estimate based on the proxy for cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI standard conditions (i.e., $\eta_{post,C}$)

Note: Use EER as efficiency "η_C" for kW and kWh cooling savings calculations. Use Heating Season Performance Factor (HSPF) as efficiency "η_H" for kW and kWh heating savings calculations.

$EFLH_{C/H}$ = Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Residential Volume 2 Table 2-37and Table 2-38); Nonresidential Volume 3 Table 2-16 through Table 2-20)

CF = Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Equations 49 and 50); Nonresidential Volume 3 Tables 2-16 through Table 2-20)

Volts = Measured voltage (Volts) on single-phase electric power leads to AC components

Amps = Measured current flow (Amps) on single-phase electric power leads to AC components

PF = Power factor stipulated based on motor type (see Table 2-2)

V_1, V_2, V_3 = Measured voltage, line to line on each of the three electric power leads (V_1, V_2, V_3) to AC components for 3-phase loads

A_1, A_2, A_3 = Measured current flow (Amps) on each line (A_1, A_2, A_3) of the three power leads to AC components for 3-phase loads

efficiency loss	=	*Efficiency loss factor; derived from a significant sample of field measurement data for units with versus without a refrigerant charge and commercial versus residential unit types (see* Table 2-1*)*
P	=	*Measured total pressure of moist air [inches Mercury]*
P_{ws}	=	*Saturation pressure over liquid water [psia]*
P_{atm}	=	*Atmospheric pressure [psia]*
v	=	*Specific volume of air [cu.ft./lb]*
Ln.	=	*Natural Logarithm*
e	=	*Natural Log constant (2.71828182845904523536028747135 27)*
Z	=	*Elevation-Altitude [feet]*
T	=	*Absolute temperature, Rankine scale* $[°R = °\mathrm{F} + 459.67]$
t_{db}	=	*Measured dry bulb temperature [°F]*
t_{wb}	=	*Measured wet bulb temperature [°F]*
$Wet\ Bulb_{Return\ Air}$	=	*Wet-bulb temperature of return air (load) to AC evaporator [°F]*
$Wet\ Bulb_{Supply\ Air}$	=	*Wet-bulb temperature of cooled supply air to indoor space [°F]*
$Dry\ Bulb_{Outdoor}$	=	*Dry-bulb temperature of outdoor air at time of tune-up [°F]*
$h_{Return\ Air}$	=	*Measured enthalpy of return air (load) to AC evaporator [Btu/lb]*
$h_{Suppy\ Air}$	=	*Measured enthalpy of cooled supply air to indoor space [Btu/lb]*
Mass Flow Rate	=	*Measured heat carrying capacity of moist return air [lb/hr]*
CFM	=	*AC supply/return air flow [cu.ft./min.] (Method 1 see Table 2-3)*
Length	=	*Measured length of duct grill long side [inches] (Method 2)*
Width	=	*Measure width of duct grill short side [inches) (Method 2)*
Air Speed	=	*Measured air velocity at duct grille [feet per second] (Method 2)*
95°F	=	*95 degrees Fahrenheit is the outdoor dry bulb temperature at AHRI test conditions*
10°F	=	*10 degrees Fahrenheit is the typical wet bulb temperature change across an evaporator coil at AHRI conditions*

Energy and Demand Savings Tables

Efficiency Loss Factors

The baseline efficiency conditions (η_{pre}) are calculated using the measured post service test-out (η_{TO}) and AHRI adjusted (η_{post}) value in combination with the appropriate *efficiency loss* value for that tune-up. The efficiency loss factors as described in Table 2-1 below are dependent on whether a refrigerant charge adjustment was made to the air conditioning unit as part of the tune-up. The efficiency loss factors are also different between unit sizes as well as distinct between the sector types. Therefore, efficiency losses should be developed separately for those with and without a refrigerant charge, and residential versus commercial units.

Table 2-1: AC Tune-Up Efficiency Loss Factors

Market Sector	Refrigerant Charge Adjusted
Residential	No
	Yes
Commercial	No
	Yes

Power Factors

Capturing power factors from units in the field can be difficult. Stipulating these factors is acceptable and suggested power factor values are presented by motor type for packaged and split system AC and heat pump units in Table 2-2.

Table 2-2: Recommended Power Factors for AC Components

Power Factors for AC Components	
Motor Type	**Power Factor**
Blower: Electrically Commutated Motor (ECM)	0.68
Blower: Permanent-Split Capacitor Motor (PSC)	0.98
Blower: Three Phase	0.98
Outdoor Condensing unit	0.85
Variable Frequency Drive (Single Phase)	0.87
Variable Frequency Drive (Three Phase)	0.65

Coincidence factor (CF) and equivalent full-load hour (EFLH) values

Residential: The reader is referred to Equations 45, 46, 48 and 49, Table 2-30 and Table 2-33 in Volume 2 of this TRM for deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values for residential building types by climate zone for central AC or heat pump units.

Nonresidential: The reader is referred to Tables 2-16 through 2-20 in Volume 3 of this TRM for deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values by building type and climate zone for packaged and split AC and heat pump units.

Cooling Load Calculation

The cooling capacity, $Cap_{TO,C}$, of the AC unit is calculated automatically from technician measurements at test-out by the data collection and tracking system software using supply and return air enthalpy measurements and the volumetric air flow (CFM) according to the Equation 19. There are two methods for estimating the air flow rate: method 1) direct air velocity measurements combined with air-grille dimensions times velocity (in feet per second) times 60 minutes per hour [CFM = *(grill area ft²)x (air speed in feet per minute)*]; or, method 2) the technician may select an estimate of air flow using manufacturer's fan charts.

The two methods for determining AC system airflow values following completion of the AC tune-up at test out are summarized in Table 2-3 below.

Table 2-3: AC Air Flow Determination Methods for Estimating Cooling Capacity at Test Out

Method for Estimating AC Air Flow	Data Source
Method 1: Handheld anemometer, grill dimension measurements; cfm calculation	L = Air intake grille length (in feet) W = Air intake grille width (in feet) S = Speed of airflow (feet per minute)
Method 2: Generic manufacturer fan charts	Select air flow (CFM) value based on closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower

Table 2-4: EER Adjustment Factor and Capacity Adjustment Factor Constants

EER Adjustment Factor and Capacity Adjustment Factor Constants[4]	
$C_1 = 1.013421588$	$D_1 = 1.003933337$
$C_2 = 0.017697661$	$D_2 = 0.016648337$
$C_3 = -0.006686796$	$D_3 = -0.006686796$
$C_4 = -0.000931159$	$D_4 = -0.000933205$
$C_5 = 8.04838 \times 10^{-5}$	$D_5 = 0.000222327$
$C_6 = -3.59283 \times 10^{-5}$	$D_6 = -0.000169511$

Table 2-5: Constants for Saturation Pressure Over Liquid Water Calculation

Saturation Pressure Over Liquid Water Constants[5]	
$C_8 = -1.0440397\text{ E} + 04$	$C_{11} = 1.2890360\text{ E}-05$
$C_9 = -1.1294650\text{ E} + 01$	$C_{12} = -2.4780681\text{ E}-09$
$C_{10} = -2.7022355\text{ E}-02$	$C_{13} = 6.5459673\text{ E} + 00$

[4] EER and Capacity AHRI adjustment factors and algorithms initially developed by Cadmus for Tune-Up programs in Texas.
[5] Developed by Cadmus: 2013 Portfolio Evaluation, Entergy Arkansas, Appendix A.

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein requires the use of equipment in accordance with the toolkit (with specified manufacturer and model numbers) to measure key AC performance parameters in the field. The use of these tools or equivalent ensures consistent data acquisition conformance by all parties. The equipment required in the toolkit is shown in Table 2-6 for reference.

Table 2-6: AC Tune-Up Toolkit Components

Device	Use Area	Quantity
Approved Digital Refrigerant Analyzer: ▪ Testo 556 ▪ Testo 560 ▪ Testo 550 ▪ iManifold 913-M and 914-M	Refrigerant Charge Adjustment Refrigerant Pressure Refrigerant Temperature Super Heat Subcooling	1-2
Test 318-V Inspection Scope	Visual Coil Inspection	Optional
Spring clamp probes matched to the Testo A/C Analyzer	Refrigerant Line Temperatures	2
Testo 417 Large Vane Anemometer	Airflow	1
Testo 605-H2 Humidity Stick Or iManifold 911-M	Supply and Return Air Wet Bulb Temperature	2
Refrigeration hoses 5' NRP 45 Deg.	Refrigerant Pressure	Set of 3
Charging Calculator (R-22)	Refrigerant Charge	1
Charging Calculator (R-410A)	Refrigerant Charge	1
Testo 905-T1 Temperature Stick or Testo 605H Humidity stick Or iManifold 912-M or wired Outdoor Air temperature probe	Ambient Air Temperature	1
Testo 510 Compact Digital Manometer (or other digital manometer of comparable accuracy)	Static Pressure	1
Magnetic Static Pressure Tips	Static Pressure	2
Set of barbed hose tees	Static Pressure	1
1/8 mpt x barbed fitting	Static Pressure	1
10' silicone tubing	Static Pressure	1
Digital Volt/ Amp Meter	Voltage and Current	1
Ruler / Tape Measure	Duct and Grill Dimensions	1
Tablet computer or smart phone if using iManifold; OR: laptop or desktop to use for data entry if using the Testo kit components	AC Tune-up Application	1

Metering Schedule

A complete metering schedule identifying the AC tune-up process and measurements performed for AC tune-ups is presented in Appendix E. The technician follows the metering schedule during the tune-up process.

Equipment Accuracy

The accuracy for each required piece of metering equipment is shown in Table 2-7.

Table 2-7: Measurement Resolution and Accuracy

Device	Model Number	Measurement	Resolution	Accuracy
Inspection Scope	Testo 318-V	Visual Coil Inspection	N/A	N/A
Anemometer	Testo 417	Air Flow Velocity	0.01m/s[1]	±0.1m/s+1.5% of reading[1]
Manometer	Testo 510	Differential pressure	0.01 inH2O[1]	±0.01 inH2O (0-0.12 inH2O), ±0.02 inH2O (0.13-0.40 inH2O), ±(0.04 inH2O +1.5 % of reading) (rest of range) [1]
Refrigerant System Analyzer	Testo 556	Refrigerant Temperature	0.1°F[1]	±0.6°F ±1 digit [1]
		Refrigerant Pressure	0.1 psi[1]	±0.5% Full Scale[1]
	Testo 560	Refrigerant Temperature	0.1°F[1]	±0.6°F ±1 digit [1]
		Refrigerant Pressure	0.1 psi[1]	±0.5% Full Scale[1]
	Testo 550	Refrigerant Temperature	0.1°F[1]	±1.8°F + 1 digit [1]
		Refrigerant Pressure	0.1 psi[1]	±0.75% Full Scale + 1 Digit[1]
	iManifold 913-M and 914-M	Refrigerant Temperature	0.1°F[5]	±0.4°F [5]
		Refrigerant Pressure	0.1 psi[5]	±0.5% Full Scale [5]
DB/WB Thermometer	Testo 605-H2	Dry/Wet Bulb	0.1°F[1]	±0.9°F[1]
	iManifold 911-M	Temperature	0.1°F[5]	±0.4°F[5]
Surface Thermometer	Testo 905-T2	Condenser Ambient Air	0.1°F[1]	±1.8°F (-58 to +212°F) [1]
	iManifold 912-M	Temperature	0.1°F[5]	±0.4°F[5]
Volt/Amp Meter	Fluke 27-II[2]	Voltage	0.1 V[3]	±(0.5% +3) [3]
		Current	0.01 A[3]	±(1.5% +2) [3]
Ruler / Tape Measure	N/A	Air Grill Dimensions	1/8 in[4]	±1/16 in[4]

[1] Obtained from Testo product manuals www.testo.us.
[2] Fluke 27-II not required, but volt/amp meter used must meet or surpass accuracy listed.
[3] Obtained from Fluke 27-II product manual: http://us.fluke.com.
[4] Ruler must have 1/8 inch graduations or less.
[5] Obtained from Imperial iManifold product website http://imanifold.com/product-specifications/.

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.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of residential and commercial AC tune-ups is 5 years.[6]

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: O&M
- Building Type
- Climate/Weather Zone
- Equipment Type
- Equipment Rated Cooling and Heating Capacities
- Equipment Cooling and Heating Efficiency Ratings
- Equipment Make and Model
- Refrigerant type
- Refrigerant adjustment (added/removed, weight)
- Note which five remaining AC tune-up service measures were completed
- Test-out measured cooling capacity
- Test-out measured power inputs
- Test-out measured mass flow rate
- All other operating measurements and parameters listed in M&V protocol

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment

[6] 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.

- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition and applicable to the tune-up measure include the following:
- Updated demand and energy coefficients for all commercial HVAC systems.
- 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.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- 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.

Document Revision History

Table 2-8: M&V AC Tune-Up Revision History

TRM Version	Date	Description of Change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Revised efficiency loss factors based on 2015 results. Added VFD motor types.
v5.0	10/10/2017	Removed reference to deemed efficiency loss factors. Added clarity to separate units by refrigerant charge adjustments and unit size/type. Updated table references.
v6.0	10/2018	No revisions.

2.1.2 Ground Source Heat Pumps Measure Overview

TRM Measure ID: NR-HV-GH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET)

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V and Whole Facility Measurement

This protocol is used to estimate savings for ground source heat pump (GSHP) measures through an M&V approach. The development of the GSHP M&V methodology is driven by the desire to create and implement a framework to provide high quality verified savings while not restricting the ability of program implementers to utilize the tools and systems they have developed. The protocol allows for flexibility in implementation while developing verified energy savings and balancing the risk associated with the uncertainty in the expected savings.

Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) system replacing an existing heating, ventilating, and air conditioning (HVAC) system. Initial estimated savings are dependent upon the energy efficiency ratings and operational parameters of the existing systems being replaced, by the new higher efficiency equipment efficiency ratings and operating parameters. The energy savings estimation process is designed to efficiently estimate electric energy and demand savings attributable to each GSHP system.

Applicable GSHP efficient measure types include:

- Single-Stage GSHP
- Multi-Stage GSHP
- Closed Loop GSHP
- Direct Geoexchange (DGX)
- Open Loop WSHP
- Water-to-Air
- Water-to-Water

Eligibility Criteria

This measure only applies to replacing an existing HVAC system with a new GSHP system. New construction GSHP systems are not eligible for applying this methodology.

Baseline Condition

Existing System Replacement: The baseline for retrofit projects is specific to the existing HVAC system being replaced by a new GSHP; that is, existing system manufacturer, model number, an AHRI nominal efficiencies, and operating parameters, define the baseline case.

High-Efficiency Condition

High-efficiency conditions for GSHP equipment must meet applicable standards. AHRI energy ratings for EER and COP by manufacturer model numbers are established following required test protocols and parameters, and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 2-9.

Water source heat pumps are verified using manufacturer specifications which clearly show the entering water temperature (EWT), gallons per minute (GPM), and the associated EER rating at ARI/ISO 13256-2 cooling conditions of 77°F EWT and 53.6°F leaving water temperature (LWT) ground loop.

Qualifying DXG GSHPs must be rated in accordance with AHRI 870 rating conditions.

Table 2-9: Minimum Efficiency Levels for Commercial Single Stage GSHPs[7]

System Type	Capacity (Btuh)	Cooling EWT Rating Condition	Minimum Cooling EER	Heating EWT Rating Condition	Minimum Heating COP
Water to Air (water loop)	< 17,000	86°F	12.2	68°F	4.3
	≥ 17,000 and < 135,000	86°F	13.0	68°F	4.3
Water to Air (groundwater)	< 135,000	59°F	18.0	50°F	3.7
Brine to Air (ground loop)	< 135,000	77°F	14.1	32°F	3.2
Water to Water (water loop)	< 135,000	86°F	10.6	68°F	3.7
Water to Water (groundwater)	< 135,000	59°F	16.3	50°F	3.1
Brine to Water (ground loop)	< 135,000	77°F	12.1	32°F	2.5

[7] Values from ASHRAE 90.1-2013.

Energy and Demand Savings Methodology

Whole Facility EM&V Methodology (Used to Estimate FINAL Savings Potential)

A whole facility EM&V methodology presents a plan for determining energy savings from replacing an existing HVAC system with a new GSHP system to provide heating and cooling for a commercial facility. This methodology measures and verifies initial energy savings estimates. The plan follows procedures guided by whole facility Option C in the International Performance Measurement and Verification Protocol (IPMVP). The development of the whole facility measurement methodology is driven by the desire to create and implement a framework to provide high quality verified savings while keeping within the standards currently used by similar commercial heating, ventilating, and air conditioning (HVAC) measures in TRM Volume 3. The Whole Facility guidance is found in the latest version of the IPMVP Volume 1 EVO 10000-1:2012.

M&V Plan and M&V Report

Preparation of an M&V plan and ultimately an M&V report is a required part of the savings determination. Advanced planning ensures that all data collection and information necessary for savings determination will be available after implementation of the measure(s). The project's M&V plan and M&V report provide a record of the data collected during project development and implementation. These documents may also serve multiple purposes throughout a project including recording critical assumptions and in case conditions change. Documentation should be complete, readily available, clearly organized and easy to understand.

The methodology described herein involves use of whole facility electric meter data. An important component of the project is to identify the existing base and new case system information.

In addition to documenting existing and new equipment information, IPMVP describes the following requirements as part of the M&V plan and M&V report contents. These requirements are listed below, and the user is directed to the current version of IPMVP for further detail and guidance.

- Measure Intent
- Selected IPMVP Option and Measurement Boundary
- Baseline—Period, Energy and Conditions
- Reporting Period
- Basis for Adjustment
- Analysis Procedure
- Energy Prices (as applicable)
- Meter Specifications
- Monitoring Responsibilities
- Expected Accuracy
- Budget (as applicable)
- Report Format

- Quality Assurance

The following equations will be used to calculate energy saving estimates:

$$\textbf{Peak } \boldsymbol{Demand\ Savings\ (kW)^{8} = kW_{Baseline} - kW_{New}}$$

Equation 31

Where:

$kW_{Baseline}$ = *The peak demand established for the measure load before the retrofit.*

kW_{New} = *The peak demand established for the measure load after the retrofit.*

$$Energy\ Savings\ (kWh) = kWh_{Baseline} - kWh_{New}$$

Equation 32

Where:

$kWh_{Baseline}$ = *Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year.*

kWh_{New} = *Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year.*

Savings Algorithms and Input Variables (Used to Estimate Initial Savings Potential ONLY)

The follow savings algorithms are provided and are only to be used as an initial means to estimate energy savings prior to measure implementation.

The algorithms utilize current deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values. The building type and climate zone must match those of the deemed look-up tables referenced herein. Otherwise, custom values for these inputs must be developed.

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

Equation 33

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

[8] TRM volume 1, section 4.2 provides a basis for estimating peak coincident demand reductions attributable to the implementation of energy efficiency measures in Texas. This is based on measure-specific load during the identified peak hours according to section 4.2.2.

Equation 34

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

Equation 35

$$Energy\ (Heating)[kWh_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times EFLH_H \times \frac{1kW}{3{,}412\ Btuh}$$

Equation 36

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

Equation 37

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

$$\eta_{pre,H/post,H} = COP = \frac{HSPF}{3.412}$$

Equation 38

Where:

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

$Cap_{post,C/H}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh];*

$\eta_{pre,C}$ = *Cooling efficiency of existing equipment [Btu/W](i.e., EER_{pre})*

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in Table 1-1) [Btu/W]*

$\eta_{pre,H}$ = *Heating efficiency of existing equipment [COP]*

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(Must exceed baseline efficiency standards in Table 1-1) [COP]*

$EFLH_{C/H}$ = *Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$CF_{C/H}$ = *Summer/winter peak coincidence factor for appropriate climate zone, building type, and equipment type (Refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$HSPF_{pre,H}$	=	*Heating Season Performance Factor (HSPF) of existing equipment [BTU/W]*
$HSPF_{post,H}$	=	*Heating Season Performance Factor (HSPF) of newly installed equipment [BTU/W]*
3.412	=	*The amount of British Thermal Units (Btu) per hour in one watt (1 W = 3.412 Btuh)*

Deemed Energy and Demand Savings Tables

Not Applicable.

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.

Additional Calculators and Tools

The regression software used for estimating annual energy use and demand should be clearly specified within the M&V plan and M&V report.

Measure Life and Lifetime Savings

The EUL for commercial split and packaged air conditioners and heat pumps is 15 years.[9]

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: ER System Type Conversion
- Building Type
- Climate Zone
- Baseline Equipment Type
- Baseline Equipment Rated Cooling and Heating Capacities
- Baseline Equipment Cooling and Heating Efficiency Ratings
- Baseline Number of Units
- Baseline Age and Method of Determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed Equipment Type

[9] A 15-year EUL is cited in several places: PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

- Installed Equipment Rated Cooling and Heating Capacities
- Installed Equipment Make and Model
- Installed Number of Units
- Installed Cooling and Heating Efficiency Ratings

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures.
- 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.

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.

Document Revision History

Table 2-10: M&V Ground Source Heat Pumps Revision History

TRM Version	Date	Description of Change
v3.1	11/05/2015	TRM v3.1 origin.
v4.0	10/10/2016	No revisions.
v5.0	10/10/2017	No revisions.
v6.0	10/2018	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.

2.1.3 Variable Refrigerant Flow Systems Measure Overview

TRM Measure ID: NR-HV-VR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Early Retirement (ER), New Construction (NC), and Replace-on-Burnout (ROB)

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V and Whole Facility Measurement, Calculator

This protocol is used to estimate savings for variable refrigerant flow systems (VRF) measures through an M&V approach. The development of the VRF M&V methodology is driven by the desire to create and implement a framework to provide high quality verified savings while not restricting the ability of program implementers to utilize the tools and systems they have developed. The protocol allows for flexibility in implementation while developing verified energy savings and balancing the risk associated with the uncertainty in the expected savings.

Measure Description

This measure requires the installation of a variable refrigerant flow (VRF) system replacing an existing heating, ventilating, and air conditioning (HVAC) system. Initial estimated savings are dependent upon the energy efficiency ratings and operational parameters of the existing systems being replaced, by the new higher efficiency equipment efficiency ratings and operating parameters. The energy savings estimation process is designed to efficiently estimate electric energy and demand savings attributable to each VRF system.

Applicable VRF efficient measure types include:

- Air-cooled systems where multiple compressors are connected to a single refrigerant loop
- Water-cooled where multiple compressors are connected to a single water-source loop, which allows heat recovery between compressor units

Eligibility Criteria

This measure applies to replacing an existing HVAC system with a new VRF system or a new construction VRF system.

Baseline Condition

Early Retirement: The baseline for retrofit projects is specific to the existing HVAC system being replaced by a new VRF; that is, existing system manufacturer, model number, an AHRI nominal efficiencies, and operating parameters, define the baseline case. Alternatively, the use of a prescriptive savings calculation procedure for savings is allowed for existing system replacements, but the baseline must follow the New Construction/Replace-on-Burnout procedure.

Replace-on-Burnout (ROB) and New Construction (NC): The baseline for ROB or NC projects is a code-minimum VRF system as specified by ASHRAE 90.1-2013. VRF system minimum efficiencies are not currently covered by IECC 2015. Minimum efficiency conditions are shown in Table 2-11 below. See the Deemed Energy and Demand Savings section below for more details.

High-Efficiency Condition

High-efficiency conditions for VRF equipment must meet applicable standards. AHRI energy ratings for EER and COP by manufacturer model numbers are established following required test protocols and parameters, and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 2-11. Both air cooled and water cooled systems are rated per AHRI Standard 1230.

Table 2-11: Baseline Efficiency Levels for Electrically Operated VRF ACs and HPs

System Type	Capacity [Btu/h]	Heating Section Type	Subcategory or Rating Condition	Baseline Efficiencies	Source
VRF Air Conditioners, Air Cooled	< 65,000	All	VRF multisplit system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-9
	≥ 65,000 and < 135,000	None or Electric Resistance		11.2 EER 13.1 IEER	
	≥ 135,000 and < 240,000			11.0 EER 12.9 IEER	
	≥ 240,000			10.0 EER 11.6 IEER	
VRF Air Cooled (cooling mode)	< 65,000	All	VRF multisplit system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000	None or Electric Resistance	VRF multisplit system	11.0 EER 12.3 IEER	
			VRF multisplit system with heat recovery	10.8 EER 12.1 IEER	
	≥ 135,000 and < 240,000		VRF multisplit system	10.6 EER 11.8 IEER	
			VRF multisplit system with heat recovery	10.4 EER 11.6 IEER	

System Type	Capacity [Btu/h]	Heating Section Type	Subcategory or Rating Condition	Baseline Efficiencies	Source
VRF Water Source (cooling mode)	≥ 240,000	All	VRF multisplit system	9.5 EER 10.6 IEER	ASHRAE 90.1-2013 Table 6.8.1-10
			VRF multisplit system with heat recovery	9.3 EER 10.4 IEER	
	< 65,000		VRF multisplit system 86°F entering water	12.0 EER	
			VRF multisplit system with heat recovery 86°F entering water	11.8 EER	
	≥ 65,000 and < 135,000		VRF multisplit system 86°F entering water	12.0 EER	
			VRF multisplit system with heat recovery 86°F entering water	11.8 EER	
	≥ 135,000		VRF multisplit system 86°F entering water	10.0 EER	
			VRF multisplit system with heat recovery 86°F entering water	9.8 EER	
VRF Air Cooled (heating mode)	< 65,000 (cooling capacity)	-	VRF multisplit system	7.7 HSPF	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multisplit system 47°F db/43°F wb outdoor air	3.3 COP_H	
			VRF multisplit system 17°F db/15°F wb outdoor air	2.25 COP_H	
	≥ 135,000 (cooling capacity)		VRF multisplit system 47°F db/43°F wb outdoor air	3.2 COP_H	
			VRF multisplit system 17°F db/15°F wb outdoor air	2.05 COP_H	
VRF Water Source (heating mode)	< 135,000 (cooling capacity)	-	VRF multisplit system 68°F entering water	4.2 COP_H	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 135,000 (cooling capacity)		VRF multisplit system 68°F entering water	3.9 COP_H	

Energy and Demand Savings Methodology

Whole Facility EM&V Methodology (Used to Estimate FINAL Savings Potential)

A whole facility EM&V methodology presents a plan for determining energy savings from replacing an existing HVAC system with a new VRF system to provide heating and cooling for a commercial facility. This methodology measures and verifies initial energy savings estimates. The plan follows procedures guided by whole facility Option C in the International Performance Measurement and Verification Protocol (IPMVP). The development of the whole facility measurement methodology is driven by the desire to create and implement a framework to provide high quality verified savings while keeping within the standards currently used by similar commercial heating, ventilating, and air conditioning (HVAC) measures in TRM Volume 3. The Whole Facility guidance is found in the latest version of the IPMVP Volume 1 EVO 10000-1:2012.

M&V Plan and M&V Report

Preparation of an M&V plan and ultimately an M&V report is a required part of the savings determination. Advanced planning ensures that all data collection and information necessary for savings determination will be available after implementation of the measure(s). The project's M&V plan and M&V report provide a record of the data collected during project development and implementation. These documents may also serve multiple purposes throughout a project including recording critical assumptions and in case conditions change. Documentation should be complete, readily available, clearly organized and easy to understand.

The methodology described herein involves use of whole facility electric meter data. An important component of the project is to identify the existing base and new case system information.

In addition to documenting existing and new equipment information, IPMVP describes the following requirements as part of the M&V plan and M&V report contents. These requirements are listed below, and the user is directed to the current version of IPMVP for further detail and guidance.

- Measure Intent
- Selected IPMVP Option and Measurement Boundary
- Baseline—Period, Energy and Conditions
- Reporting Period
- Basis for Adjustment
- Analysis Procedure
- Energy Prices (as applicable)
- Meter Specifications
- Monitoring Responsibilities
- Expected Accuracy
- Budget (as applicable)
- Report Format

- Quality Assurance

The following equations will be used to calculate energy saving estimates:

$$\boldsymbol{Peak\ Demand\ Savings\ (kW)^{10} = kW_{Baseline} - kW_{New}}$$

Equation 39

Where:

$kW_{Baseline}$ = *The peak demand established for the measure load before the retrofit.*

kW_{New} = *The peak demand established for the measure load after the retrofit.*

$$Energy\ Savings\ (kWh) = kWh_{Baseline} - kWh_{New}$$

Equation 40

Where:

$kWh_{Baseline}$ = *Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year.*

kWh_{New} = *Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year.*

Savings Algorithms and Input Variables (Used to Estimate Initial Savings Potential ONLY)

The follow savings algorithms are provided and are only to be used as an initial means to estimate energy savings prior to measure implementation.

The algorithms utilize current deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values. The building type and climate zone must match those of the deemed look-up tables referenced herein. Otherwise, custom values for these inputs must be developed.

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

Equation 41

[10] TRM volume 1, section 4.2 provides a basis for estimating peak coincident demand reductions attributable to the implementation of energy efficiency measures in Texas. This is based on measure-specific load during the identified peak hours according to section 4.2.2.

$$WinterPeak\ Demand\ Savings\ [kW_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times CF_H \times \frac{1kW}{3{,}412\ Btuh}$$

Equation 42

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

Equation 43

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

Equation 44

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

Equation 45

Note: Use EER as efficiency value for kW savings calculations and SEER/IEER and COP as efficiency value for kWh savings calculations. The COP expressed for units > 65,000 Btu/h 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:

$$\eta_{pre,H/post,H} = COP = \frac{HSPF}{3.412}$$

Equation 46

Where:

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

$Cap_{post,C/H}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh];*

$\eta_{pre,C}$ = *Cooling efficiency of existing equipment [Btu/W](i.e., EER_{pre})*

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in Table 1-1) [Btu/W]*

$\eta_{pre,H}$ = *Heating efficiency of existing equipment [COP]*

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(Must exceed baseline efficiency standards in Table 1-1) [COP]*

$EFLH_{C/H}$ = *Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$CF_{C/H}$	=	*Summer/winter peak coincidence factor for appropriate climate zone, building type, and equipment type (Refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*
$HSPF_{pre,H}$	=	*Heating Season Performance Factor (HSPF) of existing equipment [BTU/W]*
$HSPF_{post,H}$	=	*Heating Season Performance Factor (HSPF) of newly installed equipment [BTU/W]*
3.412	=	*The amount of British Thermal Units (Btu) per hour in one watt (1 W = 3.412 Btuh)*

Deemed Energy and Demand Savings

For new construction, renovation, or existing system replacements (as an alternative compliance path), the use of a deemed savings procedure is available for claiming VRF system efficiency above code minimum efficiencies. The methodology is identical to TRM Volume 3 Split System/Single Packaged Air Conditioners and Heat Pumps by substituting the efficiencies from Table 2-11 as the baseline efficiencies for the New Construction and Replace on Burnout Energy and Demand Savings Methodology.

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.

Additional Calculators and Tools

The regression software used for estimating annual energy use and demand should be clearly specified within the M&V plan and M&V report.

Measure Life and Lifetime Savings

The EUL for commercial split and packaged air conditioners and heat pumps is 15 years.[11]

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type; ER, ROB, NC, System Type Conversion
- Building Type
- Climate Zone
- Baseline Equipment Type

[11] A 15-year EUL is cited in several places: PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

- Baseline Equipment Rated Cooling and Heating Capacities
- Baseline Equipment Cooling and Heating Efficiency Ratings
- 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 Equipment Make and Model
- Installed Number of Units
- Installed Cooling and Heating Efficiency Ratings
- 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 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures.
- 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.

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-9 through Table 6.8.1-10.
- 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.
- ANSI/AHRI Standard 1230, 2010 Standard for Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment, http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/ANSI/ANSI_AHRI_Standard_1230_2010_with_Add_2.pdf

Document Revision History

Table 2-12: M&V Variable Refrigerant Systems Revision History

TRM Version	Date	Description of Change
v5.0	10/10/2017	TRM v5.0 origin.
v6.0	10/2018	Minor formula corrections.

2.2 M&V: WHOLE HOUSE

2.2.1 Residential New Construction Measure Overview

TRM Measure ID: R-HS-NH

Market Sector: Residential

Measure Category: Whole-House

Applicable Building Types: Single-Family; Manufactured

Fuels Affected: Electricity and Gas

Decision/Action Types: New Construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: For this measure, savings are not deemed and are estimated based on each house's specific characteristics and parameters.

Savings Methodology: EM&V and Whole-House Simulation Modeling

This M&V protocol details the estimation of savings for residential new construction projects. The protocol may be applied to the construction of single-family detached homes, multifamily buildings, or individual units within new multifamily buildings. The residential new construction M&V methodology seeks to create and implement a framework to provide high quality verified savings while not restricting the ability of residential new construction program implementers to utilize the tools and systems they have developed. The protocol allows for flexibility in implementation while developing verified energy savings and balancing the risk associated with uncertainty in the expected savings. The M&V methodology supports the following M&V goals for the new multifamily buildings programs:

- Improve reliability of savings estimates;
- Determine whether energy and peak demand savings goals have been met; and
- Inform future program planning processes

Streamlined measurement and verification of residential new construction shall leverage a model-based approach to energy savings for each home and adhere to typical IPMVP protocols. Modelling software new to the Texas new multifamily building market must be vetted through the EM&V team. Current software approved by the EM&V team include:

- BeOpt[12]
- RESNET accredited software
- Hourly analysis programs tested in accordance with ASHRAE 140 and meeting the requirements of ASHRAE 90.1 Appendix G (i.e., DOE-2, EnergyPlus, HAP, TRACE, IESVS, etc.)[13]

[12] Applicable for the modeling of individual multifamily dwelling units.

[13] Applicable for the modeling of multifamily buildings or portions thereof.

Additionally, implementers are permitted to use spreadsheets and algorithms that enhance the underlying modeling software as part of a larger modeling package. Such enhancements to modeling packages must also be approved by the EM&V team. Updates to the underlying models or model enhancements shall be reviewed by the EM&V team prior to acceptance of subsequent savings stemming from those changes. Documentation shall be provided by the implementer with features considered trade secret subject to approval by the EM&V team, though kept confidential.

Residential new construction projects participating in energy efficiency programs in Texas should be designed and built to standards well above those applied to standard residential new construction projects in the Texas market. A new, energy efficient Texas multifamily building should have undergone a process of inspections, testing, and verification that meet strict program requirements.

Measure Description

The Residential New Construction measure promotes a holistic approach to achieving energy efficient new homes, including a combination of envelope and equipment-based improvements to reduce home energy use. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating new home.

Eligibility Criteria

This measure does not apply to existing construction: only residential new construction projects to be completed in a given program year are eligible.[14]

This measure is to be applied to multifamily buildings, and portions thereof, based on the Implementation Guidance in Section 4.4 Multifamily of Volume 5 of the TRM.

Baseline Condition[15]

Broadly, baseline conditions for the building system (e.g., envelope materials and fenestration characteristics) are set according to relevant codes and standards. For single family detached homes and residential multifamily buildings three stories or less, these standards are detailed in the Residential Provisions of IECC 2015. As this protocol requires simulation modeling, the provisions of Section R405—Simulated Performance Alternative—are of particular importance. For larger multifamily buildings, the baseline conditions established herein reference the relevant sections of ASHRAE 90.1-2013 and the Commercial Provisions of IECC 2015. Federal manufacturing standards are reflected in the equipment efficiency requirements for space conditioning and water heating equipment. Additionally, the program requirements of reference programs for this market, such as the Energy Star New Homes, inform some baseline requirements.

Accordingly, baseline parameters and key model input values for new single family detached homes and residential multifamily buildings three stories or less are detailed in Table 2-13.

[14] In limited cases, townhomes that are constructed as part of a larger multifamily property may qualify under this measure.

[15] Baseline parameters are subject to change with updates to the relevant energy code.

Baseline parameters and key model input values for new residential multifamily buildings of more than three stories (and portions thereof/units within) are detailed in Table 2-14.

Exception:[16] Multifamily buildings with 4 or 5 stories above-grade[17] where dwelling units occupy 80% or more of the occupiable square footage of the building may select the most appropriate baseline condition. When evaluating mixed–use buildings for eligibility, exclude commercial/retail space when assessing whether the 80% threshold has been met.

Table 2-13 and Table 2-14: When a new statewide energy code is adopted by the State Energy Conservation Office (SECO), the baseline parameters for residential whole-house measures must be updated to reflect this change. Recognizing that it takes time for new energy codes to be locally adopted and enforced, this M&V methodology requires the new code as baseline for the next program year cycle, but not less than twelve months from the energy code effective date. Effective September 1, 2016, Texas adopted 2015 IECC.[13] From a TRM perspective, the new construction baseline condition change is effective January 1, 2018.

If a baseline study has been conducted since the adoption of the current statewide code that demonstrates standard practice different than the statewide energy code, the researched baseline may be used as the baseline from which to claim savings for the researched jurisdiction(s) subject to the review and approval of the EM&V team.

If a residential new construction project received a Building Permit prior to January 1, 2018, the 2009 IECC baseline may be used as the baseline from which to claim savings.

Ideally, the relevant energy code will be tracked in the program tracking system. Alternatively, it may be tracked as part of project documentation made available to evaluators upon request. Changes to baseline conditions from Table 2-13 and Table 2-14: or changes to the implementation of baseline conditions within an approved modeling package is allowable, and subject to EM&V team approval.

Table 2-13: New SF and MF Construction up to 3 Stories—Baseline Characteristics

Baseline and Dwelling Parameters and Characteristics	Baseline Specification/Value
	Envelope
Number of Stories Above Grade 1	Same as As-Built
Foundation Type	Same as As-Built
Number of Bedrooms	Same as As-Built
Total Conditioned Floor Area	Same as As-Built
Total Conditioned Volume	Same as As-Built
Wall Height Per Floor	Same as As-Built

[16] Exception aligns with ENERGY STAR Certified Homes National Program Requirements.

[17] Any above-grade story with 20% or more occupiable space, including commercial space, shall be counted towards the total number of stories for the purpose of determining eligibility to participate in the program. The definition of an 'above-grade story' is one for which more than half of the gross surface area of the exterior walls is above-grade. All below-grade stories, regardless of type, shall not be included when evaluating eligibility.

Baseline and Dwelling Parameters and Characteristics	Baseline Specification/Value
Window Distribution (N,S,E,W)	Same as As-Built
Percentage Window to Floor Area	Same as As-Built
Front Door Orientation	Same as As-Built
Aspect Ratio (Length / Width)	Use the same estimated average aspect ratio for both baseline and as-built. However, it is recommended to use actual aspect ratio when actual house footprint dimensions are available.
Roof Solar Absorptivity	Same as As-Built. When as-built data is not available, use 0.75.
Attic Insulation R-Value	See IECC 2015, Table R402.1.2
Cathedral Ceiling Insulation R-Value	R-30
Percentage Cathedral Ceilings	Same as As-Built, which should be limited to lesser of 500 square feet or 20% of total insulated ceiling area as per section R402.2.2
Wall Construction	Wood Frame.
Wall Framing Fraction	23%
Wall Insulation and Sheathing	See IECC 2015, Table R402.1.2
Wall Insulation Grade	3
Door R-Value	Same as As-Built.
Floor Insulation	See IECC 2015, Table R402.1.2
Rim Joist	Same as wall insulation and wall sheathing
Window U Factor	See IECC 2015 Table R402.1.2
Window SHGC	See IECC 2015 Table R402.1.2
Air Infiltration	5 ACH_{50} in IECC 2015 CZ 2, 3 ACH_{50} in IECC 2015 CZ 3-4
Mechanical Ventilation	Annual vent fan energy use: kWh/yr. = 0.3942 x CFA + 29.565 x (N_{br} + 1) where: CFA = conditioned floor area N_{br} = number of bedrooms
Slab Edge Insulation	See IECC 2015, Table R402.1.2
	HVAC Equipment
HVAC Equipment Type	Same as As-Built, except where As-Built home has electric resistance heat, in which case the reference home shall have an air source heat pump.[18]

[18] A baseline study for the multifamily market documenting prevalence of electric resistance units going into that segment in given climate zones would be sufficient to override this requirement.

Baseline and Dwelling Parameters and Characteristics	Baseline Specification/Value
Cooling Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Heating Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Cooling Efficiency (SEER)	14
Heating Efficiency (AFUE)	78% AFUE or 80% E_t
Heating Efficiency (HSPF) - Heat Pump	8.2
Duct Location	100% Unfinished Attic
Duct R-Value	R-8
Total Duct Leakage	4 CFM per 100 ft^2 of Conditioned Floor Area or Equivalent Leakage Based on Standard Assumption
Thermostat Type	Programmable thermostat
Heating Setpoint	70°F
Cooling Setpoint	78°F
Water Heating System	
DHW Fuel Type	Same as As-Built
DHW Capacity (Gallons)	Same as As-Built for storage-type units. Assume a 40-gallon storage water heater when as-built water heater is instantaneous.
Energy Factor (EF)	Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[19]) as of April 16, 2015
DHW Temperature	125°F
DHW Pipe Insulation	R-3
Low Flow Shower Heads	None
Lighting	
High efficacy lamps	75% of permanently installed fixtures
Appliances	
Ceiling fans	70.4 CFM per Watt

[19] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

Table 2-14: New Multifamily Buildings greater than 3 Stories—Baseline Characteristics

Baseline and Dwelling Parameters and Characteristics	Baseline Specification/Value
	Envelope
Unit Type	Multifamily Building
Number of Stories Above Grade 1	Same as As-Built
Foundation Type	Same as As-Built
Number of Bedrooms	Same as As-Built
Total Conditioned Floor Area	Same as As-Built
Total Conditioned Volume	Same as As-Built
Wall Height Per Floor	Same as As-Built
Window Distribution (N,S,E,W)	Same as As-Built
Percentage Window to Floor Area	Same as As-Built
Front Door Orientation	Same as As-Built
Aspect Ratio (Length / Width)	Use the same estimated average aspect ratio for both baseline and as-built. However, it is recommended to use actual aspect ratio when actual house footprint dimensions are available.
Roof Solar Absorptivity	Same as As-Built. When as-built data is not available, use 0.75.
Attic Insulation U-Value	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Cathedral Ceiling Insulation U-Value	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Percentage Cathedral Ceilings	Same as As-Built
Wall Construction	2x4 light gauge metal framing – 16 inch on center spacing
Wall Framing Fraction	23%
Wall Insulation	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Door R-Value	Same as As-Built.
Floor Insulation	ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Rim Joist	Same as wall insulation
Window U Factor	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Window SHGC	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
Air Infiltration	Same as Proposed
Mechanical Ventilation	See ASHRAE 90.1-2013, Appendix G

Baseline and Dwelling Parameters and Characteristics	Baseline Specification/Value
Slab Edge Insulation	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on Climate Zone
	HVAC Equipment
HVAC Equipment Type	See ASHRAE 90.1-2013, Table G3.1.1A/G3.1.1B
Cooling Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Heating Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Cooling Efficiency	See ASHRAE 90.1-2013, Section 6.8
Heating Efficiency	See ASHRAE 90.1-2013, Section 6.8
Thermostat Type	Same as As-Built
Heating Setpoint (Occ/Unoc)	70°F/70°F
Cooling Setpoint (Occ/Unoc)	78°F/80°F
	Water Heating System
DHW Fuel Type	Same as As-Built
DHW Capacity (Gallons)	Same as As-Built for Storage. Assume a 50-gallon storage water heater when as-built water heater is instantaneous.
Energy Factor (EF)	See ASHRAE 90.1-2013, Table 7.8
DHW Temperature	120°F
DHW Pipe Insulation	None
Low Flow Shower Heads	None
	Lighting
High efficacy lamps	0.51 Watts per ft^2

High-Efficiency Condition

The high-efficiency conditions are according to the as-built building's parameters and characteristics.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

House Simulation Modeling

Two simulation models should be developed for each residential new construction project or multifamily dwelling unit of building, as appropriate, utilizing an appropriate modeling package software. The first model simulates the baseline home's annual energy use and demand, while the second simulates the as-built home. The energy and demand savings are the difference in annual energy use between the as-built dwelling unit or building and the baseline dwelling unit or building.

Energy Savings Methodology

Energy savings are estimated utilizing whole-building simulation modeling based on on-site specific data collection, such as those data collected by HERS Raters.

Summer Demand Savings Methodology

Summer peak demand savings are estimated utilizing whole-building simulation modeling based on on-site data collection and load shape profiles for the specific climate zone.

Winter Demand Savings Methodology

Winter peak demand savings are estimated utilizing whole-building simulation modeling based on on-site data collection and load shape profiles for the specific climate zone.

Post-Processing for Calculating Demand and Energy Savings

Annual energy savings should be calculated as the difference between the simulated annual energy use of the baseline and as-built building for all energy end uses for each dwelling unit or building. Electricity consumption and savings shall be expressed in kilowatt hours (kWh).

Peak demand savings should be extracted from the hourly data file in a manner consistent with the definition of peak demand incorporated in TRM 3.0 and the associated methods for extracting peak demand savings from models producing 8,760 hourly savings using Typical Meteorological Year (TMY) data. Peak demand savings shall be expressed in kilowatts (kW).

Deemed Energy and Demand Savings Tables

This section is not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

EM&V team approved residential modeling package software should be used to simulate the baseline and as-built home's annual energy use and demand.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a new home measure is established at 23.0 years

Program Tracking Data and Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked to inform the evaluation and apply the savings properly. While they do not need to be tracked in the program database, they must be in a format easily made available to evaluators.

- Date of issuance of building permit
- Statewide Energy Code under which the building was built
- Building Envelope
  - Dwelling Unit Type
  - House Footprint Dimensions
  - Number of Stories Above Grade 1
  - Foundation Type
  - Number of Bedrooms
  - Total Conditioned Floor Area
  - Total Conditioned Volume
  - Wall Height Per Floor
  - Window Distribution (N,S,E,W)
  - Front Door Orientation
  - Aspect Ratio (Length / Width)—when available
  - Roof Solar Absorptivity—when available
  - Attic Insulation R-Value
  - Cathedral Ceiling Insulation R-Value
  - Percentage Cathedral Ceilings
  - Ceiling Insulation Grade
  - Wall Construction
  - Wall Framing Fraction
  - Wall Insulation (R-Value)
  - Wall Insulation Grade
  - Door Material (Wood, Metal, Vinyl, and whether Solid Core or Hollow)—when available
  - Rim Joist
  - Window U Factor
  - Window SHGC
  - Air Infiltration
  - Mechanical Ventilation
  - Slab Edge Insulation—only for houses located in IECC climate zone 4

- HVAC Equipment
  - HVAC Equipment Type
  - AHRI Number of Installed HVAC Equipment—in the absence of an AHRI number, manufacturers' cut sheets and/or make and model numbers should be provided instead.
  - Cooling Capacity
  - Heating Capacity
  - Cooling Efficiency (SEER)
  - Heating Efficiency (AFUE), and HSPF for Heat Pumps
  - Duct Location
  - Duct Insulation R-Value
  - Duct Leakage to Outside (CFA)
  - Heating Set-Point Temperature(s) (°F)
  - Cooling Set-Point Temperature(s) (°F)
  - Thermostat Type (Setback or No Setback)
  - Supply Fan Power (W/CFM)
- Water Heating System
  - Water Heating Systems
  - AHRI Number of Installed Water Heating Equipment—Raters should verify the Energy Factor (EF) on-site during the final inspection; as part of the implementer QA/QC protocol, verify the AHRI information
  - DHW Fuel Type
  - DHW Capacity (Gallons)
  - Energy Factor
  - DHW Set-Point Temperature
  - DHW Pipe Insulation
  - Number of Low Flow Shower Heads and flow rate
  - Number of Low Flow Faucets and flow rate
- Lighting
  - Number of sockets with high efficacy lamps or lighting power density, as appropriate.
- Appliances
  - Number of ceiling fans
  - Refrigerator Model Number
  - Dishwasher Model Number
  - Clothes Washer Presence

- Clothes Washer Model Number

Files to Submit for EM&V Review

The following files should be provided to the utility from which the project sponsor seeks to obtain an incentive for each new home completed:

- Reports of QA/QC or M&V
- Documentation for how the as-built home compares to the base home, and modeling and energy savings information
- Relevant modeling files from the approved modeling package
- All input data used to support the modeled energy and peak demand savings, subject to EM&V team approval as part of modeling package approval
- Output results describing energy and peak demand savings, subject to EM&V team approval as part of modeling package approval
- Savings calculations and/or calculators that perform energy savings calculation outside the model

References and Efficiency Standards

RESNET accredited software:

http://www.resnet.us/professional/programs/energy_rating_software

ASHRAE 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*

ASHRAE 140, Standard Method of Test for the Evaluation of Building Energy Analysis Programs

ENERGY STAR Multifamily High Rise Program Simulation Guidelines

International Code Council, *2015 International Energy Conservation Code*.

Petitions and Rulings

Relevant Standards and Reference Sources

Not applicable.