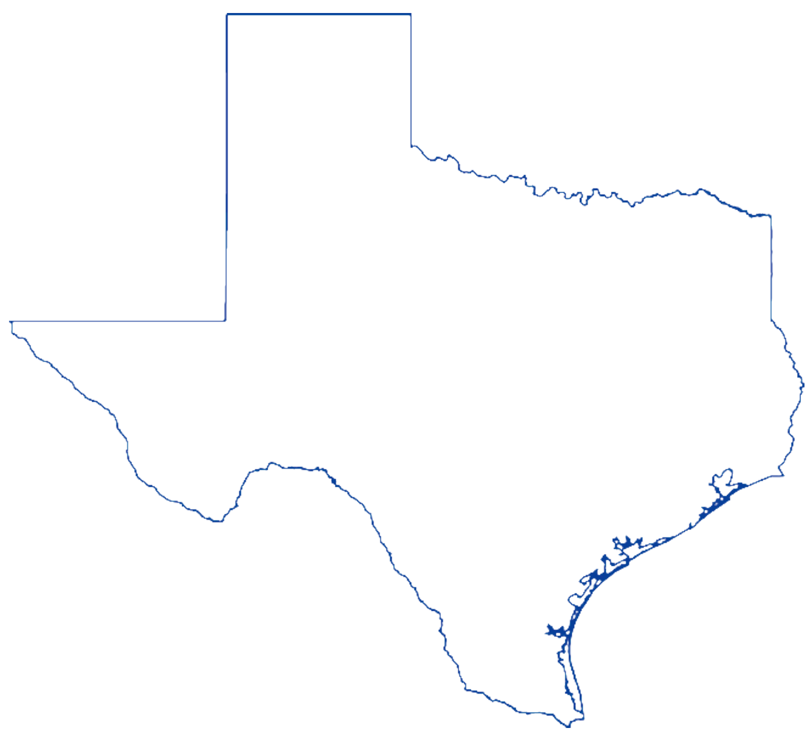
Public Utility Commission of Texas

Texas Technical Reference Manual

Version 9.0

Volume 4: Measurement and Verification Protocols

Program Year 2022



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Acknowledgments

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

This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Energy (TXu 1-904-705), ICF, CLEAResult, and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2016 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 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
- Miscellaneous: Commercial Retro-commissioning
- Miscellaneous: Thermal Energy Storage
- Load Management: Residential Load Curtailment
- Load Management: Nonresidential Load Curtailment

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. TRM Volume 1: Overview and User Guide, Section 4: Structure and Content details the organization of the measure templates presented in this volume.

Table 1. Residential and Nonresidential M&V Savings by Measure Category

Sector	Measure category	Measure description	9.0 update
Residential and nonresidential	HVAC	Air conditioning tune-ups	No revisions
Nonresidential	HVAC	Ground source heat pumps	No revisions
Nonresidential	HVAC	Variable refrigerant flow systems	No revisions
Residential	Whole house	Residential new construction	For reference home specification, added HVAC commissioning and dehumidification system
Residential and nonresidential	Renewables	Residential and nonresidential solar photovoltaics	Clarified PVWatts® kWh modeling instructions and documentation requirements; provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges
Residential and nonresidential	Renewables	Solar shingles	No revisions
Residential	Renewables	Solar attic fans	Reinstate measure requiring M&V data collection
Nonresidential	Miscellaneous	Behavioral	Updated model requirements to account for pandemic and other non-routine events
Nonresidential	Miscellaneous	Air compressors less than 75 hp	No revisions
Nonresidential	Miscellaneous	Commercial retro-commissioning	Updated model requirements to account for pandemic and other non-routine events
Nonresidential	Miscellaneous	Thermal energy storage	No revisions
Residential	Load management	Residential load curtailment	Added peak demand period by utility; added links to program manuals
Nonresidential	Load management	Nonresidential load curtailment	Added eligibility exclusion for critical load customers and removed tables detailing the utility programs; updated links to program manuals

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 and maintenance (O&M)

Program Delivery Type(s): Custom

Deemed Savings Type: Deemed efficiency loss factors are applied to measured operating performance indicators 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 improve 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 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 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 a three-year rolling average. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating AC tune-up unit. Following the completion of the six service measures, the M&V methodology for tune-ups requires 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 six 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 (split and packaged air conditioner and heat pump systems) that receive the tune-up. 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).

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

[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.

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

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

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

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 (airflow) in Equation 19 is determined using method 2 (measured airspeed 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

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

Equation 28

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

Equation 29

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

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 16); Nonresidential Volume 3 Table 32 through Table 36)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Table 17); Nonresidential Volume 3 Tables 32 through Table 36)*
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 3)*
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 three-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 three-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*)*
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 (2.7182818284590452353602874713527)*
Z	=	*Elevation altitude [feet]*
T	=	*Absolute temperature, Rankine scale* $[°R = °\mathrm{F} + 459.67]$
t_{db}	=	*Measured dry-bulb temperature [ºF]*
t_{wb}	=	*Measured wet-bulb temperature [ºF]*
$Wet\ Bulb_{Return\ Air}$	=	*Wet-bulb temperature of return air (load) to AC evaporator [ºF]*
$Wet\ Bulb_{Supply\ Air}$	=	*Wet-bulb temperature of cooled supply air to indoor space [ºF]*
$Dry\ Bulb_{Outdoor}$	=	*Dry-bulb temperature of outdoor air at time of tune-up [ºF]*
$h_{Return\ Air}$	=	*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 4)*
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)*

95ºF = *95°F is the outdoor dry-bulb temperature at AHRI test conditions*

10ºF = *10°F 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 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. 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 3.

Table 3. 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 TRM Volume 2 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 TRM Volume 3 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 airflow (CFM) according to Equation 19. There are two methods for estimating the airflow 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* ft^2*)x (airspeed in feet per minute)*]. Method 2: The technician may select an estimate of airflow 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 4 below.

Table 4. 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 airflow (CFM) value based on the closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower

Table 5. 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 6. Constants for Saturation Pressure Over Liquid Water Calculation

Saturation pressure over liquid water constants[5]	
$C_8 = -1.0440397\ \mathrm{E}+04$	$C_{11} = 1.2890360\ \mathrm{E}-05$
$C_9 = -1.1294650\ \mathrm{E}+01$	$C_{12} = -2.4780681\ \mathrm{E}-09$
$C_{10} = -2.7022355\ \mathrm{E}-02$	$C_{13} = 6.5459673\ \mathrm{E}+00$

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein require 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 7 for reference.

[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.

Table 7. 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
Testo 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 smartphone 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 M&V Metering Schedule. 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 8.

Table 8. 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[6]	Air flow velocity	0.01m/s	±0.1m/s+1.5% of reading
Manometer	Testo 510[6]	Differential pressure	0.01 inH2O	±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)
Refrigerant system analyzer	Testo 556[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 560[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 550[6]	Refrigerant temperature	0.1°F	±1.8°F + 1 digit
		Refrigerant pressure	0.1 psi	±0.75% Full Scale + 1 Digit
	iManifold 913-M and 914-M[7]	Refrigerant temperature	0.1°F	±0.4°F
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
DB/WB thermometer	Testo 605-H2[6]	Dry-/wet-bulb temperature	0.1°F	±0.9°F
	iManifold 911-M[7]		0.1°F	±0.4°F
Surface thermometer	Testo 905-T2[6]	Condenser ambient air temperature	0.1°F	±1.8°F (-58 to +212°F)
	iManifold 912-M[7]		0.1°F	±0.4°F
Volt/amp meter	Fluke 27-II[8]	Voltage	0.1 V	±(0.5% +3)
		Current	0.01 A	±(1.5% +2)
Ruler/tape measure	N/A	Air grill dimensions[9]	1/8 in	±1/16 in

Claimed Peak Demand Savings

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

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

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.[10]

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

Not applicable.

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. 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.

[10] 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 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

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. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 9. 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 the 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.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	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 use 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 when 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 10.

Water source heat pumps are verified using manufacturer specifications that 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 10. Minimum Efficiency Levels for Commercial Single Stage GSHPs[11]

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

[11] 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 to determine 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 creates and implements 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 required to determine savings. 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 changing conditions. Documentation should be complete, readily available, clearly organized, and easy to understand.

The methodology described herein involves the 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:

$$\text{Peak } Demand\ Savings\ (kW)^{12} = kW_{Baseline} - kW_{New}$$

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 use 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 lookup tables referenced herein. Otherwise, custom values for these inputs must be developed.

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

Equation 33

[12] 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.

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

Equation 34

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

Equation 35

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

Equation 36

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

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 10) [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 10) [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, Section 4 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 estimated useful life (EUL) for GSHPs is 20 years.

This value is consistent with the minimum life expectancy reported in the Department of Energy GSHP guide.[13]

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

[13] Department of Energy. “Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

- 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
- 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, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

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. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 11. 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.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	Estimated useful life changed from 15 to 20 years for consistency with Volume 2.

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), replace-on-burnout (ROB), and new construction (NC)

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 use the tools and systems they developed. The protocol allows for flexible 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.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[14,15]

Baseline Condition

Early Retirement: The baseline for retrofit projects is specific to the existing HVAC system being replaced by a new VRF; that is, the baseline case is defined by existing system manufacturer, model number, AHRI nominal efficiencies, and operating parameters. 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 12 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, follow required test protocols and parameters and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements from Table 12. Both air-cooled and water-cooled systems are rated per AHRI Standard 1230.

Table 12. 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 multi-split 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	

[14] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[15] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF air-cooled (cooling mode)	< 65,000	All	VRF multi-split system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000	None or electric resistance	VRF multi-split system	11.0 EER 12.3 IEER	
			VRF multi-split system with heat recovery	10.8 EER 12.1 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system	10.6 EER 11.8 IEER	
			VRF multi-split system with heat recovery	10.4 EER 11.6 IEER	
	≥ 240,000		VRF multi-split system	9.5 EER 10.6 IEER	
			VRF multi-split system with heat recovery	9.3 EER 10.4 IEER	
VRF water-source (cooling mode)	< 65,000	All	VRF multi-split system 86°F entering water	12.0 EER	ASHRAE 90.1-2013 Table 6.8.1-10
			VRF multi-split system with heat recovery 86°F entering water	11.8 EER	
	≥ 65,000 and < 135,000		VRF multi-split system 86°F entering water	12.0 EER	
			VRF multi-split system with heat recovery 86°F entering water	11.8 EER	
	≥ 135,000		VRF multi-split system 86°F entering water	10.0 EER	
			VRF multi-split system with heat recovery 86°F entering water	9.8 EER	

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF air-cooled (heating mode)	< 65,000 (cooling capacity)	-	VRF multi-split system	7.7 HSPF	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multi-split system 47⁰F db/43⁰F wb outdoor air	3.3 COP_H	
			VRF multi-split system 17⁰F db/15⁰F wb outdoor air	2.25 COP_H	
	≥ 135,000 (cooling capacity)		VRF multi-split system 47⁰F db/43⁰F wb outdoor air	3.2 COP_H	
			VRF multi-split system 17⁰F db/15⁰F wb outdoor air	2.05 COP_H	
VRF water-source (heating mode)	< 135,000 (cooling capacity)	-	VRF multi-split system 68⁰F entering water	4.2 COP_H	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 135,000 (cooling capacity)		VRF multi-split system 68⁰F 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 to determine 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 required to determine savings. Advanced planning ensures that all data collection and information necessary to determine savings 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 changing conditions. Documentation should be complete, readily available, clearly organized and easy to understand.

The methodology described herein involves the 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 report. 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:

$$Peak\ Demand\ Savings\ (kW)^{16} = kW_{Baseline} - kW_{New}$$

Equation 39

[16] 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.

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 use 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.

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

Equation 41

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

Equation 42

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

Equation 43

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

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 12*) [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 12) [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 12 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, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for commercial split and packaged air conditioners and heat pumps is 15 years.[17]

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 number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed number of units
- Installed equipment type
- Installed rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model

[17] 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 unit AHRI/DOE CCMS certificate or reference number
- **For other building types only**: 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, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

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. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.
- 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 13. 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.
v7.0	10/2019	No revisions.
v8.0	10/2020	Added DOE CCMS certification to eligibility list
v9.0	10/2021	No revisions.

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 savings estimate 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 creates a framework to provide high-quality verified savings while not restricting the ability of residential new construction program implementers to use 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
- Inform future program planning processes.

Streamlined measurement and verification of residential new construction shall leverage a model-based approach to determine energy savings for each home and adhere to typical IPMVP protocols. Modeling 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[18]
- 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.)[19]

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

[19] 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 achieve energy-efficient new homes, including a combination of envelope and equipment-based improvements. The energy savings estimates are 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 completed in a given program year are eligible.[20]

This measure is to be applied to multifamily buildings, and portions thereof, based on the Implementation Guidance in Section 4.6 Multifamily Guidance of TRM Volume 1.

Baseline Condition[21]

Broadly, baseline conditions for the building system (e.g., envelope materials, 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.

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

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

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 14. 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 15.

Exception:[22] Multifamily buildings with 4 or 5 stories above-grade[23] where dwelling units occupy 80 percent 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 percent threshold has been met.

Table 14 and Table 15: 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 a 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 IECC 2015.[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 might 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 the project documentation made available to evaluators upon request. Changes to baseline conditions from Table 14 and Table 15 or changes to the implementation of baseline conditions within an approved modeling package are allowable and subject to EM&V team approval.

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

[23] Any above-grade story with 20 percent 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.

Table 14. New SF and MF Construction up to Three Stories—Reference Home Characteristics

Baseline and dwelling parameters and characteristics	Reference home specification/value
Architecture	
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 of window to floor area	Same as as-built
Front door orientation	Same as as-built
Aspect ratio (length/width)	Same as as-built
Envelope	
Slab R-value and depth	See IECC 2015 Table R402.1.2 Insulation and Fenestration Requirements by Component
Floor assembly U-Factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Frame wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Mass wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Basement wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Crawl space wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Rim joist assembly U-factor	Same as wall U-Factor
Fenestration U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Skylight U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Glazed fenestration SHGC	See IECC 2015 Table R402.1.2 Insulation and Fenestration Requirements by Component
Window overhang	None
interior shading fraction	Same as as-built
Door U-factor	Same as fenestration U-factor
Ceiling assembly U-factor	Table R402.1.4 equivalent U-factors
Ceiling type	Same as as-built, except when as-built is a sealed attic assembly, then vented attic
Roof radiant barrier	None
Roof solar absorptivity	0.75

Baseline and dwelling parameters and characteristics	Reference home specification/value
Envelope testing	
Air infiltration	5 ACH_{50} in IECC 2015 CZ 2, 3 ACH_{50} in IECC 2015 CZ 3-4[24]
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[25]
HVAC equipment location	Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic
Cooling capacity	Same as as-built
Heating capacity	Same as as-built
Cooling efficiency (SEER)	14
Heating efficiency (AFUE)	80% AFUE
Heating efficiency (HSPF)—heat pump	8.2
Duct location	Exposed in a vented attic
Duct R-value	R-8[26]
Total duct leakage	4 CFM_{25} per 100 ft^2 of conditioned floor
Thermostat type	Programmable thermostat
Heating setpoint	72°F
Cooling setpoint	75°F
Mechanical ventilation type	Same as as-built or as specified in IECC 2015 Table 405.5.2
Mechanical ventilation rate	Same as as-built
Mechanical ventilation hours/day	Same as as-built or as specified in IECC 2015 Table 405.5.2
Mechanical ventilation fan watts	Same as as-built or as specified in IECC 2015 Table 405.5.2

[24] Note: The climate zones in IECC 2015 do not align with the climate zones assigned in the Texas TRM. IECC climate zones referenced in this section can be found here: https://codes.iccsafe.org/content/IECC2015/chapter-3-ce-general-requirements

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

[26] Exception: Ducts or portions thereof located completely inside the building thermal envelope.

Baseline and dwelling parameters and characteristics	Reference home specification/value
HVAC commissioning	
Grade III (untested/commissioned by rater)[27]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[28] Type: Stand-alone dehumidifier of same type (portable or whole-home) as the Rated Home Capacity: Same as rated home Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows: 25.00 or less: 0.79 liters/kWh 25.01-35.00: 0.95 liters/kWh 35.01-54.00: 1.04 liters/kWh 54.01-74.99: 1.20 liters/kWh 75.00 or more: 1.82 liters/kWh Dehumidistat setpoint: 60 percent RH	Same as as-built
Water heating system	
DHW fuel type	Same as as-built
DHW water heater location	Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic
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
DHW energy factor (UEF)	Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[29]) as of April 16, 2015

[27] ANSI/RESNET/ACCA 310-2020. Standard for Grading the Installation of HVAC Systems. June 23, 2020. https://www.resnet.us/wp-content/uploads/ANSIRESNETACCA_310-2020_v7.1.pdf.

[28] MINHERS Addendum 55i, Modifications and Clarifications for Implementation of ANSI/RESNET/ICC 301-2019 in RESNET HERS. January 22, 2021.

[29] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=cf13a6a9929a57e8a7ca3826966e322c&mc=true&n=sp10.3.430.c&r=SUBPART&ty=HTML#se10.3.430_132.

Baseline and dwelling parameters and characteristics	Reference home specification/value
DHW pipe insulation	R-3
All bath faucets and showers ≤ 2gpm	No
Hot water recirculation system	No
Drain water heat recovery	No
Lighting	
Lighting	75 percent high efficacy permanently-installed fixtures
LED lighting	None
Appliances	
Refrigerator	Reference home should be modeled with HERS reference default values, equivalent to federal standard efficiency appliances. As-built for homes without high-efficiency appliances should also use the HERS reference defaults. For modeled appliance savings, as-built should reflect high-efficiency appliances. Programs claiming prescriptive appliance savings using Volume 2 of the TRM should use standard-efficiency appliances for both reference and as-built.
Dishwasher	
Range/oven	
Clothes washer and dryer	
Ceiling fans	

Table 15. New Multifamily Buildings Greater than Three Stories—Baseline Characteristics

Baseline and dwelling parameter 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 of 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 the actual aspect ratio when actual house footprint dimensions are available

Baseline and dwelling parameter and characteristics	Baseline specification/value
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 percent
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
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 percent difference
Heating capacity	Same as as-built or simulated to reflect reference home load, not to exceed 20 percent 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 (occupied/unoccupied)	70°F/70°F
Cooling setpoint (occupied/unoccupied)	78°F/80°F

Baseline and dwelling parameter and characteristics	Baseline specification/value
HVAC commissioning	
Grade III (untested/commissioned by rater)[30]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[31] Type: Stand-alone dehumidifier of same type (portable or whole-home) as the rated home Capacity: Same as rated home Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows: 25.00 or less: 0.79 liters/kWh 25.01-35.00: 0.95 liters/kWh 35.01-54.00: 1.04 liters/kWh 54.01-74.99: 1.20 liters/kWh 75.00 or more: 1.82 liters/kWh Dehumidistat setpoint: 60 percent RH	Same as as-built
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 showerheads	None
Lighting	
High-efficacy lamps	0.51 Watts per ft^2

[30] ANSI/RESNET/ACCA 310-2020. Standard for Grading the Installation of HVAC Systems. June 23, 2020. https://www.resnet.us/wp-content/uploads/ANSIRESNETACCA_310-2020_v7.1.pdf.

[31] MINHERS Addendum 55i, Modifications and Clarifications for Implementation of ANSI/RESNET/ICC 301-2019 in RESNET HERS. January 22, 2021.

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, using 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 using 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 using 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 using 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 the TRM 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

Not applicable.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 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 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 for gas, 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 showerheads 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
- HVAC commissioning
  - Grade
- Dehumidification system
  - Type
  - Capacity
  - Efficacy
  - Dehumidistat setpoint

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 calculations outside the model

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- 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*.

Document Revision History

Table 16. M&V Residential New Construction Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	Updated baseline conditions due to federal standard updates for HVAC and water heating equipment. Modified program tracking requirements and requirements surrounding the relevant baseline code.
v2.1	1/30/2015	No revisions.
v3.0	3/13/2015	No revisions.
v3.1	11/05/2015	Moved this measure from TRM Volume 2 to TRM Volume 4. Major measure and methodology updates include the addition of lighting and appliances to the baseline conditions, addressing post-processing calculations, and adding a list of files (including modeling) for projects to submit for EM&V review. Revised and/or added detail regarding Measure Overview, Baseline Condition, Baseline Characteristics, Energy and Demand Savings Methodology, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Noted effective date of the new IECC baseline.
v5.0	10/10/2017	Added provision for multifamily new construction.
v6.0	10/2018	No revisions.
v7.0	10/2019	Added provision for multifamily new construction, updated baseline to reflect the adoption of IECC 2015.

TRM version	Date	Description of change
v8.0	10/2020	For reference home specification, added IECC 2015 for mechanical ventilation and federal standard efficiency for appliances.
v9.0	10/2021	For reference home specification, added HVAC commissioning and dehumidification system.

2.3 M&V: RENEWABLES

2.3.1 Residential Solar Photovoltaics (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

Applicable Building Types: Single-family, multifamily, and manufactured homes

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Simulation software (kWh), deemed values (kW)

Savings Methodology: Model-calculator (PVWatts®)

Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. The primary objective of these programs is to achieve cost-effective energy savings and peak demand savings. Participation in the solar photovoltaic program involves the installation of a PV system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator[32], to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

Eligibility Criteria

Only PV systems that result in reductions of customer's purchased energy or peak demand qualify for savings. Off-grid systems are not eligible. Each utility may have additional incentive program eligibility and interconnection requirements, which are not listed here.

Baseline Condition

PV system not currently installed (typical) or an existing system is present, but additional capacity (including both panels and inverters) may be added.

High-Efficiency Condition

Not applicable.

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[32] PVWatts® Calculator: http://pvwatts.nrel.gov/.

Energy and Demand Savings Methodology

All PV systems shall be modeled using the current version of the NREL PVWatts® calculator. Energy savings are estimated using the default weather data source (currently TMY2) offered by PVWatts®.[33] Demand savings use lookup tables derived from PVWatts®, which uses the NREL National Solar Radiation Database (NSRDB) weather data sources for the location of the project.

Savings Algorithms and Input Variables

All Installations

PVWatts® input variables (for each array, where an array is defined as a set of PV modules with less than five degrees difference in tilt or azimuth):

- Installation address: Use complete site address, including the five-digit ZIP code.
- Weather data file: Default NSRDB data is a detailed grid of solar radiation throughout Texas (and North America), identified as a blue square in the map (see Figure 2).
- Direct current (DC) system size (kW): Enter the sum of the DC power rating of all photovoltaic modules in the array at standard test conditions (STC) in kilowatts DC.
  - For AC modules, refer to the module specification sheet to obtain the DC (STC) power rating.
- Module type: Standard, premium, or thin film. Use the nominal module efficiency, cell material, and temperature coefficient from the module data sheet to choose the module type, or accept the default provided by PVWatts®.

Table 17. Module Type Options

Type	Approximate efficiency	Module cover	Temperature coefficient of power
Standard (crystalline silicon)	15 percent	Glass	-0.47 %/°C
Premium (crystalline silicon)	19 percent	Anti-reflective	-0.35 %/°C
Thin film	10 percent	Glass	-0.20 %/°C

- Array type: Fixed (open rack), fixed (roof mount), one-axis tracking, one-axis backtracking, two-axis tracking.
- Tilt (deg): Enter the angle from horizontal of the photovoltaic modules in the array.
- Azimuth (deg): Enter the angle clockwise from true north describing the direction that the array faces.
- All other input variables: Accept the PVWatts® default values.

[33] PVWatts® Calculator: https://pvwatts.nrel.gov/.

Annual Energy Savings (kWh)

Given the inputs above, PVWatts® calculates estimated annual energy savings for each array.

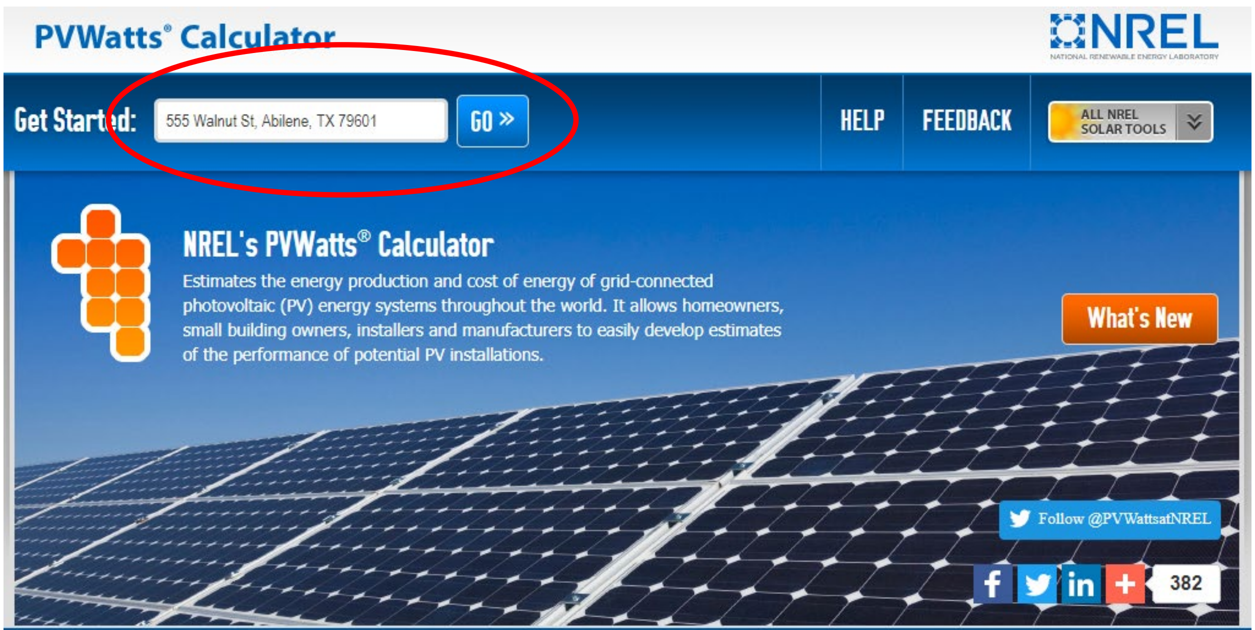
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain the total annual energy savings.

A screenshot (or other save) of the 'Results' page, displaying both the annual energy production and model inputs, is typically required in PV incentive applications, and is sufficient documentation of the annual energy savings estimate.

Example: A residential customer at 555 Walnut Street, Abilene, TX 79601 installs a 5 kW_{dc} fixed array of standard crystalline silicon modules on their roof with a tilt of 15 degrees and an azimuth of 200 degrees.

- **Step 1.** The user enters the full site address (rather than only the zip code) of the proposed PV system in PVWatts® calculator and presses "Go." See Figure 1.

Figure 1. PVWatts® Input Screen for Step 1



- **Step 2.** PVWatts® automatically identifies the nearest weather data source, defaulting to the NREL NSRDB grid cell for your location (see Figure 2). Confirm the resulting location and proceed to system info, as shown in Figure 3.

Figure 2. PVWatts® Resource Data Map

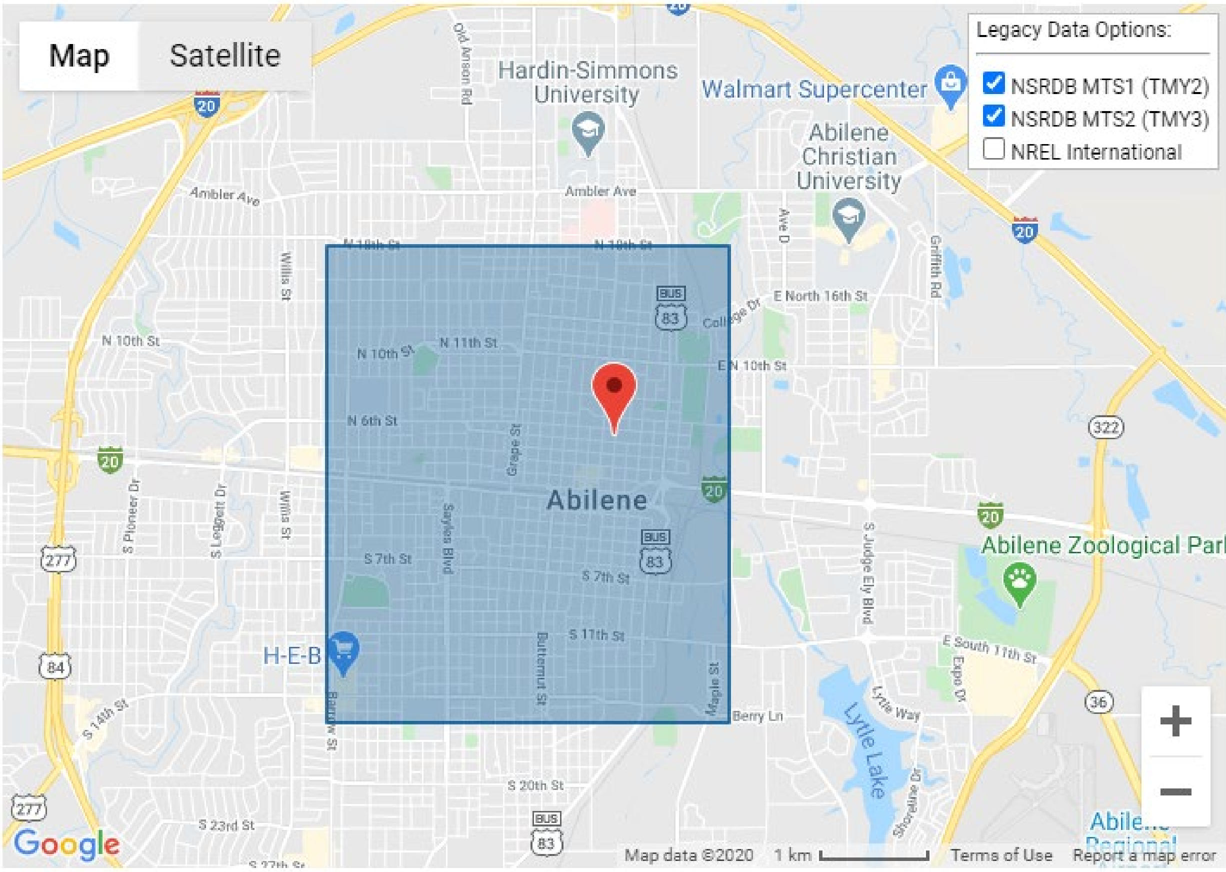
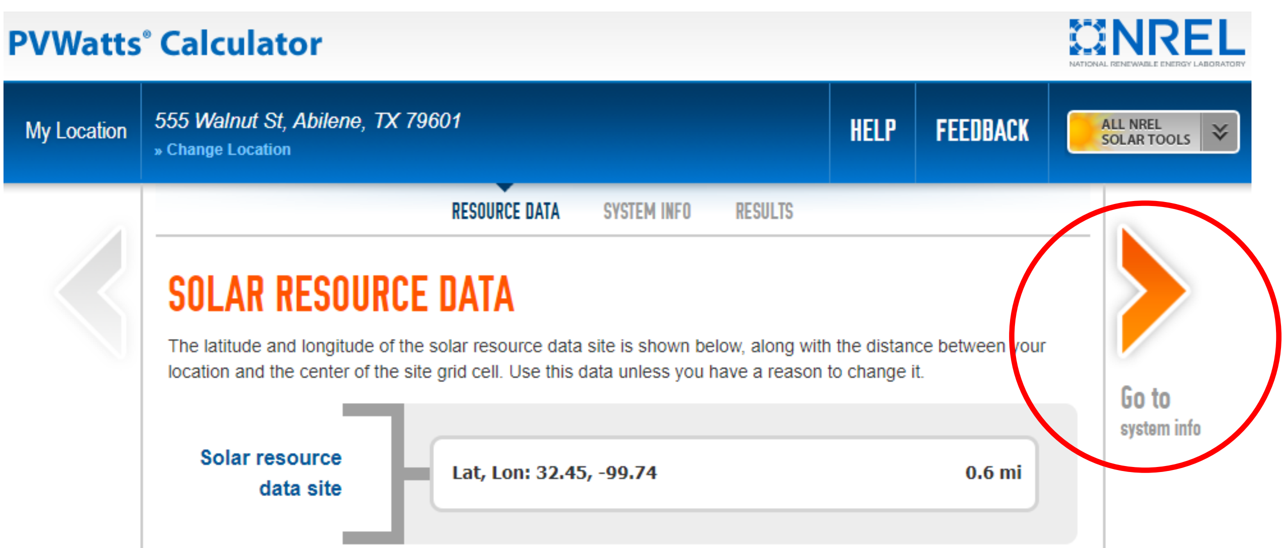


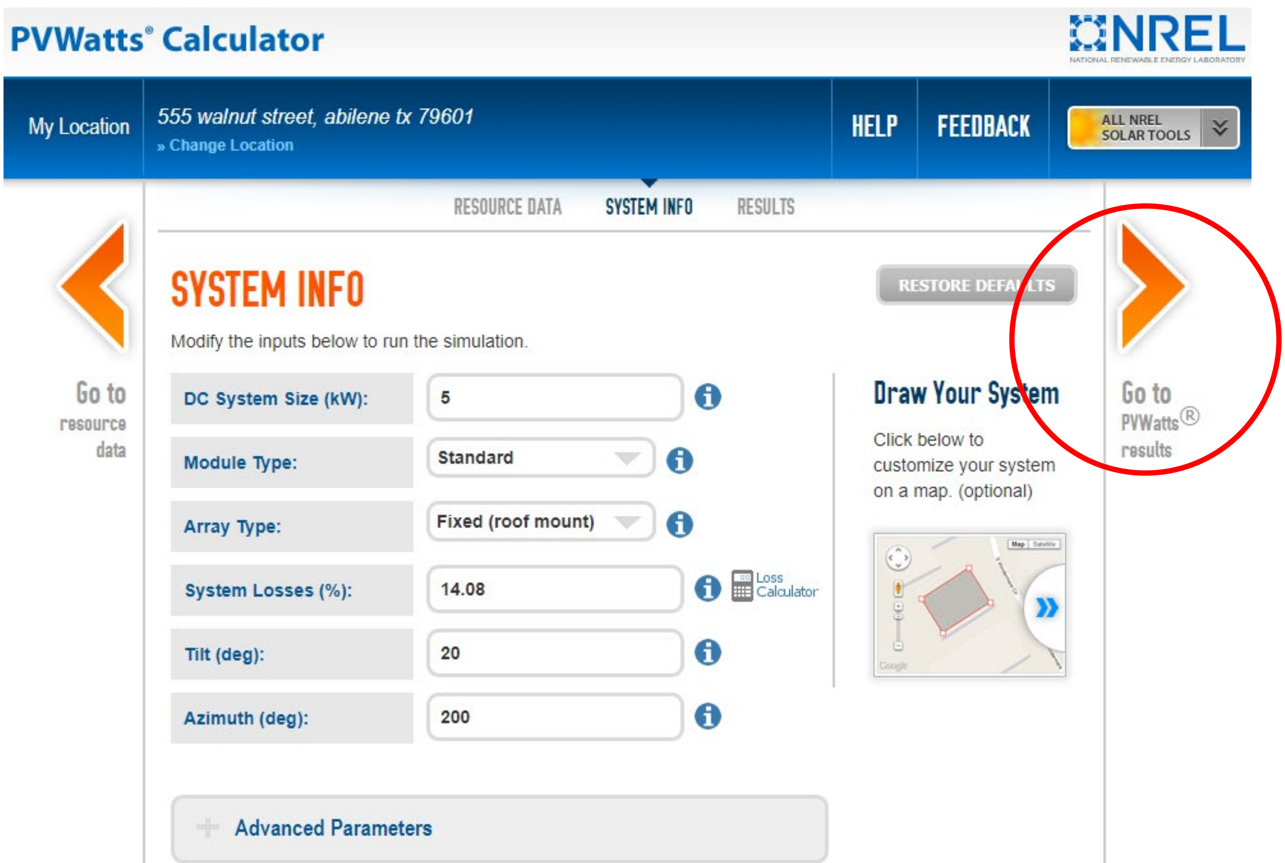
Figure 3. PVWatts® Input Screen for Step 2



- **Step 3.** The user enters system info as follows:
    - DC system size (kW): 5.00
    - Module type: Standard
    - Array type: Fixed (roof mount)
    - Tilt (deg): 20
    - Azimuth (deg): 200

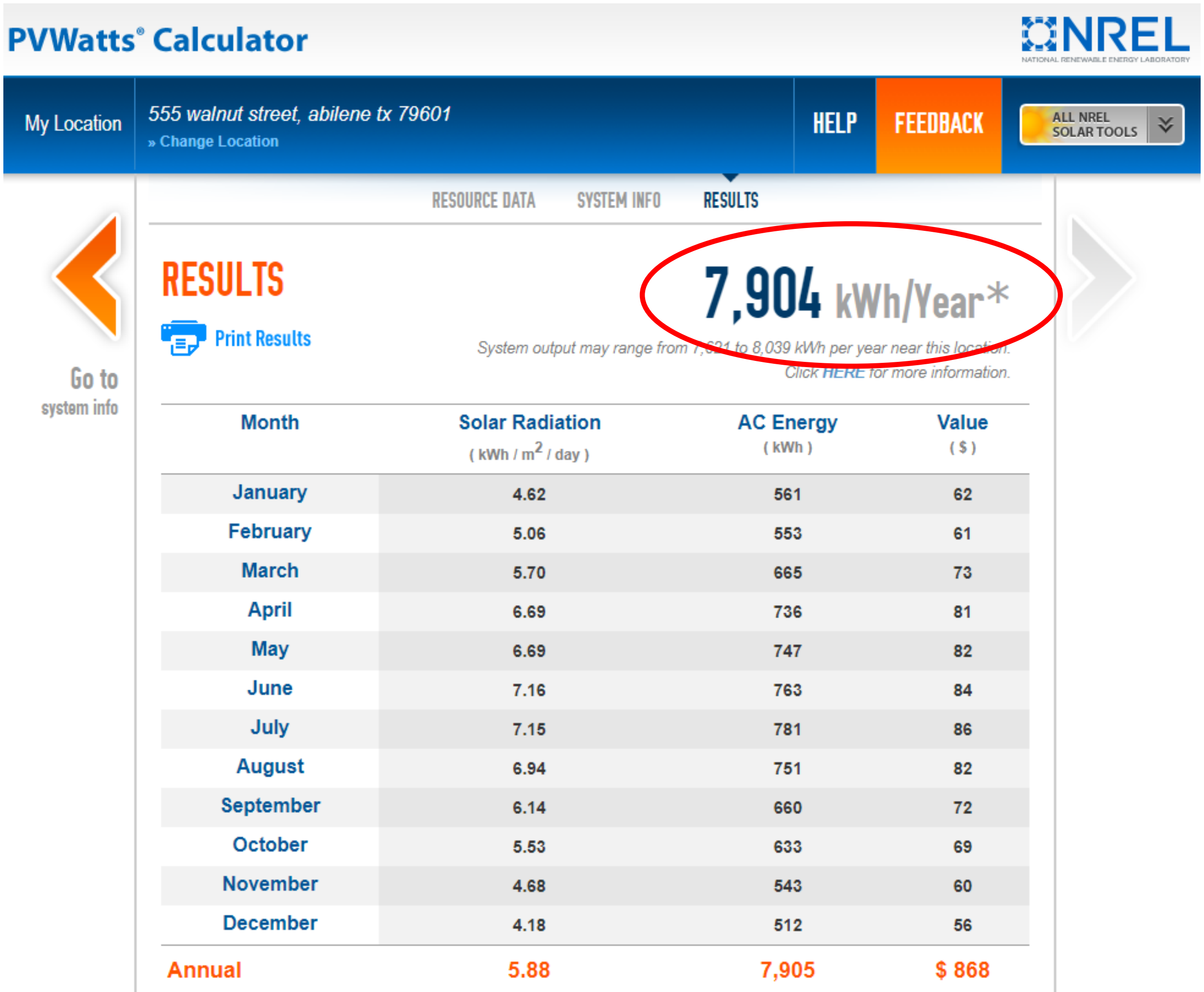
All other details (System Losses, Advanced Parameters, and Initial Economics) are left at default values. Once entered, the user presses "Go to PVWatts® results." See Figure 4 below.

Figure 4. PVWatts® Input Screen for Step 3



- **Step 4.** PVWatts® returns an estimate of annual energy production (kWh), in this case 7,904 kWh. See Figure 5.

Figure 5. PVWatts® Output Screen for Step 4



Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	4.62	561	62
February	5.06	553	61
March	5.70	665	73
April	6.69	736	81
May	6.69	747	82
June	7.16	763	84
July	7.15	781	86
August	6.94	751	82
September	6.14	660	72
October	5.53	633	69
November	4.68	543	60
December	4.18	512	56
Annual	5.88	7,905	$ 868

Further down this output page, PVWatts® returns a summary of model inputs (Figure 6).

Figure 6. PVWatts® Output Screen for Step 4 (continued)

Location and Station Identification

Requested Location	555 walnut street, abilene tx 79601
Weather Data Source	Lat, Lon: 32.45, -99.74 0.6 mi
Latitude	32.45° N
Longitude	99.74° W

PV System Specifications *(Residential)*

DC System Size	5 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	20°
Array Azimuth	200°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	0.110 $/kWh

Performance Metrics

Capacity Factor	18.0%

The coordinates (latitude and longitude) of the proposed system are also presented and determine the appropriate weather zone to use when estimating demand savings.

A screenshot (or .pdf) of the complete output page, displaying both the annual energy production and model inputs, is typically required in PV incentive applications and is sufficient documentation of the annual energy savings estimate.

Summer Demand Savings Methodology

Deemed summer demand savings are determined using the weather zone map (Figure 7) and summer demand savings lookup table values provided below. Deemed summer demand savings is the product of the system's DC system size and the appropriate lookup table value.

Deemed Summer Demand Savings

*Deemed summer demand savings = DC system size (kW) * Lookup Value*

Equation 47

For systems with multiple arrays, users should calculate summer demand savings for each array separately and sum them to obtain the total summer demand savings.

In rare cases, residential systems using trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may use the Alternative Method described on page 62.

Winter Demand Savings Methodology

Deemed winter demand savings are determined using the weather zone map (Figure 7) and winter demand savings lookup values tables (Table 18 through Table 27) provided below. Deemed winter demand savings are the product of the system's DC system size and the appropriate lookup table value.

Deemed Winter Demand Savings

*Deemed winter demand savings = DC system size (kW) * Lookup Value*

Equation 48

For systems with multiple arrays, users should derive winter demand savings for each array separately and sum them to obtain the total winter demand savings.

In rare cases, residential systems using trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may use the Alternative Method described on page 62.

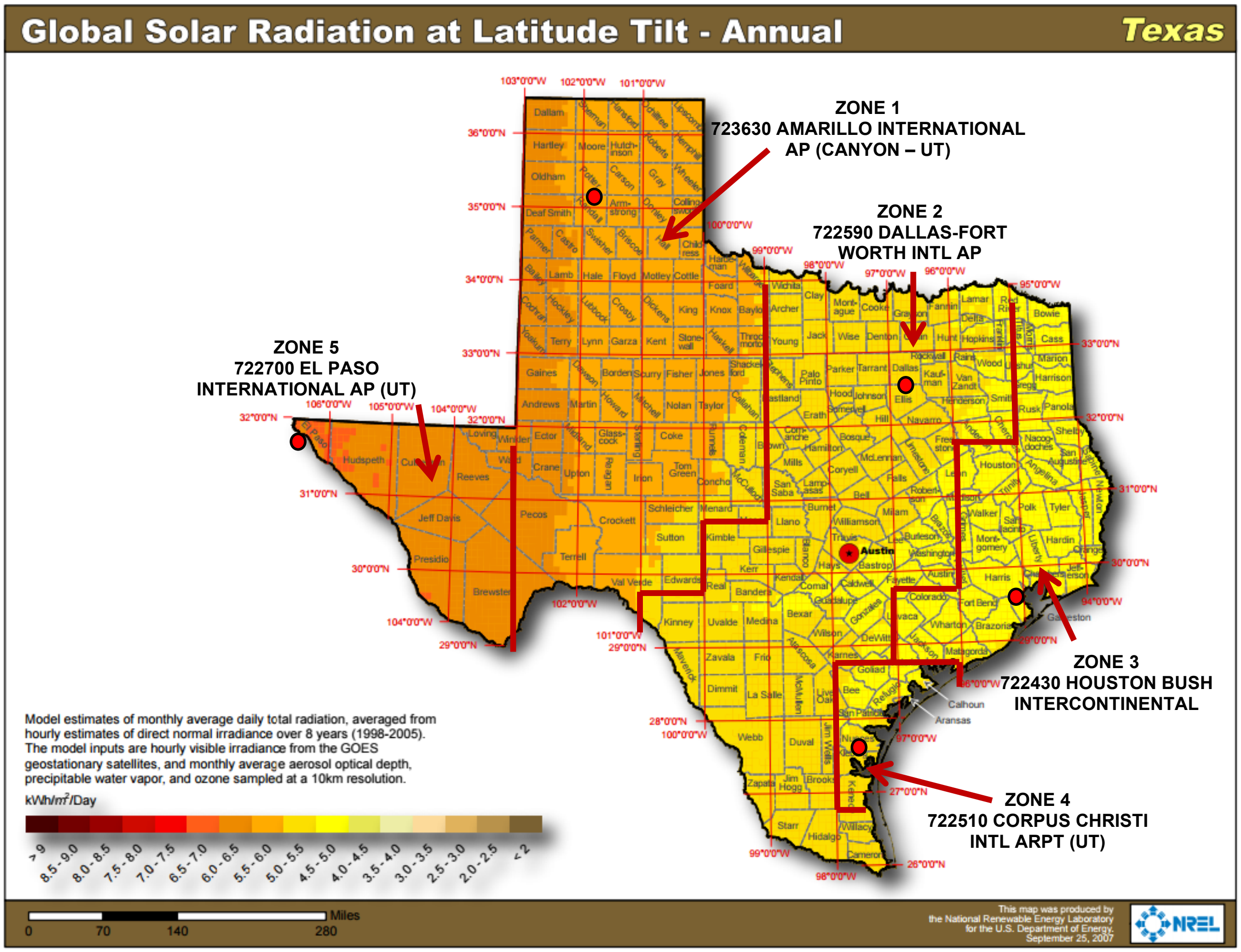
Deemed Energy Savings Tables

Not applicable.

Deemed Summer and Winter Demand Savings—Weather Zone Determination

The appropriate weather zone for each system can be determined by identifying the system's coordinates on the map in Figure 7, below. The figure identifies weather zones, and the reference TMY3 weather station name and five-digit identifier used in calculating the lookup values within each weather zone. An example of how to use the weather zone map and tables to derive summer and winter peak demand savings is provided below the tables.

Figure 7. Weather Zone Determination for Solar PV Systems[34]



Deemed Summer and Winter Demand Savings—Lookup Value Tables

The tables below provide lookup values used to calculate deemed summer and winter demand savings based on the weather zone, tilt, and azimuth. Table 18 through Table 27 present lookup values to determine deemed summer and winter demand savings given various array tilt/azimuth combinations. The values in the tables express summer and winter peak demand savings as a percentage of an array's DC rating at standard test conditions (STC).

Some rooftops are essentially flat but have a slight tilt (< 7.5 degrees) to facilitate runoff. If the azimuth of a slightly tilted (< 7.5 degrees) array falls outside the 67.5 - 292.5-degree azimuth ranges provided in the lookup tables below, the user should apply the deemed savings factors from the first line of the appropriate tables, corresponding to a tilt of 0 degrees. For example, in Amarillo, the summer demand factor for an array with a tilt of 4 degrees and an azimuth of 0 degrees (e.g., slightly tilted to the north) would be 48 percent, as shown in Table 18.

[34] NREL: https://openei.org/w/images/4/46/NREL-eere-pv-h-texas.pdf.

Table 18. Climate Zone 1 Amarillo—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	48%	48%	48%	48%	48%
15	>7.5-22.5	35%	40%	49%	56%	58%
30	>22.5-37.5	20%	30%	47%	60%	64%
45	>37.5-52.5	10%	18%	42%	61%	66%
60	>52.5-67.5	7%	10%	34%	59%	65%

Table 19. Climate Zone 1 Amarillo—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	1%	1%	1%	1%	1%
15	>7.5-22.5	3%	3%	2%	1%	0%
30	>22.5-37.5	4%	5%	3%	1%	0%
45	>37.5-52.5	6%	6%	4%	1%	0%
60	>52.5-67.5	6%	7%	4%	0%	0%

Table 20. Climate Zone 2 Dallas—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	46%	46%	46%	46%	46%
15	>7.5-22.5	35%	39%	46%	52%	54%
30	>22.5-37.5	22%	29%	43%	55%	59%
45	>37.5-52.5	12%	19%	38%	56%	60%
60	>52.5-67.5	8%	12%	31%	53%	58%

Table 21. Climate Zone 2 Dallas—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	3%	3%	3%	3%	3%
15	>7.5-22.5	5%	6%	4%	2%	1%
30	>22.5-37.5	8%	8%	5%	2%	1%
45	>37.5-52.5	9%	10%	6%	1%	1%
60	>52.5-67.5	10%	11%	6%	1%	1%

Table 22. Climate Zone 3 Houston—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	36%	36%	36%	36%	36%
15	>7.5-22.5	26%	29%	36%	42%	44%
30	>22.5-37.5	16%	21%	34%	45%	49%
45	>37.5-52.5	9%	14%	29%	46%	51%
60	>52.5-67.5	8%	9%	23%	44%	51%

Table 23. Climate Zone 3 Houston—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	6%	6%	6%	6%	6%
15	>7.5-22.5	10%	11%	8%	5%	3%
30	>22.5-37.5	14%	15%	10%	4%	1%
45	>37.5-52.5	17%	18%	11%	3%	1%
60	>52.5-67.5	18%	19%	12%	2%	1%

Table 24. Climate Zone 4 Corpus Christi—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	41%	41%	41%	41%	41%
15	>7.5-22.5	30%	33%	41%	48%	51%
30	>22.5-37.5	16%	23%	39%	52%	57%
45	>37.5-52.5	8%	14%	34%	53%	60%
60	>52.5-67.5	8%	9%	27%	51%	59%

Table 25. Climate Zone 4 Corpus Christi—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	5%	5%	5%	5%	5%
15	>7.5-22.5	8%	9%	7%	4%	2%
30	>22.5-37.5	11%	12%	8%	3%	1%
45	>37.5-52.5	13%	14%	9%	2%	1%
60	>52.5-67.5	13%	15%	9%	2%	1%

Table 26. Climate Zone 5 El Paso—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	49%	49%	49%	49%	49%
15	>7.5-22.5	40%	44%	49%	54%	55%
30	>22.5-37.5	29%	35%	47%	56%	58%
45	>37.5-52.5	16%	25%	42%	55%	58%
60	>52.5-67.5	10%	15%	34%	51%	55%

Table 27. Climate Zone 5 El Paso—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	0%	0%	0%	0%	0%
15	>7.5-22.5	0%	0%	0%	0%	0%
30	>22.5-37.5	0%	0%	0%	0%	0%
45	>37.5-52.5	0%	0%	0%	0%	0%
60	>52.5-67.5	0%	0%	0%	0%	0%

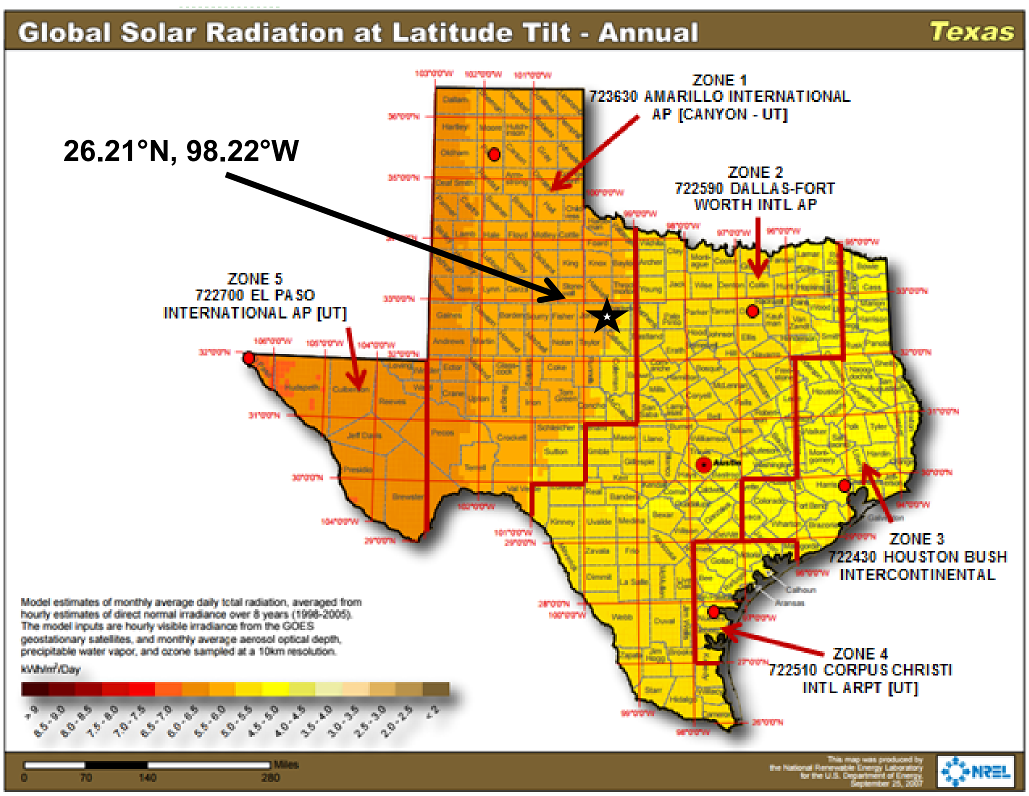
Deemed Summer and Winter Demand Savings—Example

Example: A residential customer at 555 Walnut Street, Abilene, TX 79601 installs a 5 kW_{dc} fixed array of standard crystalline silicon modules on their roof with a tilt of 20 degrees and an azimuth of 200 degrees.

- **Step 1.** Determine the appropriate weather zone. Geographic coordinates for this system (26.21°N, 98.22°W from Figure 8) were derived when determining the annual energy savings (kWh).

  From the weather zone map, this location is in zone 1. See Figure 8.

Figure 8. Application of the Weather Zone Map



- **Step 2.** Calculate summer and winter demand savings. From the zone 1 lookup table, 20-degree tilt falls within the 7.5-22.5 degree tilt range, and 200-degree azimuth falls within the 157.5-202.5 azimuth range. The summer lookup value is 49 percent, and the winter lookup value is 2 percent.

  Applying Equation 47,

  *Deemed summer demand = DC system size (kW) * Lookup Value*

  *Deemed summer demand = 5.000 kW * 49%*

  *Deemed summer demand = 5.000 kW * 0.49*

  Deemed summer demand = 2.450 kW

  Applying Equation 48,

  *Deemed winter demand = DC system size (kW) * Lookup Value*

  *Deemed summer demand = 5.000 kW * 2%*

  *Deemed summer demand = 5.000 kW * 0.02*

  Deemed summer demand = 0.100 kW

Summer and Winter Demand Savings—Alternative Method

An alternative method to estimate summer and winter demand savings is available to residential systems using trackers or systems for which deemed savings lookup values are not available due to extreme array of tilt or azimuth. To use the alternative method, follow these steps:

- **Step 1.** Determine the applicable weather zone for the proposed system using Figure 8 above.
- **Step 2.** Use PVWatts® to model the proposed system as described in the Annual Energy Savings (kWh) section above. However, instead of using the zip code/default weather file, select the TMY3 reference location and weather file associated with the applicable weather zone of the proposed system (e.g., a system in Abilene, weather zone 1, would be modeled based on the AMARILLO INTERNATIONAL AP [CANYON-UT], TX TMY3 weather file). Leave all other inputs the same.
- **Step 3.** On the PVWatts 'Results' page, select 'Download Results: Hourly.' Save the **pvwatts_hourly.csv** output file to your computer and open it using Microsoft Excel.
- **Step 4.** Open the provided calculation tool **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field) on your computer, and select the Alt. Method Inputs tab.

- **Step 5.** From the PVWatts hourly output file, highlight and copy the output data (A1:K8780). Paste this data to cell M1 on the Alt. Method Inputs tab in **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field).
- **Step 6.** On the Alt. Methods Outputs tab, the tool calculates and displays summer and winter demand savings as AC capacity (kW_{ac}) and as a percentage of the DC capacity of the modeled system.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

TRM 4.0 PV tool YYYYMMDD_locked.xlsx (in which the version date is indicated by the YYYYMMDD field), provided by Frontier Energy, is used to determine summer and winter demand savings. The most current version is posted at the Texas energy efficiency website, http://www.texasefficiency.com/. Utilities have the option to create their own versions.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of photovoltaic systems is established at 30 years. This value is consistent with engineering estimates based on manufacturers' warranties and historical data.

Program Tracking Data and Evaluation Requirements

The following information will be required to be collected.

- Project location (full address, including city, state, and zip code)
- Module type: Standard, premium, or thin film
- Array type: Fixed (open rack), fixed (roof mount), one-axis tracking, one-axis backtracking, two-axis tracking, etc.
- Tilt, azimuth, and DC system size rating for each array
- The calculation of electricity production through PVWatts® can be completed by accessing the online calculator or utilizing an application programming interface (API). The required documentation varies between the two methods.
    - Online calculator: Date of PVWatts® run, and PVWatts® printed results report (as a file retained with project documentation)
- API: Date of API access and response, documentation of API programming (including the access endpoint and request parameters), and the response results.
- Selected climate zone and demand method used
- For projects using the alternative method, retention of the TRM 4.0 PV tool workbook for each array evaluated

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides estimate for EUL.

Relevant Standards and Reference Sources

- National Electric Code (NEC) 690, “Solar Photovoltaic Systems” or local building codes.
- P. Dobos. PVWatts® Version 5 Manual. National Renewable Energy Laboratory. NREL/TP-6A20-62641. September 2014. http://www.nrel.gov/docs/fy14osti/62641.pdf. PVWatts® calculator available at: https://pvwatts.nrel.gov/index.php.

Document Revision History

Table 28. M&V Residential Solar PV Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	Minor edits to language and structure.
v2.1	01/30/2015	No revisions.
v3.0	04/10/2015	No revisions.
v4.0	10/10/2016	Removed deemed savings option for energy. Provided new method for calculating summer and winter demand savings and provided deemed summer and winter demand savings lookup tables.
v5.0	10/10/2017	Corrected equation, figure, and table references.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	Updated instructions for new version of PVWatts® and references to NREL National Solar Radiation Database (NSRD) (previously TMY3).
v9.0	10/2021	Clarified PVWatts® kWh modeling instructions and documentation requirements. Provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges.

2.3.2 Nonresidential Solar Photovoltaics (PV) Measure Overview

TRM Measure ID: NR-RN-PV

Market Sector: Commercial

Measure Category: Renewables

Applicable Building Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit (RET), new construction (NC)

Program Delivery Type: Prescriptive

Deemed Savings Type: Simulation software (kWh), deemed values (kW)

Savings Methodology: Model-calculator (PVWatts®)

Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. These programs are offered by Texas utilities, with the primary objective to achieve cost-effective energy and peak demand savings. Participation in the PV program involves the installation of a solar photovoltaic system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator,[35] to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

Eligibility Criteria

Only photovoltaic systems that result in reductions of the customer's purchased energy or peak demand qualify for savings. Off-grid systems are not eligible. Each utility may have additional incentive program eligibility and interconnection requirements, which are not listed here.

Baseline Condition

PV system not currently installed (typical) or an existing system is present, but additional capacity (including both panels and inverters) may be added.

High-Efficiency Condition

Not applicable.

[35] PVWatts® Calculator: http://pvwatts.nrel.gov/.

Energy and Demand Savings Methodology

Solar PV systems shall be modeled using the current version of the National Renewable Energy Laboratory's (NREL) PVWatts® calculator. Energy savings are estimated using the default weather data source offered by PVWatts®.[36] Demand savings use lookup tables derived from PVWatts®, based on NREL National Solar Radiation Database (NSRDB) weather data sources defined by location of the project.

Savings Algorithms and Input Variables

All Installations

PVWatts® input variables (for each array, where an array is defined as a set of PV modules with less than 5 degrees difference in tilt or azimuth):

- Installation address: Use complete site address, including 5-digit ZIP code.
- Weather data file: Default NSRDB data is a detailed grid of solar radiation throughout Texas (and North America), identified as a blue square in the map (see Figure 10).
- DC system size (kW): Input the sum of the DC (direct current) power rating of all photovoltaic modules in the array at standard test conditions (STC), in kilowatts DC.
    - For AC modules, refer to the module specification sheet to obtain the DC (STC) power rating.
- Module type: Standard, premium, or thin film. Use the nominal module efficiency, cell material, and temperature coefficient from the module datasheet to choose the module type, or accept the default provided by PVWatts®.

Table 29. Module Type Options

Type	Approximate efficiency	Module cover	Temperature coefficient of power
Standard (crystalline silicon)	15 percent	Glass	-0.47 %/°C
Premium (crystalline silicon)	19 percent	Anti-reflective	-0.35 %/°C
Thin film	10 percent	Glass	-0.20 %/°C

- Array Type: Fixed (open rack), fixed (roof mount), one-axis tracking, two-axis backtracking, two-axis tracking.
- Tilt (deg): Enter the angle from horizontal of the photovoltaic modules in the array.
- Azimuth (deg): Enter the angle clockwise from true north describing the direction that the array faces.
- All other input variables: accept the PVWatts® default values.

[36] PVWatts® Calculator: https://pvwatts.nrel.gov/.

Annual Energy Savings (kWh)

Given the inputs above, PVWatts® calculates the estimated annual energy savings for each array.

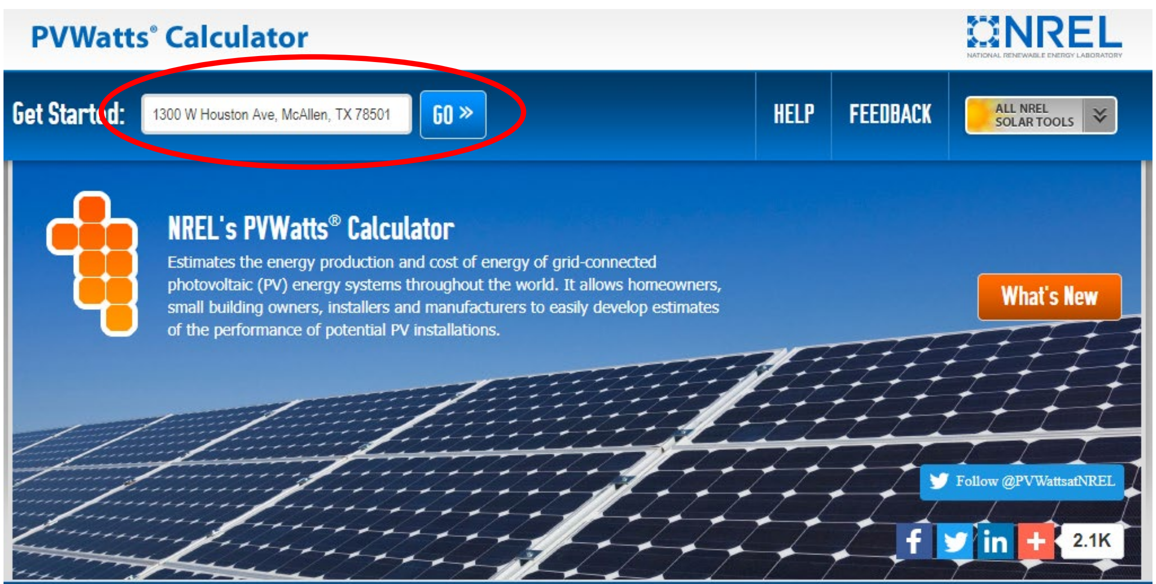
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain total annual energy savings.

A screenshot (or other save) of the 'Results' page, displaying both the annual energy production and model inputs, is typically required in PV incentive applications and is sufficient documentation for the annual energy savings estimate.

Example: A commercial customer at 1300 W. Houston Avenue, McAllen, TX 78501 installs a 50 kW_{dc} fixed array of standard crystalline silicon modules on their roof with a tilt of 5 degrees and an azimuth of 175 degrees.

> **Step 1.** The user enters the full site address (rather than only the zip code) of the proposed PV system in PVWatts® calculator and presses "Go." See Figure 9.

Figure 9. PVWatts® Input Screen for Step 1



> **Step 2.** PVWatts® automatically identifies the nearest weather data source, defaulting to the NREL grid cell for your location. The user should change the default weather data source, as shown in Figure 10. Confirm the resulting location and proceed to system info, as shown in Figure 11.

Figure 10. PVWatts® Resource Data Map

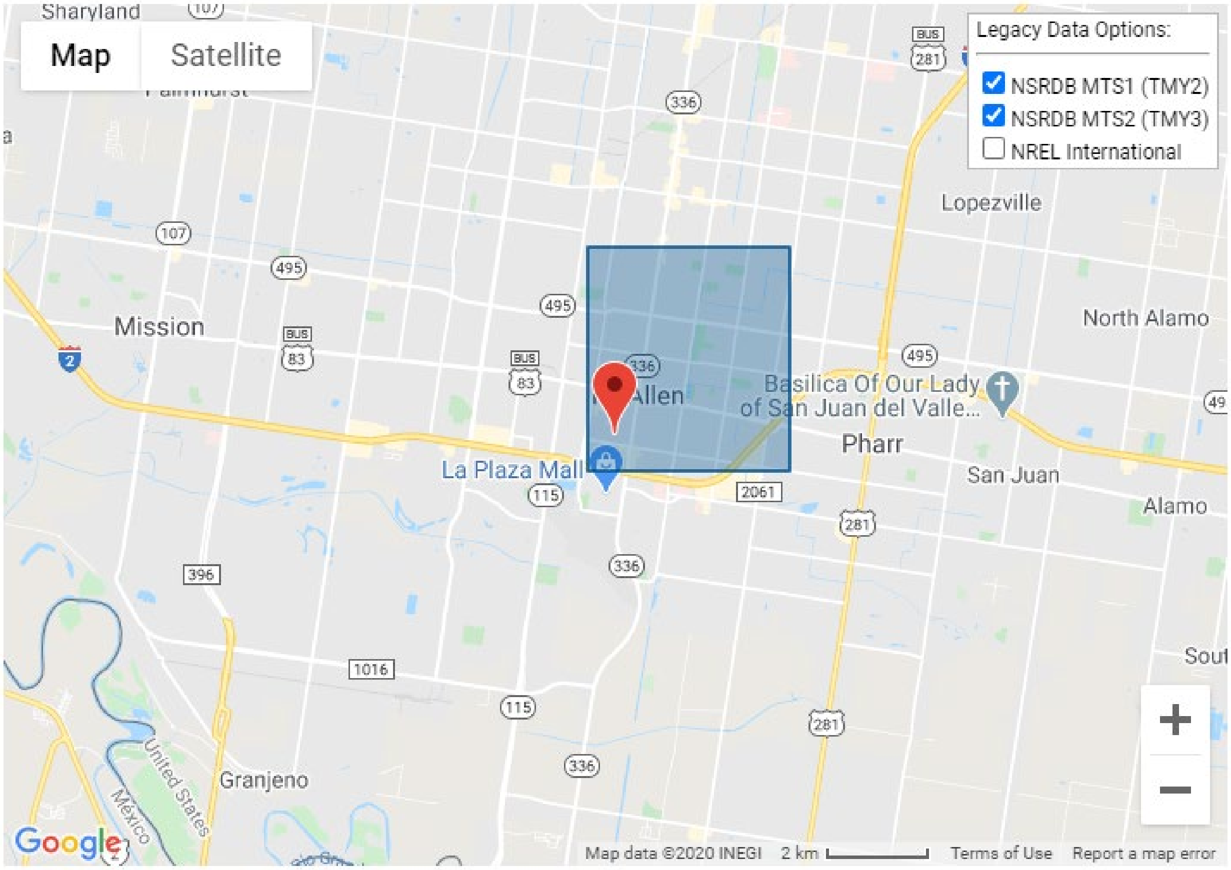
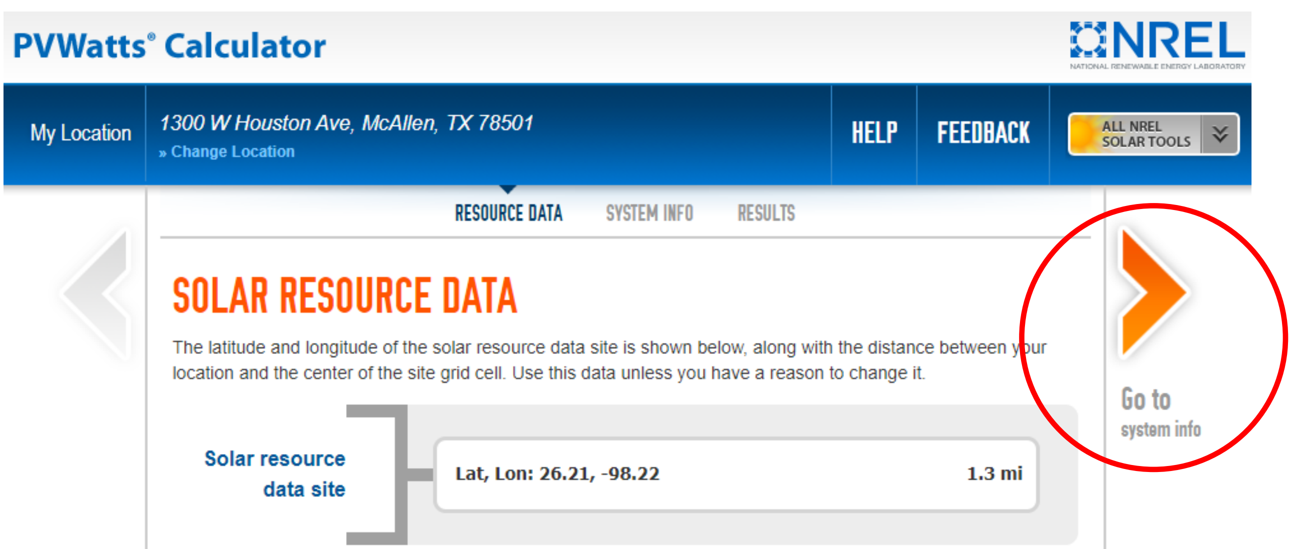


Figure 11. PVWatts® Input Screen for Step 2

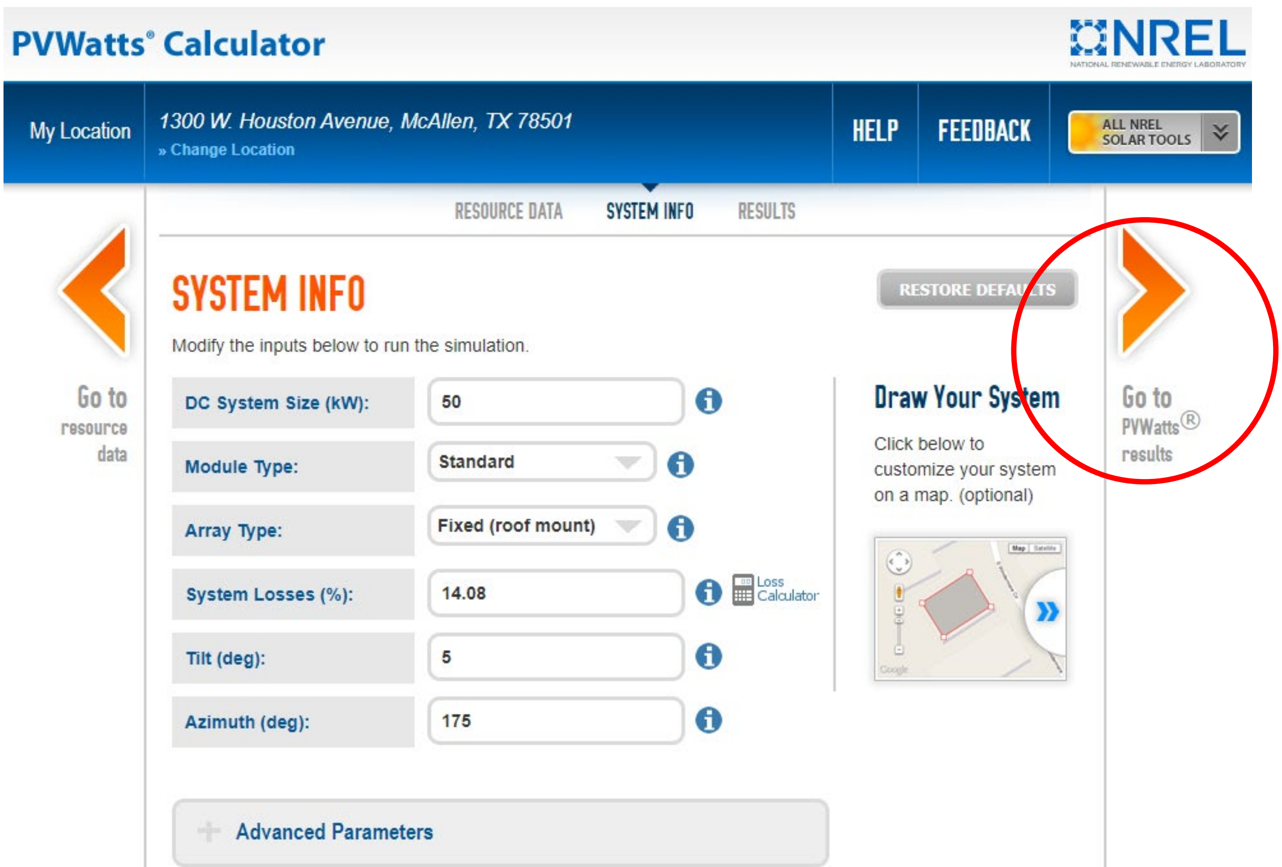


Step 3. The user enters system info as follows:

- DC system size (kW): 50.00
- Module type: Standard
- Array type: Fixed (roof mount)
- Tilt (deg): 5
- Azimuth (deg): 175

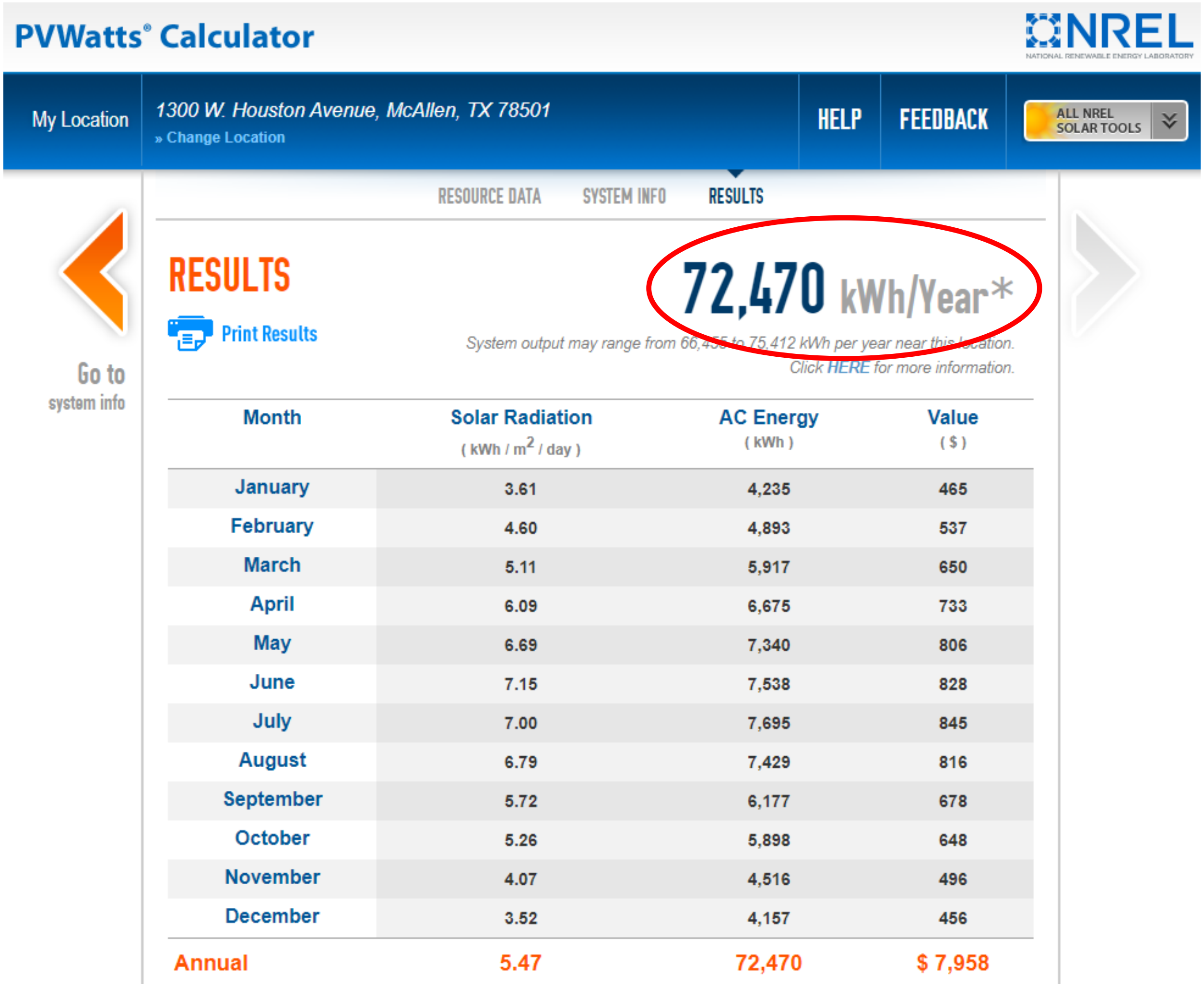
All other details (System Losses, Advanced Parameters, Initial Economics) are left at default values. Once entered, the user presses "Go to PVWatts® results." See Figure 12.

Figure 12. PVWatts® Input Screen for Step 3



Step 4. PVWatts® returns an estimate of annual energy production (kWh), in this case 72,470 kWh. See Figure 13.

Figure 13. PVWatts® Output Screen for Step 4



Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.61	4,235	465
February	4.60	4,893	537
March	5.11	5,917	650
April	6.09	6,675	733
May	6.69	7,340	806
June	7.15	7,538	828
July	7.00	7,695	845
August	6.79	7,429	816
September	5.72	6,177	678
October	5.26	5,898	648
November	4.07	4,516	496
December	3.52	4,157	456
Annual	5.47	72,470	$ 7,958

Further down this output page, PVWatts® returns a summary of model inputs (Figure 14).

Figure 14. PVWatts® Output Screen for Step 4 (continued)

Location and Station Identification	
Requested Location	1300 W. Houston Avenue, McAllen, TX 78501
Weather Data Source	Lat, Lon: 26.21, -98.22 1.3 mi
Latitude	26.21° N
Longitude	98.22° W
PV System Specifications *(Residential)*	
DC System Size	50 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	5°
Array Azimuth	175°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2
Economics	
Average Retail Electricity Rate	0.110 $/kWh
Performance Metrics	
Capacity Factor	16.5%

The coordinates (latitude and longitude) of the proposed system are presented and useful to determine the appropriate weather zone to use when estimating demand savings.

A screenshot (or .pdf) of the complete output page, displaying both the annual energy production and model inputs, is typically required in PV incentive applications and is sufficient documentation for annual energy savings estimate.

Summer Demand Savings Methodology

Deemed summer demand savings are determined using the weather zone map (Figure 15) and summer demand savings lookup values (Table 30) provided below. Deemed summer demand savings is the product of the system's DC system size and the appropriate lookup table value.

Deemed Summer Demand Savings

*Deemed summer demand savings = DC system size (kW) * Lookup Value*

Equation 49

For systems with multiple arrays, users should calculate summer demand savings for each array separately and sum them to obtain the total summer demand savings.

Commercial systems may be modeled using the alternative method described below.

Winter Demand Savings Methodology

Deemed winter demand savings are determined using the weather zone map (Figure 15) and winter demand savings lookup values tables (Table 30 through Table 39) provided below. Deemed winter demand savings is the product of the system's DC system size and the appropriate lookup table value.

Deemed Winter Demand Savings

*Deemed winter demand savings = DC system size (kW) * Lookup Value*

Equation 50

For systems with multiple arrays, users should derive winter demand savings for each array separately and sum them to obtain the total winter demand savings.

Commercial systems may instead be modeled using the alternative method described below.

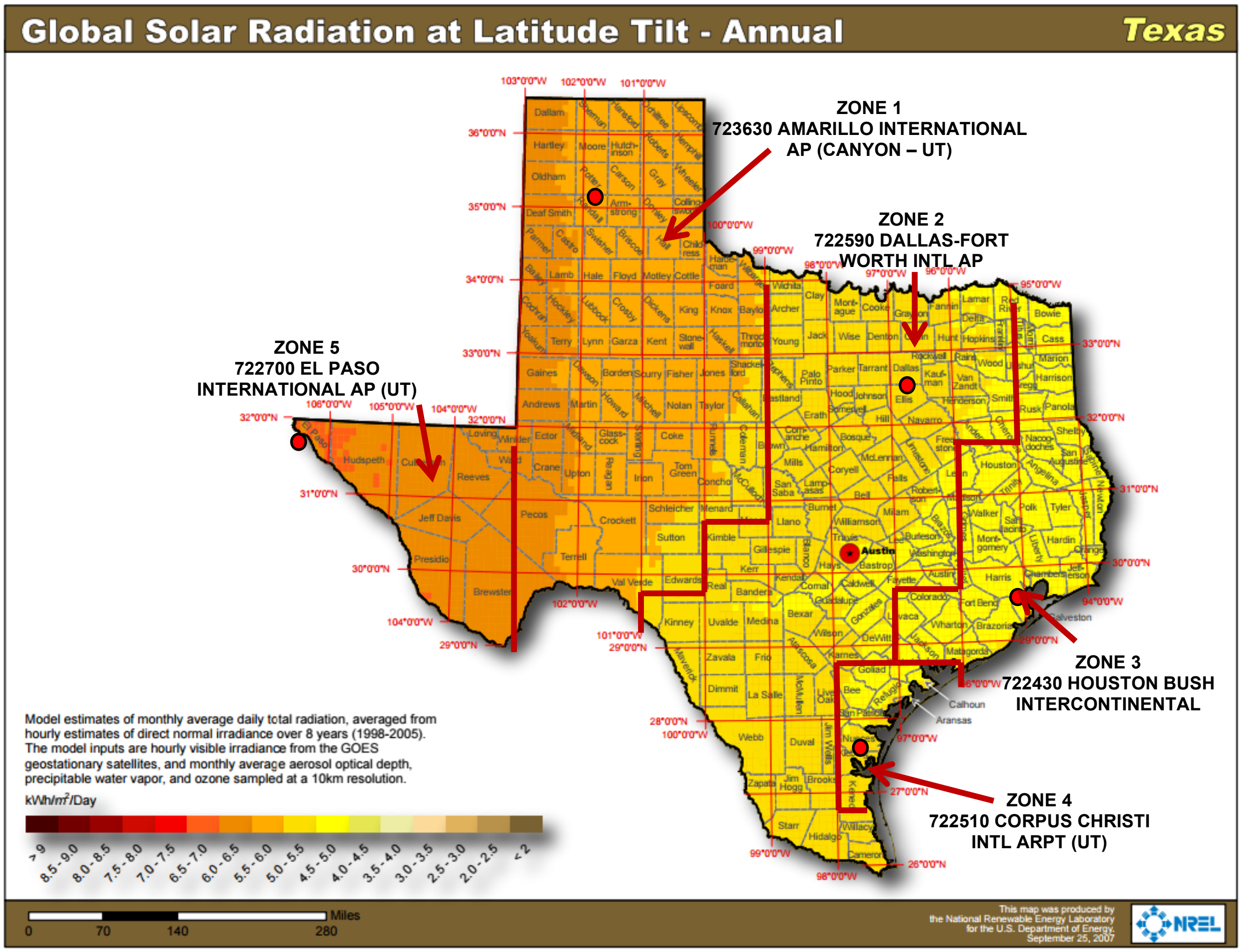
Deemed Energy Savings Tables

Not applicable.

Deemed Summer and Winter Demand Savings—Weather Zone Determination

The appropriate weather zone for each system can be determined by identifying the system's coordinates on the map in Figure 15 Weather Zone Determination for Solar PV Systems below. The map identifies weather zones, and the reference TMY3 weather station name and six-digit identifier used in calculating the lookup values within each weather zone. An example of how to use the weather zone map and tables to derive summer and winter peak demand savings is provided below the tables.

Figure 15. Weather Zone Determination for Solar PV Systems[37]



Deemed Summer and Winter Demand Savings—Lookup Value Tables

The tables below provide lookup values used to calculate deemed summer and winter demand savings based on the weather zone, tilt, and azimuth. Table 30 through Table 39 present lookup values to determine deemed summer and winter demand savings given various array tilt/azimuth combinations. The values in the tables express summer and winter peak demand savings as a percentage of an array's DC rating at standard test conditions (STC).

Some rooftops are essentially flat but have a slight tilt (< 7.5 degrees) to facilitate runoff. If the azimuth of a slightly tilted (< 7.5 degrees) array falls outside the 67.5–292.5-degree azimuth ranges provided in the lookup tables below, the user should apply the deemed savings factors from the first line of the appropriate tables, corresponding to a tilt of 0 degrees. For example, in Amarillo, the summer demand factor for an array with a tilt of 4 degrees and an azimuth of 0 degrees (e.g., slightly tilted to the north) would be 48 percent, as shown in Table 30.

[37] NREL: https://openei.org/w/images/4/46/NREL-eere-pv-h-texas.pdf.

Table 30. Climate Zone 1 Amarillo—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	48%	48%	48%	48%	48%
15	>7.5-22.5	35%	40%	49%	56%	58%
30	>22.5-37.5	20%	30%	47%	60%	64%
45	>37.5-52.5	10%	18%	42%	61%	66%
60	>52.5-67.5	7%	10%	34%	59%	65%

Table 31. Climate Zone 1 Amarillo—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	1%	1%	1%	1%	1%
15	>7.5-22.5	3%	3%	2%	1%	0%
30	>22.5-37.5	4%	5%	3%	1%	0%
45	>37.5-52.5	6%	6%	4%	1%	0%
60	>52.5-67.5	6%	7%	4%	0%	0%

Table 32. Climate Zone 2 Dallas—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	46%	46%	46%	46%	46%
15	>7.5-22.5	35%	39%	46%	52%	54%
30	>22.5-37.5	22%	29%	43%	55%	59%
45	>37.5-52.5	12%	19%	38%	56%	60%
60	>52.5-67.5	8%	12%	31%	53%	58%

Table 33. Climate Zone 2 Dallas—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	3%	3%	3%	3%	3%
15	>7.5-22.5	5%	6%	4%	2%	1%
30	>22.5-37.5	8%	8%	5%	2%	1%
45	>37.5-52.5	9%	10%	6%	1%	1%
60	>52.5-67.5	10%	11%	6%	1%	1%

Table 34. Climate Zone 3 Houston—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	36%	36%	36%	36%	36%
15	>7.5-22.5	26%	29%	36%	42%	44%
30	>22.5-37.5	16%	21%	34%	45%	49%
45	>37.5-52.5	9%	14%	29%	46%	51%
60	>52.5-67.5	8%	9%	23%	44%	51%

Table 35. Climate Zone 3 Houston—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	6%	6%	6%	6%	6%
15	>7.5-22.5	10%	11%	8%	5%	3%
30	>22.5-37.5	14%	15%	10%	4%	1%
45	>37.5-52.5	17%	18%	11%	3%	1%
60	>52.5-67.5	18%	19%	12%	2%	1%

Table 36. Climate Zone 4 Corpus Christi—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	41%	41%	41%	41%	41%
15	>7.5-22.5	30%	33%	41%	48%	51%
30	>22.5-37.5	16%	23%	39%	52%	57%
45	>37.5-52.5	8%	14%	34%	53%	60%
60	>52.5-67.5	8%	9%	27%	51%	59%

Table 37. Climate Zone 4 Corpus Christi—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	5%	5%	5%	5%	5%
15	>7.5-22.5	8%	9%	7%	4%	2%
30	>22.5-37.5	11%	12%	8%	3%	1%
45	>37.5-52.5	13%	14%	9%	2%	1%
60	>52.5-67.5	13%	15%	9%	2%	1%

Table 38. Climate Zone 5 El Paso—Summer Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	49%	49%	49%	49%	49%
15	>7.5-22.5	40%	44%	49%	54%	55%
30	>22.5-37.5	29%	35%	47%	56%	58%
45	>37.5-52.5	16%	25%	42%	55%	58%
60	>52.5-67.5	10%	15%	34%	51%	55%

Table 39. Climate Zone 5 El Paso—Winter Demand kW Savings

Tilt (degrees)		Azimuth (degrees, center, and range)				
		90	135	180	225	270
Center	Range	>67.5-112.5	>112.5-157.5	>157.5-202.5	>202.5-247.5	>247.5-292.5
0	0-7.5	0%	0%	0%	0%	0%
15	>7.5-22.5	0%	0%	0%	0%	0%
30	>22.5-37.5	0%	0%	0%	0%	0%
45	>37.5-52.5	0%	0%	0%	0%	0%
60	>52.5-67.5	0%	0%	0%	0%	0%

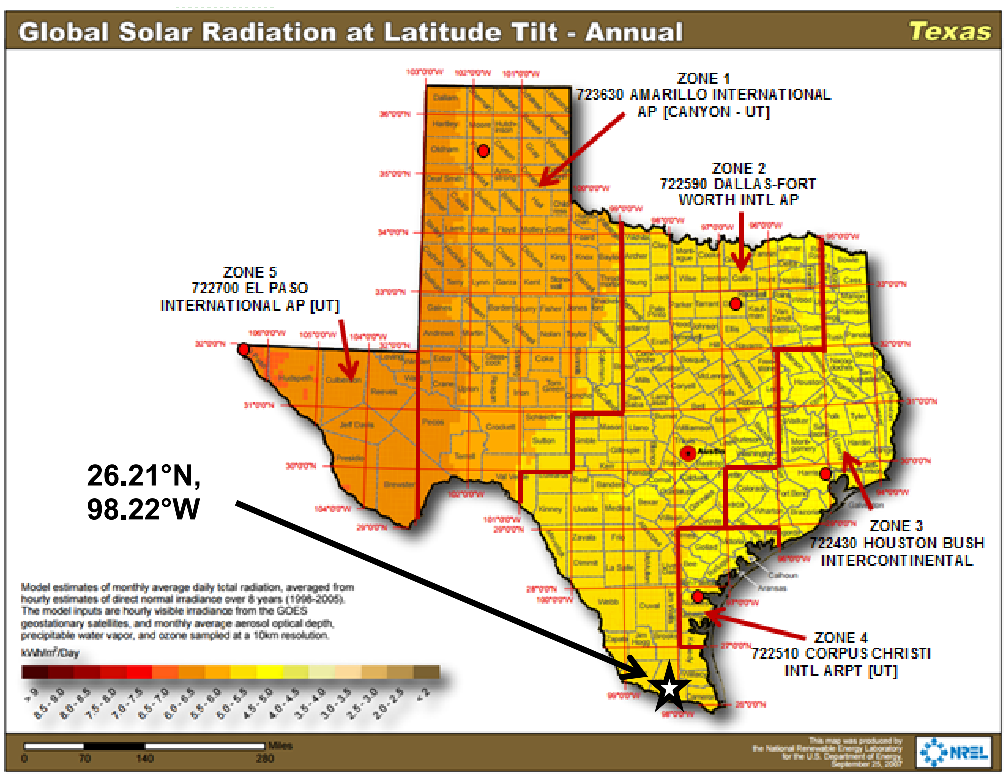
Deemed Summer and Winter Demand Savings—Example

Example: A commercial customer at 1300 W. Houston Avenue, McAllen, TX 78501 installs a 50 kW_{dc} fixed array comprised of standard crystalline Silicon modules on their rooftop with a tilt of 5 degrees and an azimuth of 175 degrees.

Step 1. Determine the appropriate weather zone. Geographic coordinates for this system (26.21°N, 98.22°W from Figure 14) were derived when determining the annual energy savings (kWh).

From the weather zone map, this location is in Zone 2. See Figure 16.

Figure 16. Application of the Weather Zone Map



Step 2. Calculate the summer and winter demand savings. From the zone 2 lookup tables, 5 degree tilt falls within the 0-7.5 degree tilt range, and 175 degree azimuth falls within the 157.5-202.5 azimuth range. The summer lookup value is 46 percent, and the winter lookup value is 3 percent.

Applying Equation 49,

*Deemed summer demand = DC system size (kW) * Lookup Value*

*Deemed summer demand = 50.000 kW * 46%*

*Deemed summer demand = 50.000 kW * 0.46*

Deemed summer demand = 23.000 kW

Applying Equation 50,

*Deemed winter demand = DC system size (kW) * Lookup Value*

*Deemed summer demand = 50.000 kW * 3%*

*Deemed summer demand = 50.000 kW * 0.03*

Deemed summer demand = 1.500 kW

Summer and Winter Demand Savings—Alternative Method

An alternative method to estimate summer and winter demand savings is also available. To use the alternative method, follow these steps:

- **Step 1.** Determine the applicable weather zone of the proposed system using Figure 16 above.
- **Step 2.** Use PVWatts® to model the proposed system as described in the Annual Energy Savings (kWh) section above. However, instead of using the zip code/default weather file, select the TMY3 reference location and weather file associated with the applicable weather zone of the proposed system. (e.g., a system in McAllen in weather zone 1 would be modeled based on the DALLAS-FORT WORTH INTL AP, TX TMY3 weather file). Leave all other inputs the same.
- **Step 3.** On the PVWatts Results page, select Download Results: Hourly. Save the **pvwatts_hourly.csv** output file to your computer and open it using Microsoft Excel.
- **Step 4.** Open the provided calculation tool **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field) on your computer, and select the Alt. Method Inputs tab.
- **Step 5.** From the PVWatts hourly output file, highlight and copy the output data (A1:K8780). Paste this data to cell M1 on the Alt. Method Inputs tab in **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field).

- **Step 6.** On the Alt. Methods Outputs tab, the tool calculates and displays summer and winter demand savings as AC capacity (kW_{ac}) and as a percentage of the DC capacity of the modeled system.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) of photovoltaic system is established at 30 years. This value is consistent with engineering estimates based on manufacturers' warranties and historical data.

Additional Calculators and Tools

TRM 4.0 PV tool YYYYMMDD_locked.xlsx (in which the version date is indicated by the YYYYMMDD field), provided by Frontier Energy, is used to determine summer and winter demand savings. The most current version is posted at the Texas energy efficiency website, http://www.texasefficiency.com/. Utilities have the option to create their own versions.

Program Tracking Data and Evaluation Requirements

The following information will be required to determine the project eligibility.

- Project location (full address, including city, state, and zip code)
- Module type: Standard, premium, or thin film
- Array Type: Fixed (open rack), fixed (roof mount), one-axis tracking, one-axis backtracking, two-axis tracking, etc.
- Tilt, azimuth, and DC system size rating for each array
- The calculation of electricity production through PVWatts® can be completed by accessing the online calculator or utilizing an API, application programming interface. The required documentation varies between the two methods.
    - Online Calculator: Date of PVWatts® run, and PVWatts® printed results report (as a file retained with project documentation)
    - API: Date of API access and response, documentation of API programming (including the access endpoint and request parameters), and the response results.
- Selected climate zone and demand method used
- For projects using the alternative method, retention of the TRM 4.0 PV tool workbook for each array evaluated

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides estimate for EUL.

Relevant Standards and Reference Sources

- National Electric Code (NEC) 690, “Solar Photovoltaic Systems” or local building codes.
- P. Dobos. PVWatts® Version 5 Manual. National Renewable Energy Laboratory. NREL/TP-6A20-62641. September 2014. http://www.nrel.gov/docs/fy14osti/62641.pdf. PVWatts® calculator available at https://pvwatts.nrel.gov/index.php.

Document Revision History

Table 40. M&V Nonresidential Solar PV Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v3.1	11/05/2015	Updated to reflect EPE’s 2016 program and revised maximum incentivized size for EPE from 50 to 10 kW.
v4.0	10/10/2016	Removed deemed savings option for energy. Provided new method for calculating summer and winter demand savings and provided deemed summer and winter demand savings lookup tables.
v5.0	10/10/2017	Corrected equation, figure, and table references.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	Updated instructions for new version of PVWatts® and references to NREL National Solar Radiation Database (NSRD) (previously TMY3)
v9.0	10/2021	Clarified PVWatts® kWh modeling instructions and documentation requirements. Provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges.

2.3.3 Solar Shingles Measure Overview

TRM Measure ID: R-RN-SS and NR-RN-SS

Market Sector: Residential and commercial

Measure Category: Renewables

Applicable Building Types: All

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET), new construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: Prescribed simulation software EM&V

Savings Methodology: Software modeling tool and calculator-SAM

Streamlined measurement and verification of solar shingles installations shall consist of the development of a project-specific model of the installed solar shingle system using the System Advisor Model (SAM), developed by the National Renewable Energy Lab (NREL). A solar shingles system consists of all connected arrays, sub-arrays, and inverter(s).

Measure Description

A solar shingles system consists of all connected arrays, sub-arrays, and inverter(s). The M&V method used to estimate savings is a simulation model approach using the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM). Either version 2015.6.30 or a more recent version of the SAM software shall be used.

Eligibility Criteria

Solar shingle systems consisting of connected arrays, sub-arrays, and inverters.

The installation must meet the following requirements to be eligible for incentives:

- Systems shall be installed by a licensed electrical contractor or, in the case of a residential installation by the homeowner, with the approval of the electrical inspector in accordance with the National Electric Code (NEC 690, "Solar Photovoltaic Systems") and local building codes.
- If the system is utility interactive, the inverter shall be listed and certified by a national testing laboratory authority (e.g., UL 1741, "Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems") as meeting the requirements of the Institute of Electrical and Electronics Engineers (IEEE) Standard 929-2000 "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems."
- The estimated annual energy generation from the solar shingles system shall not exceed the customer's annual energy consumption.

Baseline Condition

PV system not currently installed (typical).

High-Efficiency Condition

PV systems must meet the eligibility criteria shown above to be eligible for reporting claimed energy impacts. The high-efficiency conditions are estimated based on appropriate use of NREL's SAM software modeling tool for solar shingle installation analysis.

Energy and Demand Savings Methodology

Not applicable.

Savings Algorithms and Input Variables

SAM solar shingle installation data, modeling and analysis

SAM can be downloaded from the NREL website.[38]

SAM Data Input

The following steps present the information and sequence required to accurately model solar shingle projects using the SAM software tool.

- **Step 1.** Create a new solar PV project in SAM
- **Step 2.** Specify a Solar PV project and select a market segment (e.g., residential, commercial)
- **Step 3.** Solar systems are configured in the SAM main model interface that is organized across a number of screens, selected by a topics menu on the left-hand side of the window. The following items must be configured:

Location and Resource. An appropriate weather file must be specified in the subsequent screen. SAM is pre-loaded with a selection of weather files from the NREL NSRDB TMY3 datasets. The user should specify one of the five locations provided in Table 41, according to where in Texas the solar shingles are being installed. The map in Figure 17 indicates the delineation of the weather zones by county.

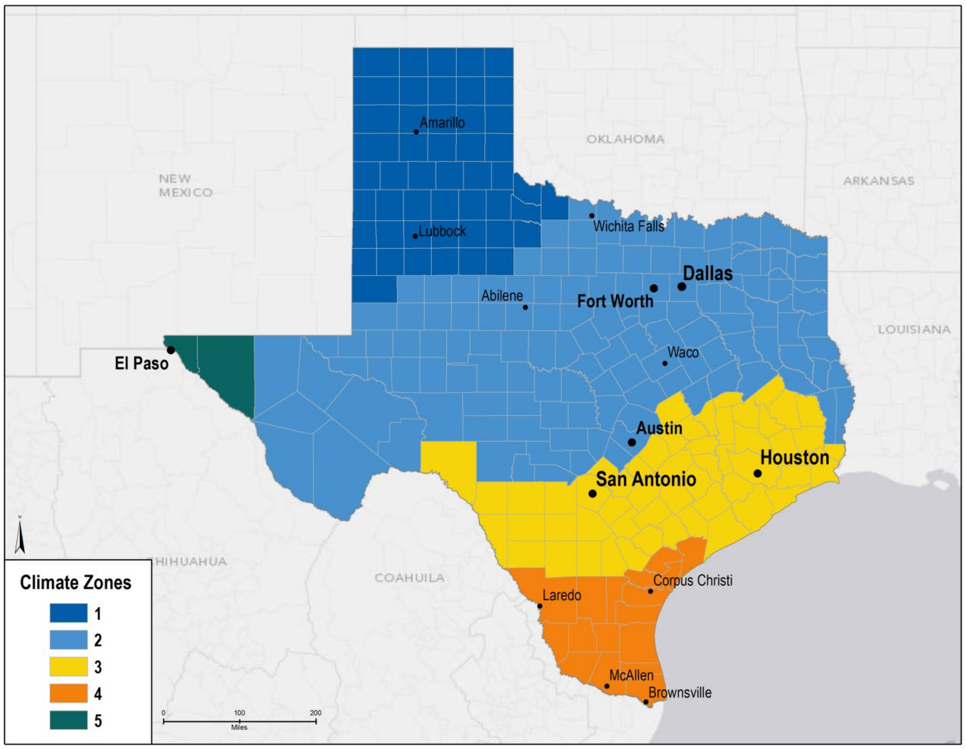
NOTE: It is critical that the TMY3 files are specified in the model for estimating peak demand impacts and that the corresponding set of peak hours and relative probabilities from TRM Volume 1, Section 4 shall be used to estimate peak demand impacts.

[38] As of publication of this version, the latest release of SAM is Version 2015.6.30. Instructions provided herein are intended to be sufficiently generic to allow for successful model creation in this and subsequent iterations of the software; however, it is impossible to anticipate the exact nature of future software revisions.

Table 41. TMY Data File by TRM Weather Zone

TRM weather zone		TMY3 file	TMY3 location
1	Panhandle Region	723630	Amarillo Intl AP (Canyon—UT)
2	North Region	722590	Dallas Fort Worth Intl AP
3	South Region	722430	Houston Bush Intercontinental
4	Valley Region	722510	Corpus Christi Intl AP (UT)
5	West Region	722700	El Paso International AP (UT)

Figure 17. Texas Technical Reference Manual Weather Zones



Module. The default action in the Module screen allows users to select a product with required performance data pre-loaded into SAM. Several CertainTeed Apollo modules and Dow DPS-XXX modules can be specified in this window. However, modeling options for the PV Module can be modified in SAM 2015.6.30 by selecting the dropdown menu that is set to "CEC Performance Model with Module Database" (at the top of this window). Other modeling options provide flexibility to adequately model products from other manufacturers.

Temperature correction. The module screen includes a 'Temperature Correction' window, in which one of two-cell temperature models must be specified. The 'Nominal operating cell temperature (NOCT) method' should be selected, and within the 'Nominal output cell temperature (NOCT) parameters' section, the 'Mounting standoff' should be specified as 'Building integrated.' The 'Building integrated' option accounts for solar shingles integrated on buildings.

Inverter. Inverter-specific information must be provided. Similar to the Module screen, an inverter can be selected from the Inverter CEC Database (default). Inverters not in the CEC database should use data from the manufacturer (Inverter Datasheet mode) or inverter efficiencies at different loading rates from inverter part load curves (Inverter Part Load Curve mode). Any of these methods is satisfactory. Note that the number of inverters can be specified on the following 'Array' screen, but only one inverter type can be specified here, so when multiple inverters are used with systems modeled in SAM, they must be the same make and model.

System design (array). The following array-level information shall be provided:

- System sizing: Specified by solar module capacity and count and inverter system losses.
- Configuration at reference conditions (Modules and Inverters) DC subarrays. SAM allows modeling up to 4 subarrays. If the system model has only one array, the data for this array is entered in the column for subarray 1; subarrays 2-4 should be left disabled. If there are multiple arrays, check the boxes to enable subarrays 2-4, as needed, and the number of strings in that subarray. Pre-inverter derates should be specified as appropriate.
- Estimate of overall land usage. Not needed (used for economic analysis only).
- PV subarray voltage mismatch. For CEC modules (true of CertainTEED and Dow DPS products), losses due to subarray mismatch can be estimated. For arrays with multiple orientations, this option should be selected.

Shading and snow. A good faith effort should be made to represent features likely to affect incidence of solar radiation on the solar shingle system. Appropriate shading for the installation site should be incorporated; however, it is not necessary to modify the annual average soiling, as first year generation values will be used.

Losses. Specify all DC and AC losses.

For the remaining topics/screens listed below, no data entry is required:

- Lifetime
- Battery storage
- System costs
- Financial parameters
- Incentives
- Electricity rates
- Electric load

Model Run and Data Output

Execute the model calculations (in 2015.6.30) by clicking “Simulate” in the bottom left corner. SAM generates many output data fields: create an 8,760 hourly output file by selecting “Time Series” at the top of the screen (option appears only after clicking “Simulate”) and then select “Power generated by system (kW)” from the options on the right-hand side of the screen. Output data can be saved as Excel or .csv by right clicking on the generated plot and selecting the desired option.

Deemed Energy and Demand Savings Tables

There are no lookup tables available for this measure. See SAM software tool guidance in the previous section to calculate energy and demand savings.

Claimed Peak Demand Savings

Peak demand savings should be extracted from the hourly data file in a manner consistent with the peak demand definition and the associated methods to extract peak demand savings from models producing 8,760 hourly savings using Typical Meteorological Year (TMY) data. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of solar shingles is established at 20 years. This value is consistent with engineering estimates based on manufacturers' warranties and historical data.

Program Tracking Data and Evaluation Requirements

The following inputs should be collected in program databases to inform the evaluation and calculate energy savings accurately.

- Decision/action type: retrofit, new construction
- Building type
- Climate/weather zone
- System latitude
- System tilt from horizontal
- System azimuth

The following files should be provided to the utility from which the project sponsor seeks to obtain an incentive for a solar shingles system installation:

- SAM model file (*.zsam format)
- 8,760 hourly output file (csv or similar format)
- Calculator with annual energy savings and peak demand savings estimate

References and Efficiency Standards

Not applicable.

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- National Electric Code (NEC) 690, "Solar Photovoltaic Systems" or local building codes.
- Institute of Electrical and Electronics Engineers (IEEE) Standard 929-2000 "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems." http://standards.ieee.org/findstds/standard/929-2000.html.
- System Advisor Model (SAM) Version 2014.1.14. National Renewable Energy Laboratory. SAM is available for registration and download at: https://sam.nrel.gov/download.

Document Revision History

Table 42. M&V Solar Shingles 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 the reference to latest version of SAM software and removal of TMY2 weather data file use. Revised measure details to match format of TRM volumes 2 and 3. This included adding 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	No revisions.
v5.0	10/10/2017	No revisions.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	11/2021	TRM v9.0 update. Updated EUL.

2.3.4 Solar Attic Fans Measure Overview

TRM Measure ID: R-RN-SF

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Residential

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculations

Savings Methodology: Engineering calculations and estimates

Measure Description

Solar attic fans increase the extraction rate of accumulated hot air in attics during the cooling season. Solar attic fans introduce no new electrical load to the home since they are powered by an attached photovoltaic (PV) panel. They save energy by reducing the load on air conditioning equipment, cooling the conditioned space directly underlying the attic, and by reducing heat exchange with supply ducts located in the attic when present.

Deemed savings are provided for a reduced air conditioning load.

Note: This measure was developed with limited savings information for Texas; therefore, solar attic fans should be implemented with the expectation of a savings methodology update in future TRMs as Texas-specific field information becomes available. This measure will be reconsidered on an annual basis. If sufficient M&V data is provided, this measure may be incorporated into Volume 2 as a fully-deemed measure.

Eligibility Criteria

The measure applies to existing homes with central- or mini-split-electric-refrigerated air conditioning. Ineligible applications include new homes, homes with tile roofs, homes with metal roofs, and evaporatively-cooled homes. Customers participating in hard-to-reach or low-income programs are also eligible to claim cooling savings for homes cooled by one or more room air conditioners by applying an adjustment factor to the provided deemed savings. Solar fans must have an automatic low-temperature shut-off to ensure cold outside air is not drawn into the attic during the heating season.

Baseline Condition

The baseline condition is an existing home with refrigerated air and a vented attic.

High-Efficiency Condition

The high-efficiency condition is the installation of sufficient solar attic fans to remove 400 cubic feet per minute (cfm) for every thousand square feet of attic floorspace. A solar attic fan consists of an electric fan powered by an integrated PV panel installed for the exclusive purpose of powering the fan.

Energy and Demand Savings Methodology

Savings have been estimated by performing energy balances on the roof surface and on the attic airspace on an hourly time step. The energy balances account for heat flux from the roof into the attic and between the attic and the underlying conditioned space. Solar attic fans are assumed to operate in the cooling season in the hours of the day when there is incident solar irradiation on the panel. Deemed savings are based on replacing hot attic air with outside air using solar attic fans with a capacity of 400 cfm per thousand square feet of attic floor. Estimated savings are a function of the difference in heat transfer to conditioned space with and without solar attic fans, considering that the heat transferred to conditioned space must be removed by the air conditioning system. For homes with ducts in the attic, additional savings are estimated considering heat transfer to supply ducts.

Hourly data for the ambient conditions is from TMY3 files for the Texas TRM climate zones.

Savings Algorithms and Input Variables

Attic temperature for each hour is estimated according to the following equation for both the baseline and high-efficiency conditions:[39]

$$T_a = \frac{A_r * U_r * \dfrac{\alpha * I_s + h_o * T_o}{h_o + U_r} + Q * \rho * c_p * T_o + (A_c * U_c + A_d * U_d) * T_i}{\dfrac{A_r * U_r * h_o}{h_o + U_r} + Q * \rho * c_p + (A_c * U_c + A_d * U_d)}$$

Equation 51

Where:

A_r = *Roof surface area (ft²)*

U_r = *U-factor of the roof between the unconditioned attic and the exterior (Btu/ft²-hr-°F)*

α = *Absorption coefficient of the roof (dimensionless)*

I_s = *Solar irradiance (Btu/ft²-hr)*

h_o = *Convective heat transfer coefficient for air (Btu/ft²-hr-°F)*

[39] This equation results from solving the energy balance on the roof for Tr and inserting this value into the energy balance for the attic airspace, while solving for Ta. The equations are drawn from ASHRAE Fundamentals, Chapter 17, Residential Heat Load Guidebook. Approach originally derived by Tetra Tech, Inc. (see references section).

T_o = *Exterior temperature (°F)*

T_r = *Temperature of the roof (°F)*

T_a = *Temperature of the attic (°F)*

Q = *Ventilation airflow rate (CFM)*

ρ = *Density of air (lb/ft^3)*

c_p = *Specific heat of air (Btu/lb-°F)*

A_c = *Ceiling surface area (ft^2)*

U_c = *U-factor of the ceiling between the conditioned space and the unconditioned attic (Btu/ft^2-hr-°F)*

A_d = *Surface area of supply ducts in the attic (ft^2); set to zero if there are no supply ducts in the attic*

U_d = *U-factor of the insulation on the ducts, (Btu/ft^2-hr-°F)*

T_i = *Temperature of the conditioned space (°F)*

Once hourly attic temperatures are estimated for the baseline and high-efficiency conditions, hourly energy savings are estimated as follows:

$$Hourly\ Energy\ Savings\ (kWh) = \frac{(\mathrm{A}_c * \mathrm{U}_c + \mathrm{A}_d * \mathrm{U}_d)}{1000 * \mathrm{EER}} * \left(T_{a,b} - T_{a,he}\right) * 1\ hr$$

Equation 52

Where:

A_c = *Ceiling surface area (ft^2)*

U_c = *U-factor of the ceiling between the conditioned space and the unconditioned attic (Btu/ft^2-hr-°F)*

A_d = *Surface area of supply ducts in the attic (ft^2); set to zero if there are no supply ducts in the attic*

U_d = *U-factor of the insulation on the ducts (Btu/ft^2-hr-°F)*

EER = *Efficiency of the air conditioner (Btu/W-h)*

$T_{a,b}$ = *Temperature of the baseline attic, without solar powered attic fan (°F)*

$T_{a,he}$ = *Temperature of the attic in the high-efficiency condition, with solar-powered attic fan (°F)*

Deemed Energy and Demand Savings Tables

Energy and demand savings are estimated for homes with ducts in the attic and for homes with no ductwork in their attics.

Table 43. Solar Attic Fans Deemed Annual Energy Savings (kWh)

Climate zone	No ducts in attic	Ducts in attic
Climate Zone 1: Amarillo	147	245
Climate Zone 2: Dallas	212	350
Climate Zone 3: Houston	236	391
Climate Zone 4: Corpus Christi	260	431
Climate Zone 5: El Paso	252	420

Annual energy savings are simply the sum of the hourly energy savings:

$$Annual\ Energy\ Savings\ (kWh) = \sum_{hr=1}^{8760} Hourly\ Energy\ Savings \times CAF$$

Equation 53

Where:

CAF = *Cooling savings adjustment factor: set to 1.0 for homes with central refrigerated air; for homes with one or more room air conditioners set to 0.6*

Table 44. Solar Attic Fans Deemed Summer Peak Demand Savings (kW)

Climate zone	No ducts in attic	Ducts in attic
Climate Zone 1: Amarillo	0.16	0.26
Climate Zone 2: Dallas	0.12	0.20
Climate Zone 3: Houston	0.10	0.15
Climate Zone 4: Corpus Christi	0.15	0.24
Climate Zone 5: El Paso	0.17	0.28

The cooling adjustment factor is also applied to the demand savings:

$$Peak\ Demand\ Savings\ (kW) = Summer\ Peak\ Demand\ Savings \times CAF$$

Equation 54

Where:

The *Summer Peak Demand Savings* are the appropriate value from Table 44, and

CAF	=	*Cooling savings adjustment factor: set to 1.0 for homes with central refrigerated air; for homes with one or more room air conditioners set to 0.6*

Winter peak demand savings are not estimated. Solar attic fans that operate in the winter would likely require more space heating and produce negative savings by increasing the temperature gradient between conditioned space and the cooler attic air (while potentially creating condensation issues).

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar attic fan is closely related to its motor. The US DOE Advanced Manufacturing Office's Motor Systems Tip Sheet #3 suggests motors should last approximately 35,000 hours. The average annual hours of operation for solar attic fans across the Texas TRM zones is about 2,300 hours. Accordingly, the EUL for solar attic fans in Texas is estimated to be 15 years.

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Attic floor area (ft^2)
- Installed capacity of installed solar attic fans (CFM)
- Absence/presence of ducts in attic space
- Absence/presence of A/C equipment in attic space
- Length and insulation R-value of ducts in the attic if applicable
- Attic insulation R-value
- Exterior roof type (e.g., black asphalt shingles, metal seam)
- Air conditioning type, age, and estimated EER
- Azimuth of fan solar panel

- Temperature measurements (for PY2020, 5 of initial 10 projects in Texas and 10 percent of the subsequent 200 projects in Texas, not to exceed 25 installations); future program years' (PYs) measurement requirements will be determined on an annual basis.
    - Pre-install spot measurements (near insulation level and underside of roof)
    - Post-install two-week logging, minimum on reading per hour (near insulation level and underside of roof)

References and Efficiency Standards

Petitions and Rulings

- TBD

Relevant Standards and Reference Sources

- 2017 ASHRAE Handbook-Fundamentals; Chapter 17, Residential Cooling and Heating Load Calculations.
- Tetra Tech Memorandum to the Independent Electricity System Operator (IESO) of Ontario, Canada. Attic Fan Measure Characterization. Authors Mark Bergum and Marc Collins. August 20, 2018.
- US Department of Energy, EERE Advanced Manufacturing Office. Motor Systems Tip Sheet #3. Online. Available: https://www.osti.gov/servlets/purl/15020347

Document Revision History

Table 45. Residential Solar Attic Fans Revision History

TRM Version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	Remove measure due to lack of M&V data collection to refine preliminary deemed savings estimates.
v9.0	10/2021	Reinstate measure requiring M&V data collection.

2.4 M&V: MISCELLANEOUS

2.4.1 Behavioral Measure Overview

TRM Measure ID: NR-MS-BC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Operation and maintenance (O&M)

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 various behavioral changes that remain persistent and reliable long term. The purpose of this measure is to create a framework to provide verified savings within standards currently applied to other commercial energy savings measures.

Measure Description

This measure is not defined but requires that any behavioral project develop an M&V plan and report. The project may include associated equipment installation. The M&V plans and reports should include a description of the proposed behavioral changes, how the changes will save energy, and why the behavioral change should be considered a permanent change, similar to other high-efficiency equipment retrofits.

One example is to establish an authorized facility-wide energy policy with an implementation plan and quality assurance processes. Another example is to establish electric fleet vehicle energy charging policies to shift energy consumption to off-peak periods and reduce peak demand.

M&V plans and reports should describe how changes in operations and/or sequence of operations translate into energy savings. The measure description should include how initial energy savings estimates will be verified by IPMVP-compliant M&V.

Eligibility Criteria

This measure applies to behavioral measures that provide persistent energy reductions that are measurable at the facility level. Project sites that do not have hourly interval consumption data available should contact the EM&V team for approval.

Baseline Condition

The baseline condition for each behavioral measure has two aspects: 1) the existing operating parameters (e.g., temperatures, hours of operation, loads) and existing energy use for each behavior change and 2) the proposed new case for each behavior change with equations that meet the model fitness requirements to quantify energy savings.

The M&V plan should document the source and accuracy/confidence of the parameters used in the proposed equations to estimate baseline and new case energy use for each behavior impact (e.g., interior lights are to be turned off). The M&V plan should explain assumptions for both baseline and behavior change cases, citing sources.

High-Efficiency Condition

Demonstrated by conclusive energy savings following IPMVP protocols.

Energy and Demand Savings Methodology

Not applicable.

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

Savings equations, algorithms, and inputs should be used to estimate initial energy savings prior to measure implementation and follow standard engineering practices and accepted energy efficiency engineering methods. M&V plans should cite sources used to develop energy savings estimates. Final whole facility savings should be included in the M&V report.

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

The EM&V methodology presents a plan to determine (i.e., calculate and verify) energy savings due to significant and persistent facility-wide behavioral changes for a commercial facility, following IPMVP option C and standards followed by other commercial measures. Whole facility guidance is found in IPMVP Volume 1 EVO 10000-1:2012. CalTRACK 2.0 technical appendix should be used to support the development of consistent normalized energy consumption models.

The option C methodology should document details regarding model development, testing, handling of errors, and information to validate regression model(s). However, there are many assumptions in regression modeling that may require more detailed explanation in an M&V report.

Model documentation should be transparent and allow for repeating modeling steps and results, including the use of any adjustments made outside of the primary modeling method. Procedures and their results should be documented and may include:

- Describe how modeling outliers were identified and addressed
- Describe how missing data errors were addressed and document what changed from the original model. Any data removed or changed should be annotated with a cause.
- Description of non-routine events and adjustments across the measurement periods. The COVID-19 pandemic[40] altered many C&I customer operations in multiple ways, and each major adjustment in operation should be described, such as full shutdown periods, partial operation periods, and full operation periods.

M&V Plan and M&V Report

Preparation of an M&V plan and report is required to determine savings. An M&V plan ensures that collected data and information necessary to determine savings will be available after implementation of the behavioral change(s). The M&V plan and report will provide a record of the energy savings estimates and data collected during the project. The M&V plans and reports may also record critical assumptions, conditions, and changes that occur during the project. For example, the M&V plan describes how variables that affect energy use is documented and recorded while the M&V report documents such findings. Documentation should be complete, readily available, clearly organized, and easy to understand.

Changes to required documentation may be possible if a viable comparison group can be used. The EM&V team will review M&V plans that include the make-up and selection of the comparison group in lieu of required documentation.

The methodology described herein uses whole facility electric meter data.

M&V plans and reports must include:

- Measures and actions implemented
- IPMVP option and measurement boundary
- Weather station information
- Baseline period, energy consumption readings, on-site energy production, and conditions
- Performance period, energy consumption readings, on-site energy production and conditions
- Adjustment factor for energy consumption measurements to account for known and unknown operation adjustments in response to the COVID-19 pandemic. Include description and period for each factor.
- Non-routine adjustment description, period, impact, and adjustments
- Basis for adjustment and multi-year interaction

[40] Starting March 2019

- Analysis procedure
- Baseline normalized energy consumption and peak demand model
- Performance period normalized energy consumption and peak demand model
- Energy prices (as applicable)
- Meter specifications
- Monitoring responsibilities
- Expected accuracy
- Quality assurance

Normalized Energy Model Fitness

The model should be designed to develop the most accurate normalized metered energy consumption using a replicable method. The models used for the baseline and performance periods should be the simplest model available with the best R^2 and CV(RMSE)[41]. It is required that selected variables are reasonably understood to impact consumption levels and not coincidental during a measurement period. The least-squares regression method is most common and should be completed separately for electric consumption (kWh) and electric demand (kW). Other methods are acceptable if the least squares method is not sufficient. The model shall attempt to meet the following model fitness metric requirements:

- Energy savings is greater than 10 percent of baseline consumption
- R^2 value greater than or equal to 0.75

The electric demand model based on one-hour interval data will lead to the best model to determine peak demand savings. The model shall be evaluated to determine if the peak demand is accurately represented during the peak conditions as described in TRM Volume 1. An alternate regression model for the peak demand is required when the measured peak demand varies from the modeled peak demand at the high and low measured temperature period by greater than 20 percent.

Where possible, one year of pre and post utility, building, or system level data is preferred for conducting a regression analysis. Where less than a year of data is not feasible, methodologies should be considered on a case-by-case basis with prior approval from the EM&V team.

Baseline Data and Model

The participants baseline data shall be used to create a baseline model equation. The M&V plan should document the data used to determine the baseline completely and accurately, including the selection of constants and independent variables. The baseline and independent variables shall be derived based on the historical electric consumption 12 months immediately prior to the engagement, the nearest TMY3 weather data file, and other relevant variables, such as floor

[41] Coefficient of Variation Root Mean Squared Error

area or operating profile[42]. Historic electricity consumption is expected to be an hour interval to support the development of the peak demand savings detailed in Volume 1.

Baseline energy models can be used for multiple years for long-term behavior engagements. A baseline normalized energy model can be used for a maximum five years from the start of the baseline period to the start of the performance period. Although the period may be reset earlier if non-routine adjustments are unable to be identified or quantified.

Reporting Period Data and Model

The M&V plan should document the data used to determine the baseline completely and accurately, including the selection of constants and independent variables. The baseline and independent variables shall be derived based on the historical electric consumption 12 months, the nearest TMY3 weather data file, and other relevant variables, such as floor area or operating profile. Historic electricity consumption is expected to be an hour interval to support the development of the peak demand savings detailed in Volume 1, Section 4.

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

The methodology used to determine peak demand savings should be consistent with the methodology of energy savings. The calculation of peak demand savings should include the weather-dependent peak demand probability factors, as outlined in Volume 1, Section 4. The methodology should be documented clearly in the M&V plan and report. Because models are developed for a normalized year, the factors outside the date, time, and temperature should be assumed to be the maximum for the date and time combination, such as considering the date a weekday operation day for an office building.

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is one year.

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

[42] CalTRACK 2.0 provides a compliance checklist that can be used as best practices during model development, https://www.caltrack.org/caltrack-compliance.html.

- Climate zone
- Baseline equipment types affected by behavior change
- Baseline equipment capacities
- Baseline equipment efficiency ratings
- Baseline number of units
- Baseline operating practice
- Efficient operating practice

References and Efficiency Standards

Not applicable.

Petitions and Rulings

- Behavioral programs are allowed energy efficiency programs as specified in the Energy Efficiency Rule (16 TC 25.181 (c)(12))

Relevant Standards and Reference Sources

- International Performance and Measurement Verification Protocol: https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp
- CalTRACK 2.0 Technical Appendix: http://docs.caltrack.org/en/latest/technical-appendix.html
- Unique to each project and to be documented in M&V plan and report

Document Revision History

Table 46. M&V Behavioral Revision History

TRM version	Date	Description of change
v3.1	11/05/2015	TRM v3.1 origin.
v4.0	10/10/2016	Updated documentation of methodology and measure life.
v5.0	10/10/2017	No revisions.
v6.0	10/2018	No revisions.
v7.0	10/2019	Transferred relevant guidance language from Vol. 5
v8.0	10/2020	Added hourly interval data as a requirement, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period.
v9.0	10/2021	Updated model requirements to account for pandemic and other non-routine events.

2.4.2 Air Compressors Less than 75 hp Measure Overview

TRM Measure ID: NR-MS-CA

Market Sector: Commercial

Measure Category: Miscellaneous

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

This protocol is used to estimate savings for compressed air system controls measures for systems with less than 75 horsepower in total compressor power. The compressed air methodology is a framework to provide high quality verified savings for smaller compressed air projects. This measure uses site collected data, follows savings methodologies as outlined by the Ohio Technical Reference Manual, and uses research on compressed air systems conducted by the Long Island Power Authority.

Measure Description

This measure requires the installation of flow controls on existing compressed air systems with a total compressor power of less than 75 hp. This methodology limits the amount of savings that can be claimed to 20 kW and 100,000 kWh for a project. For projects that are expected to exceed 20 kW or 100,000 kWh savings, full M&V is recommended.

Applicable controls measure types include:

- Load/unload controls: allow the motor to run continuously at a constant speed but unloads the compressor when adequate pressure has been achieved. Efficient load/unload controls use storage tank(s) to increase the available compressor air capacity without requiring compressor operation during all load periods. This protocol provides estimated savings for systems that exceed 3 gal/CFM or 5 gal/CFM in storage capacity.
- Modulating inlet controls: restricts inlet air to the compressor to progressively reduce compressor output to meet the flow requirements of the system. Also referred to as throttling or capacity control. The amount of capacity reduction is limited by the potential for surge and minimum throttling capacity.
- Variable displacement systems: have compressors that operate in two or more partially loaded conditions. Since the compressor can operate efficiently at multiple output points, it can more closely align with the load of the system.

- Variable speed with unloading: controls the compressor motor to match the load of the system, offering the highest efficiency gains. During periods of low demand, the compressor is unloaded and operates at the minimum variable speed until the flow and pressure demand exceeds the minimum output of the compressor.

Eligibility Criteria

This measure applies to retrofitting an existing compressed air system with new, higher efficiency flow controls or the installation of a new compressed air system with eligible flow controls.

Baseline Condition

Existing System Retrofit: The baseline for existing system retrofit shall be the applicable control type from the pre-existing system, from Table 47.

Replace-on-Burnout (ROB) and New Construction (NC): The baseline for ROB and NC projects is assumed to be a modulating air compressor with blow down (a standard industry practice). The baseline efficiency is given from the Modulation category in Table 47.

High-Efficiency Condition

High-efficiency conditions for compressed air system are in Table 47.

Table 47. Air Compressor Energy Factors

Control type	ACEF	Source
Modulation	89.0 percent	LIPA Clean Energy Initiative[43]
Load/No Load with 3 gal/CFM	83.1 percent	
Load/No Load with 5 gal/CFM	80.6 percent	
Variable Displacement	76.9 percent	
Variable Speed with Unloading	67.5 percent	

[43] Data obtained from Long Island Power Authority's Clean Energy Initiative, See ACEF Development section for more details.

Energy and Demand Savings Methodology

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

Standard IPMVP option A procedures will be used to compare stipulated values to actual site conditions to confirm or adjust values found in the Ohio TRM, Long Island Power Authority's Clean Energy Initiative, Arkansas C&I program, and Texas Pilot program. Savings are determined by comparing measured energy use before and after implementation of a project, with adjustments for changes in conditions.

Option Type and Measurement Boundary

The M&V plan will follow the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) option A—Retrofit Isolation: Key Parameter Measurement. This method calculates energy savings using key energy consumption parameters before the equipment retrofit begins and after the retrofit is completed. The option A guidelines are described in the latest version of the IPMVP Volume 1 EVO 10000-1:2012.

The key parameter being measured is interval true power (kW).

Baseline and Reporting Period

Two weeks of logging data before and two weeks of logging data after the controls upgrade.

Savings Methodology—Measured Data Analysis

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

$$Peak\ Demand\ Savings\ (kW)\ = kW_{PDPF,existing} - kW_{PDPF,new}$$

Equation 55

$$Annual\ Energy\ Savings\ (kWh) = (kW_{avg\ op,existing} - kW_{avg\ op,new}) * Hours$$

Equation 56

Where:

kW_{PDPF}	=	*Compressor motor kW from metered data corresponding to PDPF period as outlined in TRM Volume 1*[44]
$kW_{avg,\ op}$	=	*Average compressor motor kW from metered data during the operating hours*
Hours	=	*Compressor total hours of operation per year; assumed to be the facility-posted annual operating hours*

[44] TRM Volume 1, section 4.7 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.

Savings Methodology—Stipulated Analysis

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

$$Peak\ Demand\ Savings\ (kW) = (kW_{full\ load,existing} * ACEF_{existing} - kW_{full\ load,new} * ACEF_{new}) * CF_{PDPF}$$

Equation 57

$$Annual\ Energy\ Savings\ (kWh) = (kW_{full\ load,existing} * ACEF_{existing} - kW_{full\ load,new} * ACEF_{new}) * Hours$$

Equation 58

$$kW_{full\ load,existing} = \frac{0.7456 * Motor\ Nominal\ HP_{existing}\ * LF_{rated}}{Motor\ Nominal\ Efficiency_{existing}}$$

Equation 59

Where:

$kW_{full\ load}$ = *Compressor motor full-load kW from CAGI data sheet; if baseline CAGI data isn't available, use Equation 59*

Hours = *Compressor total hours of operation per year; assumed to be the facility posted annual operating hours*

ACEF = *Air compressor energy factor from Table 47*

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

CF_{PDPF} = *Coincident factor determined from peak demand probability factors; for projects whose business hours encompass the entire PDPF period for the building's climate zone, the factor is 1.0*[45]

Deemed Energy and Demand Savings

There are no deemed energy or demand savings for this measure.

Claimed Peak Demand Savings

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

[45] 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.

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 report.

ACEF Development

As part of the Long Island Power Authority (LIPA) Clean Energy Initiative, a study of air compressors was conducted with collected data on the operating capacity of the compressed air systems. LIPA provided data from this study, which was used as the basis for the ACEF development.

The capacity data was divided into percent of full-load capacity bins to determine average system loading across the population. This data was weighted by the brake horsepower of each compressor in the population. For each capacity bin, the percent power was determined for the control schemes from the Department of Energy air compressor savings calculator (no longer publicly available). The percent power curves were used with the load profile (from the study data) to develop average compressor energy factors for each control scheme for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for commercial air compressors is 10 years, pending further research.

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ER, ROB, NC, system type conversion
- Building type
- Climate zone
- Baseline equipment type
- Baseline equipment controls
- Baseline number of units
- Baseline compressor CAGI data sheets
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed equipment type
- Installed equipment controls
- Installed equipment make and model
- Installed number of units
- Installed compressor CAGI data sheets
- A description of the actual building type, the primary business activity, the business hours, and the operating schedule

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- State of Ohio Energy Efficiency Technical Reference Manual, https://focusonenergy.com/sites/default/files/Focus%20on%20Energy%20TRM%20-%20PY2017_1%28Archive%29.pdf#page=52

Document Revision History

Table 48. Air Compressors Less than 75 HP Revision History

TRM version	Date	Description of change
v5.0	10/10/2017	TRM v5.0 origin.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	No revisions.

2.4.3 Nonresidential Retro-Commissioning

TRM Measure ID: NR-MS-RC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Commercial

Fuels Affected: Electricity, natural gas

Decision/Action Types: Operational/maintenance

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 retro-commissioning (RCx) projects where a substantial portion of the savings are expected to come from operational and maintenance (O&M) activities. Since RCx often involves improvements through control system optimization, maintenance changes, and other system-level enhancements, determining savings often involves numerous assumptions and extensive interactive effects. This protocol provides a framework to calculate savings involving whole building or sub-system monitoring.

Measure Description

Retro-commissioning is a systematic process to improve a building's energy use. RCx involves an assessment of all energy systems within a building and applies energy savings strategies to reduce overall energy use. The process usually begins with an energy audit of a building, an inventory of energy-use equipment, development of energy conservation measures (ECMs), cost-benefit analysis of ECMs, and implementation of selected ECMs.

ECMs that may be considered RCx projects include:

- Identification of maintenance issues observed during the energy audit, plans for fixing the issues, and plans to identify similar issues in the future.
- Development of optimization strategies for existing systems, including correcting air balancing issues, controls reductions of simultaneous heating/cooling operations, and incorrect control sequences.
- Implementation of control system strategies, or optimization of existing strategies, including economizer setpoint control, demand-controlled ventilation, HVAC occupancy schedules, hot water reset, chilled water reset, and system lockout temperatures.
- Maintenance scheduling improvements aimed to keep equipment operating at peak condition through proper adherence to manufacturer's recommended maintenance and advanced identification of issues through personnel inspections or control system parameters.

- Replacement options for aged equipment or development of a plan for future replacement of equipment.
- Removal of unnecessary equipment by disconnecting[46] from the electric grid.

Eligibility Criteria

Comprehensive RCx projects must be compliant with IPMVP option C. Projects shall meet the model fitness metrics. Project sponsors should contact the EM&V team for approval of RCx projects that do not have hourly interval consumption data available or do not meet the model fitness metrics. For RCx projects with smaller savings (< 20 kW) where standard M&V efforts may be cost prohibitive, simplified strategies to reduce M&V costs (e.g., using TRM values for lighting fixture wattage) will be considered with prior EM&V-team approval.

Baseline Condition

The baseline condition is the existing building energy use, prior to the engagement of initial RCx activities.

High-Efficiency Condition

The high-efficiency condition is the building or system energy use after implementation of RCx ECMs as agreed upon between the customer, utility, and/or third-party contractors.

Energy and Demand Savings Methodology

Whole Facility EM&V Methodology

The EM&V methodology presents a plan to determine (i.e., calculate and verify) energy savings due to operations and maintenance RCx projects for a commercial facility, following IPMVP option C and standards followed by other commercial measures. Whole facility guidance is found in IPMVP Volume 1 EVO 10000-1:2012.

The option C methodology should document in an M&V report details regarding model development, testing, handling of errors, and information to validate regression model(s). However, there are many assumptions in the regression modeling which require more detailed guidance. CalTRACK 2.0 technical appendix should be used to support the development of consistent normalized energy consumption models.

Model documentation should be transparent and allow for repeating modeling steps and results, including the use of any adjustments made outside of the primary modeling method. Procedures and their results should be documented and may include:

- Describing how modeling outliers were identified and addressed.
- Describing how missing data errors were addressed and document what changed from the original model. Any data removed or changed should be annotated with a cause.

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[46] Tag-out/lock-out of the electric breaker is acceptable to confirm disconnection from the electric grid.

- A description of non-routine events and adjustments across the measurement periods. The COVID-19 pandemic[47] altered many C&I customer operations in multiple ways and each major adjustment in operation should be described, such as full shutdown periods, partial operation periods, and full operation periods.

Where a significant portion of energy/demand savings is expected to come from prescriptive measures or custom measures whose savings have been independently determined through sub-system modeling (greater than 50 percent from a preliminary assessment), savings should be claimed following this M&V methodology exclusively OR savings should be claimed for the prescriptive measures and custom measures ONLY, to prevent overstating savings due to interactive effects.

Since most O&M savings involve HVAC systems, which are inherently driven by climatological factors, the whole facility analysis should use a normalization approach for the weather-dependent factors. Typical meteorological year (TMY) data should be used in the pre- and post-regression results to estimate normalized savings for comprehensive RCx projects.

M&V Plan and M&V Report

Preparation of an M&V plan and report is required to determine savings. An M&V plan ensures that collected data and information necessary to determine savings will be available after implementation of the behavioral change(s). The M&V plan and report will provide a record of the energy savings estimates and data collected during the project. The M&V plan and report may also record critical assumptions, conditions, and changes that occur during the project. For example, the M&V plan describes how variables that affect energy use is documented and recorded, while the M&V report documents such findings. Documentation should be complete, readily available, clearly organized, and easy to understand.

Changes to required documentation may be possible if a viable comparison group can be used. The EM&V team will review M&V plans that include the make-up and selection of the comparison group in lieu of required documentation.

The methodology described herein uses whole facility electric meter data.

The following requirements as part of the M&V plan and report.

- Measures and actions implemented
- IPMVP option and measurement boundary
- Weather station information
- Baseline period, energy consumption readings, on-site energy production, and conditions
- Performance period, energy consumption readings, on-site energy production and conditions
- Adjustment factor for energy consumption measurements to account for known and unknown operation adjustments in response to the COVID-19 pandemic; include description and period for each factor

[47] Starting March 2019.

- Non-routine adjustment description, period, impact, and adjustments
- Basis for adjustment and multi-year interaction
- Analysis procedure
- Baseline normalized energy consumption and peak demand model
- Performance period normalized energy consumption and peak demand model
- Energy prices (as applicable)
- Meter specifications
- Monitoring responsibilities
- Expected accuracy
- Quality assurance

Normalized Energy Model Fitness

The model should be designed to develop the most accurate normalized metered energy consumption using a replicable method. The models used for RCx should be the simplest model available with the best R^2 and CV(RMSE)[48]. Most common is the least-squares regression method completed separately for electric consumption (kWh) and electric demand (kW). The model shall attempt to meet the following model fitness metric requirements:

- Energy Savings is greater than 10 percent of baseline consumption.
- R^2 value greater than or equal to 0.75

The electric demand model based on one-hour interval data will lead to the best model to determine peak demand savings. The model shall be evaluated to determine if the peak demand is accurately represented during the peak conditions as described in TRM Volume 1. An alternate regression model for the peak demand is required when the measured peak demand varies from the modeled peak demand at the high and low measured temperature period by greater than 20 percent.

Where possible, one year of pre and post utility, building, or system level data is preferred for conducting a regression analysis. When less than a year of data is not feasible, methodologies should be considered on a case-by-case basis and prior approval from with the EM&V team.

Baseline Data and Model

The participant baseline data should be used to create a baseline model equation. The M&V plan should document the data used to determine the baseline completely and accurately, including the selection of constants and independent variables. The baseline and independent variables shall be derived based on the historical electric consumption 12 months immediately prior to the capital project, the nearest TMY3 weather data file, and other relevant variables,

[48] Coefficient of Variation Root Mean Squared Error

such as floor area or operating profile.[49] Historic electricity consumption is expected to be an hour interval to support the development of the peak demand savings detailed in Volume 1.

Performance Period Data and Model

The participants consumption data starting immediately after completion of all project components and the electricity savings exceeds 10 percent of the baseline energy consumption shall be used to create a performance period model equation. The M&V plan should document the data used to determine the baseline completely and accurately, including the selection of constants and independent variables. The baseline and independent variables shall be derived based on the historical electric consumption 12 months, the nearest TMY3 weather data file and other relevant variables, such as floor area or operating profile. Historic electricity consumption is expected to be an hour interval to support the development of the peak demand savings detailed in Volume 1.

Rounding

Data rounding to the nearest whole number should only occur at the annual consumption of the baseline or performance period. The hourly or daily results should not be rounded in calculations.

Savings Methodology—Measured Data Analysis

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

$$Peak\ Demand\ Savings\ (kW)\ = kW_{PDPF,existing} - kW_{PDPF,new} \pm kW_{adjustments} - \ kW_{other\ mees}$$

Equation 60

$$Energy\ Savings\ (kWh)\ = kWh_{existing} - kWh_{new} \pm kWh_{adjustments} - \ kWh_{other\ mees}$$

Equation 61

Where:

$kW_{PDPF,\ existing}$	=	*Building or system level kW for the existing building/system*
$kW_{PDPF,\ new}$	=	*Building or system level kW for the post retro-commissioning building/system*
$kWh_{existing}$	=	*Building or system level kWh normalized for the existing building/system from metered data*
kWh_{new}	=	*Building or system level kWh normalized for the post retro-commissioning building/system from metered data*

[49] CalTRACK 2.0 provides a compliance checklist that can be used as best practices during model development, https://www.caltrack.org/caltrack-compliance.html.

$kW/kWh_{adjustments}$	=	*Adjustments to the kW and kWh building/system metered data results that account for operational changes which are not attributable to the project*
$kW/kWh_{other\ meas}$	=	*Adjustments to the kW and kWh building/system metered data results that account for prescriptive and custom measures which are calculated independently*

Deemed Energy and Demand Savings

There are no deemed energy or demand savings for this measure. Prescriptive savings for individual measures may be calculated in accordance with other commercial measures in TRM volumes 3 and 4 if an initial assessment indicates they are less than 50 percent of the total project savings.

Simplified M&V Energy and Demand Savings

For smaller-scale RCx projects that will result in smaller savings (<20 kW), a simplified M&V approach may be used, pending EM&V pre-approval. These smaller RCx projects will be considered on a case-by-case basis.

The simplified M&V approach can provide custom calculations that incorporate all required data collection, spot measurements, and weather data to create detailed estimates of energy savings. Calculations must be able to determine the demand at the specific hour and temperature detailed in the peak demand savings methodology. Calculations must also incorporate the interactive effects between the implemented improvements, assuming conservative energy efficiency improvements when the interactive effects are unknown.

The description of the baseline and efficient condition in the Simplified M&V plan is required. It is required that improvements and assumptions are documented to support the calculations.

Claimed Peak Demand Savings

The methodology used to determine peak demand savings should be consistent with the methodology of energy savings. The calculation of peak demand savings should include the weather-dependent peak demand probability factors, as outlined in TRM Volume 1, Section 4. The methodology should be documented clearly in the M&V plan and report. Because models are developed for a normalized year, the factors outside the date, time, and temperature should be assumed to be the maximum for the date and time combination, such as considering the date a weekday operation day for an office building.

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 estimated useful life (EUL) for RCx projects is 5 years, pending further research for O&M measures.[50]

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 zone

References and Efficiency Standards

Not applicable.

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- International Performance and Measurement Verification Protocol: https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp
- CalTRACK 2.0 Technical Appendix: http://docs.caltrack.org/en/latest/technical-appendix.html
- Unique to each project and to be documented in M&V plan and report

[50] Kolwey, Neil. SWEEP Industrial Re-commissioning: Not Just a Building Tune-up. February 2017. https://www.swenergy.org/data/sites/1/media/documents/publications/documents/SWEEP%20Industrial%20Recommissioning%20Feb%202017.pdf.

Document Revision History

Table 49. Nonresidential Retro-Commissioning Revision History

TRM version	Date	Description of change
v6.0	10/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. Clarifications for small project exemptions and proper use of IPMVP Option C. Correction for erroneous eligibility criteria in v6.0.
v8.0	10/2020	Updated model fitness requirements, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period.
v9.0	10/2021	Updated model requirements to account for pandemic and other non-routine events. Added alternate calculation method.

2.4.4 Thermal Energy Storage Measure Overview

TRM Measure ID: NR-MS-TS

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Commercial

Fuels Affected: Electricity, natural gas

Decision/Action Types: Retrofit (RET), new constriction (NC)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V

This protocol is used to estimate savings for thermal energy storage (TES) projects. TES projects are systems that use heat transfer to a medium during off-peak hours or non-critical seasonal periods and then use stored heat during the on-peak hours or critical seasonal period. TES systems often have non-energy benefits (economic, equipment sizing, etc.) while having negligible, or even negative, energy savings.

Measure Description

Thermal energy storage systems represent a wide range of available technologies. Potential TES systems under this protocol include, but are not limited to, solar energy storage, molten-salt technologies, ice-based technologies, general heat storage in any technology, miscibility gap alloy technology, cryogenic energy storage, and hot silicon technology.

Eligibility Criteria

TES projects must be compliant with IPMVP option A, B, or C. For option C, the project should save more than 10 percent of peak demand with 30-minute (or more frequent) interval data. For option B, full M&V of the thermal energy storage system and affected systems is expected. For option A, the assumptions that support monitoring of only key datapoints should be discussed with the EM&V team prior to M&V plan development. An M&V plan should be developed when using Options A or B and approved by the EM&V team prior to the conducting of any metering for the project.

Baseline Condition

The baseline condition is the existing building energy use systems (retrofit) or minimal code-compliant systems (new construction).

High-Efficiency Condition

The high-efficiency condition is the building with the thermal energy storage system.

Energy and Demand Savings Methodology

Whole Facility EM&V Methodology

IPMVP option C can be used as the basis of analysis for thermal energy storage systems. If the thermal energy storage system is expected to have daily cycling, metering intervals must be 30-minutes or less (preferably 15-minutes) for all affected fuel types. Options A or B can be used when interval data is not available. The expected peak demand reduction from the TES must exceed 10 percent to attempt an option C analysis, and analyzed trends must exceed an R^2 of 0.75. Further, all hours defined in Volume 1 PDPF tables for the project's climate zone must be directly metered, as well as representative weather periods must be observed during the monitoring period. For TES systems with seasonality cycling, the monitoring interval can be increased and must be approved by the M&V team on a case-by-case basis.

For projects that follow, or need to follow, IPMVP Option A or B, all necessary parameters must be directly metered, or the assumptions need to be approved by the EM&V team. These may include the power use of affected systems, temperatures of storage mediums, and flow rates of liquids. An M&V plan for option A or B projects should be developed and approved by the EM&V team prior to conducting metering.

Baseline and Reporting Period

The baseline and reporting periods for TES systems will be approved on a case-by-case basis by the EM&V team.

Savings Methodology

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

$$Peak\ Demand\ Savings\ (kW) = kW_{PDPF,existing} - kW_{PDPF,new} \pm kW_{adjustments} - kW_{other\ mees}$$

Equation 62

$$Energy\ Savings\ (kWh) = kWh_{existing} - kWh_{new} \pm kWh_{adjustments} - kWh_{other\ mees}$$

Equation 63

Where:

$kW_{PDPF,\ existing}$ = *Building or system level kW for the existing building/system from metered data corresponding to PDPF period as outlined in TRM volume 1*[51]

$kW_{PDPF,\ new}$ = *Building or system level kW for the post TES building/system from metered data corresponding to PDPF period as outlined in TRM volume 1*[51]

[51] 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.

$kWh_{existing}$	=	*Building or system level kWh for the existing building/system from metered data*
kWh_{new}	=	*Building or system level kWh for the post TES building/system from metered data*
$kW/kWh_{adjustments}$	=	*Adjustments to the kW and kWh building/system metered data results that account for operational changes which are not attributable to the TES project*
$kW/kWh_{other\ meas}$	=	*Adjustments to the kW and kWh building/system metered data results that account for prescriptive and custom measures which are calculated independently*

Deemed Energy and Demand Savings

There are no deemed energy or demand savings for this measure.

Claimed Peak Demand Savings

The methodology used to determine peak demand savings should be consistent with the methodology of the energy savings. Furthermore, the calculation of peak demand savings should into account the weather dependent peak demand probability factors, as outlined in Volume 1, Section 4. The methodology should be documented clearly in the M&V plan and M&V report.

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for thermal energy storage (TES) projects is 15 years, pending further research for specific TES measures.

Program Tracking Data and Evaluation Requirements

The following should be documented in the M&V plan and M&V report:

- Decision/action type
- Building type

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- International Performance and Measurement Verification Protocol https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp
- U.S. Department of Energy: M&V Guidelines: Measurement and Verification of Performanced-Based Contracts (Version 4.0) https://www.energy.gov/sites/prod/files/2016/01/f28/mv_guide_4_0.pdf

Document Revision History

Table 50. Thermal Energy Storage Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	Added 30-minute interval data as a requirement when using IPMVP option C
v9.0	10/2021	No revisions.

2.5 M&V: LOAD MANAGEMENT

2.5.1 Residential Load Curtailment Measure Overview

TRM Measure ID: R-LM-LM

Market Sector: Residential

Measure Category: Load management

Applicable Building Types: Single family, multifamily, and manufactured

Fuels Affected: Electricity

Decision/Action Types: Operation and maintenance (O&M)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V

Utilities operate residential load management programs to obtain demand savings: energy savings are estimated as a function of the estimated demand savings.[52] Demand savings calculations are performed using utility customer interval energy demand data from IDRs or advanced meters. Measured and verified demand savings for the curtailment period is presented here.

Measure Description

This document presents the M&V savings methodology to participate in a load management program that involves the curtailment of an interruptible load during the summer peak period. Measures participating in a residential load management program may be air-conditioners, heat pumps, swimming pool pumps, or other electricity loads as specified by utility programs. Specific methods of load management for this measure are not defined and are determined by individual programs. The savings reflect the cumulative effect of all participant actions to reduce residence-wide demand during a load management event.

Eligibility Criteria

A project will be eligible for incentives and reporting demand and energy savings if the following criteria are met:

- Participants are homes and reduce their demand during curtailment events throughout the summer peak demand period outlined in Table 51.
- Each meter has a continuous demand interval recording capability (30-minute intervals or less)

[52] Some utilities may determine energy savings associated with load management events, which would be calculated as the difference between the baseline and curtailment kW values times the length of the event(s).

- Sufficient interval data exists to measure and verify sufficient comparison-days to establish demand baselines and interval demands during load management events.

Table 51. Peak Demand Period

Hours	Months	Exceptions
1:00 p.m.—7:00 p.m.	June, July, August, September	Weekends, federal holidays

Baseline Condition

The baseline condition is an individual participants' load that would have occurred had the load management event and subsequent load management activities not taken place.[53]

High-Efficiency Condition

Not applicable.

Energy and Demand Savings Methodology

Not applicable.

Savings Algorithms and Input Variables

$$Verified\ Demand\ Savings = Baseline\ Period\ kW - Curtailment\ kW$$

Equation 64

Where:

$Baseline\ Period\ kW$ = *Baseline average demand calculated according to the High 3 of 5 Baseline Method*

$Curtailment\ kW$ = *Average demand measured during the curtailment period*

High 3 of 5 Baseline with Day-of Adjustment

A high X of Y baseline considers the Y most recent days preceding an event and uses the data from the X days with the highest load within those Y days to calculate the baseline. Day-of adjustments are used to scale the baseline load estimate to the load conditions on the day of the event using data from the two hours prior to the time on the event day when participants were notified of the pending call for curtailment.

Applying this concept to the residential load management measure, the High 3 of 5 baseline for a given curtailment event is estimated by first identifying the five non-holiday weekdays immediately preceding the event in which no prior program curtailment events were called, and calculating each participant's average demand during the same hours as the hours for

[53] Some utilities may determine energy savings associated with load management events, which would be calculated as the difference between the baseline and curtailment kW values times the length of the event(s).

which the curtailment event was implemented on each of those five days. The three highest of these five average-like day demand values are then averaged to estimate the "unadjusted high three baseline."

The day-of baseline adjustment is estimated by comparing participants' average demand for electricity on the day of the event during the two hours prior to notification of the pending event (the "adjustment period") to participants' average demand for electricity on the "high three" days during those same two hours. In the situation where notification may not be given, the two hours preceding one hour before the event begins on the event day and baseline days will be used as the adjustment period. The average load of the adjustment period on the event day are compared to the average load of the adjustment periods from the baseline days. The difference (positive or negative) between day-of demand and high three baseline day demand in the adjustment period is the uncapped additive adjustment. To apply the adjustment period to the unadjusted baseline, one of two options are selected in the following steps:

- **Step 1.** Calculate an uncapped additive adjustment. The uncapped additive adjustment is the difference of the adjustment period hours' load of the event day subtracted from the baseline days' average adjustment period load. For example, if the baseline days have an adjustment period average load of 3.20 kW and the event day has an adjustment period load of 3.80 kW, the uncapped additive adjustment is 3.80 kW (-) 3.20 kW = 0.60 kW.
- **Step 2.** Calculate an adjustment cap. The adjustment cap is 80 percent of the baseline days' average load during the event hours. For example, if a participant has a load of 4.00 kW during the baseline days' event hours, the adjustment cap is 4.00 kW (x) 0.80 = 3.2 kW.
- **Step 3.** Select the lowest of the adjustment cap and the absolute value of the uncapped additive adjustment to be the additive adjustment. Using the examples of the preceding two steps, the uncapped additive adjustment (0.60 kW) has the lowest magnitude between the two numbers and is selected as the additive adjustment.
- **Step 4.** Add the additive adjustment to the unadjusted High 3 of 5 baseline to calculate the final baseline used for calculating changes to consumption for the load management event.

Following the calculation of the baseline using the High 3 of 5 method, the following steps are taken to arrive at an event's total savings and program savings for the year:

- **Step 1.** For an individual meter, the change in consumption is calculated by subtracting the baseline from the average load recorded during the event. If the result is positive, the meter exhibits savings, whereas a negative result indicates an increase in consumption during the event.
- **Step 2.** For a given load management event, sum the change in consumption of all participating meters. If documented, those meters enrolled in the program that opt-out of an event may be removed from the summation. If opt-out meters are not documented, an enrolled meter will be considered to have participated in the event. The sum represents the event's total change in consumption, presumed to be positive and representing savings.
- **Step 3.** With each event's savings results, average the event-level savings. The average of the events' savings represents the program year savings.

An example below illustrates the entirety of applying the high 3 of 5 method to calculate load management savings for a single residential participant.

Example Calculation

Table 52 illustrates the steps of the High 3 of 5 baseline calculation method. Specific participant's results may vary.

Table 52. High 3 of 5 Example Load Management Event Data

Event day and potential baseline days	Potential baseline day 5	Potential baseline day 4	Potential baseline day 3	Potential baseline day 2	Potential baseline day 1	Load mgmt. event date
Event hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600
Average kW during event hours	5.67	5.96	4.95	4.58	6.01	5.12
Notification hour						1400
Adjustment period hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400
Adjustment period average kW	5.54	5.87	4.86	4.44	5.89	6.03

Calculation Steps:

- **Step 1.** Unadjusted High Three Baseline = Average kW during event times in three highest days of five prior to event day (kW)

  Unadjusted High Three Baseline = (5.67+5.96+6.01)/3 = 5.88 kW

- **Step 2.** Uncapped Additive Adjustment = Average kW during adjustment time on event day (kW)—Average kW during adjustment time in the same three highest days of five prior to event day

  Uncapped Additive Adjustment = 6.03 - (5.54+5.87+5.89)/3 = 0.26 kW

- **Step 3.** Adjustment Cap = 80% of Unadjusted High Three Baseline (kW)

  Adjustment Cap = 0.8 * 5.88 = 4.7 kW

- **Step 4.** Choose Additive Adjustment = Minimum {Absolute value of Uncapped Additive Adjustment, Adjustment Cap} (kW)

  Additive Adjustment = Minimum {0.26, 4.7} = 0.26 kW

- **Step 5.** Final Baseline = Additive Adjustment + Unadjusted High Three Baseline (kW)

  Final Baseline = 0.26 + 5.88 = 6.14 kW

- **Step 6.** kW Savings = Final Baseline—Curtailment kW (kW)

  kW Savings = 6.14—5.12 = 1.02 kW

Additional Calculation Considerations

In the case that individual meters fail to record data sufficient for applying the High 3 of 5 calculation method, savings may still be calculated under the following conditions and method:

- Less than two percent of participating residential customers experience meter recording failures
- The customer can be confirmed as having participated via the practices of the sponsor operating the program or lack of opt-out notification
- The EM&V team is engaged to discuss applying the average savings and any program participation segmentation, and the specific cases are documented
- Savings for the residential segment will be calculated using the average savings of the segment as calculated via the High 3 of 5 method for the balance of the program or segment.

When selecting baseline days in the High 3 of 5 method, in some cases it is possible that some days have the same load for an individual participant, potentially leading to more than three days that could be selected for the baseline days. If four or more days could be selected as baseline days based on their loads during event hours, the days with the highest loads and closest to the event should be picked for the baseline.

Program year kW load management event savings will be calculated as the average savings of all events.

<u>Rounding</u>

Data rounding to the nearest whole number should only occur at the event and program levels for residential load management programs (NOT at the customer level). Utilities that prefer not to round the savings should document that in their calculations and inform the EM&V team (see Volume 5, Section 3.1 for more details).

<u>Meters</u>

Utilities are responsible for calling a test event each program year for the load management programs. The test event has several purposes, including assuring the proper functioning of program meters. Utilities are responsible for maintaining working program meters.

If there are random, non-systematic errors in smart meter data for less than two percent of total participants, the average savings from a similar group of participants (e.g., single-family, multifamily) may be used for claimed savings if: 1) the control event technology and intervention are the same, and 2) the control event intervention can be confirmed based on standard program practices for event confirmation. Utilities should notify the EM&V team in these circumstances to discuss the approach for determining and applying average savings for those customers with incomplete meter data.

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

A summer peak period value is used for this measure, based on calculation methodology described for this measure.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 1 year.

Program Tracking Data and Evaluation Requirements

The following data and information shall be tracked and provided to the EM&V team to enable savings verification:

- For each participant for which savings are being claimed, kWh consumption at intervals no greater than 30-minutes for each event day and for no less than five non-holiday and non-weekend days prior to each event day. Interval data shall be time-stamped with the date and no less than the time period ending the interval.
- Documentation describing the time stamp and whether the time stamp reflects the forward-looking period or period preceding the time stamp
- A list of all load management events affecting residential participants, describing their date, the time the event started, and the time the event ended.
- A list of all participants and addresses with a variable linking to the load or energy consumption interval data and that describes their enrollment date, load management control commissioning date, and any events in which the participant did not participate due to enrollment or equipment installation timing, equipment failures, or other factors known to the implementer or utility.
- Tools, calculators or other datasets that may be useful to the EM&V team, based on discussion between the EM&V team, utilities, and/or program implementer. The process for calculating kW and kWh savings should be provided in the program documentation, including any summation and rounding practices.
- Memos, reports, or results of any equipment test or metering data that provides perspectives, calculations, or metrics related to failure rates of load control receivers, thermostats or similar devices used to control participant loads during events.

The EM&V team may conduct participant-level independent metering studies to inform the verification of load management program savings.

References and Efficiency Standards

Not applicable.

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Oncor: Residential Load Management Program Manual can be found under Residential Load Management at https://eepm.oncor.com/Residential.aspx
- CenterPoint: Residential Load Management Program Guidelines https://cnprlm.programprocessing.com[54]

Document Revision History

Table 53. M&V Residential Load Management History

TRM version	Date	Description of change
v2.1	3/31/2015 revised 6/2015	Memo to PUCT staff initiating and establishing High 3 of 5 baseline with day-of adjustment.
v3.1	11/05/2015	TRM v3.1 Volume 4 origin.
v4.0	10/10/2016	Clarified language related to applying the adjustment factor to the High 3 of 5 baseline and additional data provision details
v5.0	10/10/2017	Further clarified the baseline calculation using the High 3 of 5 method.
v6.0	10/2018	No revisions.
v7.0	10/2019	Transferred metering and rounding guidance from Vol. 5.
v8.0	10/2020	Added guidance on rounding, ensuring meters are functioning prior to an event, and changing the error threshold from one to two percent of total participants
v9.0	10/2021	Added peak demand period by utility. Added links to program manuals.

[54] The link provided is for the 2021 Residential Load Management Program page and may not be available in 2022. The 2022 Residential Load Management Program Guidelines can be requested from the utility.

2.5.2 Nonresidential Load Curtailment Measure Overview

TRM Measure ID: NR-LM-LM

Market Sector: Nonresidential

Measure Category: Load management

Applicable Building Types: Any building that meets minimum facility demand requirements

Fuels Affected: Electricity

Decision/Action Type: Operation and maintenance (O&M)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V

Utilities operate nonresidential load management programs to obtain demand savings. Energy savings are estimated as a function of the estimated demand savings.[55] Demand savings calculations are performed using utility customer interval energy demand data from IDRs or advanced meters. Measured and verified demand savings for the curtailment period is presented here.

Measure Description

This document presents the M&V savings methodology for participation in a load management program that involves the curtailment of an interruptible load during the summer or winter peak periods. Project sponsors, who have agreed to deliver demand savings to the utility from the utility's customer, must commit to an availability of curtailed load throughout the summer or winter peak demand periods. These project sponsors may include national or local energy efficiency service providers (EESPs), retail electricity providers (REPs), or individual customers. Different utilities offer different details on their programs, but they all have similar eligibility criteria, listed below:

Eligibility Criteria

A project will be eligible for incentives under the load management standard offer program (SOP) if the following criteria are met:

- Each meter included in a project must include a total potential demand savings of a specified minimum kW (varies by utility, as seen in Table 54) during the peak demand periods outlined in Table 55.

[55] Some utilities may determine energy savings associated with load management events, which would be calculated as the difference between the baseline and curtailment kW values times the length of the event(s).

Table 54. Minimum Facility Demand Savings by Utility

Utility	Minimum demand savings (kW)
AEP SWEPCO	50
AEP Texas (Central & North)	5
CenterPoint	100
El Paso Electric	100
Entergy	250
Oncor (summer / winter)	100 / 50
TNMP[56]	50
Xcel[57]	100

Table 55. Peak Demand Periods

Hours[58]	Months	Exceptions
1:00 p.m.—7:00 p.m.	June, July, August, September	Weekends, federal holidays
6:00 a.m.—10:00 a.m., 6:00 p.m. —10:00 p.m.	December, January, February	No exceptions, 24/7 curtailment period

- A single project may involve identifying curtailable load at more than one customer facility, provided the curtailment demand savings at the facilities are recorded using a single interval data recorder (IDR).
- The project sponsor agrees to verify that the curtailable load that is being used in its application will not be used and counted in any other curtailable load or load management program during the duration of the customer contract. The project sponsor will notify the utility company within 15 business days of any change in the status of the curtailable load or its inclusion in another load management program.
- Curtailable load must produce demand savings through a curtailment of electrical consumption during the performance period.
- Project sponsors must commit to making the curtailable load available during the summer or winter peak periods for the program.

[56] TNMP prefers that project sponsors be capable of providing at least 50 kW of peak demand reduction at each site for which load reduction is offered; however, TNMP may accept applications including sites providing less than 50kW of peak demand reduction in the interest of meeting its peak load reduction targets.

[57] The utility prefers that project sponsors be capable of providing at least 100 kW of peak demand reduction at each site for which load reduction is offered; however, the utility may accept applications including sites providing less than 100 kW of peak demand reduction in the interest of meeting its peak load reduction targets.

[58] Xcel's period hours are 12:00 p.m. to 8:00 p.m. Note that although Xcel starts and ends events outside the 1:00 p.m. to 7:00 p.m. period, Xcel only claims savings for deliveries during the rule-defined 1:00 p.m. to 7:00 p.m. peak period.

- Be served by an interval data recorder (IDR) and/or smart meter that is monitored by the utility. A sponsor owned meter may be substituted in the event of a non-systemic utility-owned IDR meter failure. When using a sponsor owned meter, all data must otherwise conform to the High 5 of 10 method and be used for both the baseline and event-day calculations. Documentation of the case must be provided along with all supporting meter data.
- Customer agrees to respond to at least one event (scheduled or unscheduled) per year for the purpose of verifying the load reduction is available for potential calls. Scheduled events are used to provide an estimate of the load reduction in the event that no unscheduled interruptions occur during the season.
- For sponsors on a curtailment tariff, if the event or baseline periods include a tariff-based curtailment, the event day performance for the load management program will be net of firm delivery under the tariff. Documentation must be provided to describe the overlap of load management and tariff-based curtailments along with supporting firm delivery contract amounts.

The following loads are excluded from consideration:

- A customer who has load contracted with a REP where that contract prevents the load from participating in a curtailment
- Loads where curtailment would result in negative environmental or health effects
- Curtailable load that receives an incentive through any other energy efficiency program
- Curtailable load that takes electric service at transmission voltage and that serves a for-profit end-use customer
- A customer that is categorized as a critical load customer (an exception may be if the customer has back-up generation and can still curtail when requested)

Baseline Condition

Standard facility operation.

High-Efficiency Condition

Load management customers are required to participate in a number of unscheduled interruptions. Programs will provide a minimum of 30 minutes advanced notice, allowing facility managers time to use non-automated approaches. Another option is for facilities to install a load-control device on specific end-uses, equipment, or circuit loads.

Additional Utility Program Details

Each utility in Texas provides slightly different guidelines for its load management program. These details differ in the length of the unscheduled interruptions (also called curtailments), the maximum number or maximum number of hours of unscheduled interruptions, and the length of notification provided to the project sponsor. Table 56 highlights these differences.

Each utility states that participants will be willing to participate in a maximum number of unscheduled interruptions, or a maximum number of scheduled (test) interruption hours. In addition to these, all utilities require that a scheduled interruption be performed. The purpose of this is to ensure that the project sponsor will be able to curtail the requested kW within the required notification time and to provide an estimate of the load reduction in the event that no unscheduled interruptions occur during the season. Additionally, some of the utilities offer different baseline methods or options for their customers to choose from.[59] These options are shown in Table 53 through Table 59.

Table 56. Utility Program Details Overview

Utility	Options available	Scheduled interruption length	Maximum length	Notification required	Maximum unscheduled interruptions
AEP SWEPCO	See Table 58	1 hour	2 hours or 4 hours	1 hour	4 or 12 interruptions
AEP Texas (Central & North)	See Table 57	1 hour	2 hours or 4 hours	30 minutes	4, 8, or 12 interruptions
CenterPoint	No	1-3 hours	4 hours	30 minutes	4 interruptions
El Paso Electric	No	1-5 hours	5 hours	1 hour	4 interruptions; 20 hours
Entergy	No	1 hour	4 hours	—	4 interruptions
Oncor (summer)	No	3 hours	4 hours	30 minutes	25 hours
Oncor (winter)	No	3 hours	12 hours	30 minutes	25 hours
TNMP	No	1-2 hours	4 hours	30 minutes	4 interruptions; 18 hours
Xcel[60]	See Table 59	—	4 hours	1 hour	6 or 12 interruptions; 24 or 48 hours

Table 57. AEP (TNC & TCC) Interruption Options

Option	Maximum number of unscheduled interruptions	Minimum length (hours)	Maximum length (hours)
A	4	1	4
B	12	1	4
C	12	1	2
D	8	1	4
E	8	1	2

[59] More details about the utility programs can be found in the program manuals (see Relevant Standards and Reference Sources).

[60] At the discretion of the program manager, Xcel may also choose to execute a one-hour test event during the performance period, either in lieu of or in addition to unscheduled interruptions.

Table 58. AEP (SWEPCO) Interruption Options

Option	Maximum number of unscheduled interruptions	Minimum length (hours)	Maximum length (hours)
A	4	1	4
B	12	1	4

Table 59. Xcel Interruption Options

Option	Maximum number of unscheduled interruptions	Maximum length (hours)
A	6	4
B	12	4

Energy and Demand Savings Methodology

Not applicable.

Savings Algorithms and Input Variables

Utilities operate load management programs to obtain demand savings: to the extent energy savings are also estimated, they are estimated as a function of the estimated demand savings.[61] Demand savings calculations are performed using utility customer interval energy usage data from IDRs or advanced meters. The verified demand savings for the curtailment period uses the following algorithm:

$$Verified\ Demand\ Savings = Baseline\ Period\ kW - Curtailment\ kW$$

Equation 65

Where:

$Baseline\ Period\ kW$ = *Baseline average demand calculated according to the High 5 of 10 for summer or High 8 of 10 for winter baseline method, detailed below*

$Curtailment\ kW$ = *Average demand measured during the curtailment period*

High X of Y method with day-of adjustment:

For summer peak periods, a High X of Y baseline considers the Y most recent days preceding an event and uses the data from the X days with the highest load within those Y days to calculate the baseline. For winter peak periods, to accommodate the greater variability in winter weather patterns, a High X of Y baseline considers the Y most recent days directly preceding and/or succeeding an event and uses the data from the X days with the highest load within

61 Some utilities do determine energy savings, which would be calculated as the difference between the baseline and curtailment kW values times the length of the event(s).

those Y days to calculate the baseline. Day-of adjustments are used to scale the baseline load estimate to the load conditions on the day of the event using data from the hours prior to the time on the event day when participants were notified of the pending call for curtailment.

Applying this concept to the load management measure, the High 5 of 10 baseline (summer) or High 8 of 10 baseline (winter) for a given curtailment event is estimated by first identifying the 10 non-holiday weekdays immediately preceding or preceding/succeeding the event depending on summer or winter peak as described above in which no prior program curtailment events were called, and calculating each participant's average demand during the same hours as the hours for which the curtailment event was implemented on each of those 10 days. The five highest of these ten average demand values are then averaged to estimate the "unadjusted High 5 for summer or 8 for winter baseline".

The day-of baseline adjustment is estimated by comparing participants' average demand for electricity on the day of the event during the two hours prior to notification of the pending event (the "adjustment period") to participants' average demand for electricity on the "High 5 or 8" days during those same two hours. The difference (positive or negative) between day-of demand and "High 5 or 8" demand in the adjustment period is the "uncapped additive adjustment". In the situation where notification may not be given, the two hours preceding one hour before the event begins on the event day and baseline days will be used as the adjustment period. The average load of the adjustment period on the event day are compared to the average load of the adjustment periods from the baseline days. The difference (positive or negative) between day-of demand and "High 5 or 8" baseline day demand in the adjustment period is the uncapped additive adjustment. To apply the adjustment period to the unadjusted baseline, one of two options are selected in the following steps:

- **Step 1.** Calculate an uncapped additive adjustment. The uncapped additive adjustment is the difference of the adjustment period hours' load of the event day subtracted from the baseline days' average adjustment period load. For example, if the baseline days have an adjustment period average load of 530.20 kW and the event day has an adjustment period load of 575.80 kW, the uncapped additive adjustment is 575.80 kW (-) 530.20 kW = 45.60 kW.
- **Step 2.** Calculate an adjustment cap. The adjustment cap is 50 percent of the baseline days' average load during the event hours. For example, if a participant has a load of 504.00 kW during the baseline days' event hours, the adjustment cap is 504.00 kW (x) 0.50 = 252.00 kW.
- **Step 3.** Select the lowest of the adjustment cap and the absolute value of the uncapped additive adjustment to be the additive adjustment. Using the examples of the preceding two steps, the uncapped additive adjustment (45.60 kW) has the lowest magnitude between the two numbers and is selected as the additive adjustment.
- **Step 4.** Add the additive adjustment to the unadjusted High 5 of 10 baseline (summer) or High 8 of 10 baseline (winter) to calculate the final baseline used for calculating savings.

An example, below, illustrates the entirety of applying the High 5 of 10 summer method to calculate load management savings for a single participant.

Example Calculation

Table 60 serves to illustrate the steps of the High 5 of 10 summer baseline calculation method. Specific participant's results may vary. Numbers from the table in bold font represent data selected for the calculation.

Table 60. High 5 of 10 Example Load Management Event Data

Event day and potential baseline days	Load mgmt. event date	Potential baseline day 1	Potential baseline day 2	Potential baseline day 3	Potential baseline day 4	Potential baseline day 5
Event hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600
Average kW during event hours	1078.89	990.57	919.45	926.36	892.42	880.13
Notification hour	1400					
Adjustment period hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400
Adjustment period average kW	959.39	752.26	672.08	637.98	695.12	698.88
Event day and potential baseline days	**Potential Baseline day 6**	**Potential Baseline day 7**	**Potential Baseline day 8**	**Potential Baseline day 9**	**Potential baseline day 10**	
Event hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600	
Average kW during event hours	950.63	842.19	1008.69	795.80	1049.24	
Notification hour						
Adjustment period hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400	
Adjustment period average kW	657.64	539.75	801.02	647.12	850.18	

Calculation steps:

- **Step 1.** *Unadjusted High 5 baseline* = Average kW during event times in five highest days of ten prior in summer prior to event day (kW)

  Unadjusted High 5 baseline = (990.57+926.36+950.63+1008.69+1049.24)/5 = 985.10 kW

- **Step 2.** *Uncapped additive adjustment* = Average kW during adjustment time on event day (kW)—Average kW during adjustment time in the same five highest days of ten prior to event day

  Uncapped additive adjustment = 959.39—(752.26+637.98+657.64+801.02+850.18)/5 = 219.57 kW

- **Step 3.** *Adjustment cap* = 50% of *Unadjusted High 5 baseline* (kW)

  Adjustment cap = 0.5 * 985.10 = 492.55 kW

- **Step 4.** Choose *Additive adjustment* = Minimum {Absolute value of *Uncapped additive adjustment*, *Adjustment cap*} (kW)

  Additive adjustment = Minimum {219.57, 492.55} = 219.57 kW

- **Step 5.** *Final baseline = Additive adjustment + Unadjusted High 5 baseline* (kW)

  Final baseline = 219.57 + 985.10 = 1204.67 kW

- **Step 6.** kW Savings = *Final baseline—Curtailment kW* (kW)

  kW Savings = 1204.67—1078.89 = 125.78 kW

Additional Calculation Considerations

In the case that individual meters fail to record data sufficient for applying the High 5 or 8 of 10 calculation method, savings will not be calculated.

When selecting baseline days in the High 5 or 8 of 10 method, it is possible that some days have the same load for an individual participant, potentially leading to more than five or eight days that could be selected for the baseline days. If more days could be selected as baseline days based on their loads during event hours, the days with the highest loads and closest to the event should be picked for the baseline.

Program year kW load management event savings will be calculated as the sum of each sponsor's average savings of all events in which the sponsor participated.

<u>Rounding</u>

Data rounding to the nearest whole number should only occur at the customer and program levels for commercial load management programs. Without this standard practice, utilities should document when rounding is occurring in their calculations (e.g., no rounding or rounding at the event level) and inform the EM&V team (see Volume 5, Section 3.1 for more details). Utilities should round commercial load management impacts consistent with how incentives are awarded, which is at the customer-sponsor level for each event.

<u>Meters</u>

Utilities are responsible for calling a test event each program year for the load management programs. If a program has both a winter and summer peak component, a test event needs to be called in each applicable peak period. The test event has several purposes, including assuring the proper functioning of program meters. Utilities are responsible for maintaining working program meters.

Without complete interval meter data to calculate the baseline and event impacts, savings may not be claimed. However, if a customer has alternate interval meter data available, this can be used in lieu of program meter data to calculate claimed savings. Using customer meters for load management program savings requires that the data meet interval metering requirements presented in the version of the current TRM. In general, it is recommended that customer owned interval meters should only be used if utility interval meters fail. Data from each meter should not be combined for claiming savings for a specific event and must be able to cover both the event day data and baseline data.

Utilities should notify the EM&V team in these circumstances. All calculations and data stemming from the use of customer meters should be provided as part of the EM&V data request similar to when program meter data is used. If requested by the utility, the EM&V team is available to review the use of customer meter data in advance of a program claiming savings from customer meters.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 1 year.

Program Tracking Data and Evaluation Requirements

- IDR or Advanced Meter data associated with the project will be provided by the project sponsor or retrieved by the utility following an event. Depending on the utility, the data will be provided at 30-minute increments (or smaller) to evaluate both baseline demand usage and demand usage during curtailment.
- Documentation describing the time stamp and whether the time stamp reflects the forward-looking period or period preceding the time stamp
- Utilities should provide a description of their practices related to whether scheduled or test events are or are not included in their program year kW savings results. kWh savings will be calculated from all events.
- A list of all load management events affecting nonresidential participants within the program year, describing the date of each event, the time the event started, and the time the event ended.
- A list of all participants and addresses with a variable linking to the load or energy consumption interval data and that describes their enrollment date, load management control commissioning date, and any events in which the participant did not participate due to enrollment or equipment installation timing, equipment failures, or other factors known to the implementer or utility.
- Tools, calculators or other datasets that may be useful to the EM&V team, based on discussion between the EM&V team, utilities, and/or program implementer. The process for calculating kW and kWh savings should be provided in the program documentation, including any summation and rounding practices.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- **AEP SWEPCO:** Manual not available online.
- **AEP Texas:** Load Management Standard Offer Program Manual can be found under Load Management at https://aeptexasefficiency.com/#/commercial
- **CenterPoint**: Commercial Load Management Program Manual can be found under Commercial Load Management at https://www.centerpointenergy.com/en-us/business/services/commercial-industrial/efficiency-programs?sa=ho
- **El Paso Electric**: Load Management Program Manual can be found at https://www.epelectric.com/business/save-money-and-energy/texas-load-management-program
- **Entergy**: Load Management Manual can be found at https://www.entergy-texas.com/your_business/save_money/ee/load-management/
- **Oncor**: Commercial Load Management Program Manual can be found under Commercial Load Management at https://eepm.oncor.com/Commercial.aspx
- **TNMP**: Load Management Program Manual can be found under Resources at https://www.tnmpefficiency.com/commercial.php#load-management
- **Xcel Energy**: Load Management Program Manual can be found at http://www.xcelenergyefficiency.com/TX/Business/LM/

Document Revision History

Table 61. M&V Nonresidential Load Management History

TRM version	Date	Description of change
v3.0	4/10/2015	The baseline calculation methodology was modified to be the highest 5 of 10 prior days for all the programs. In addition, a new day-of adjustment factor was added with an adjustment cap.
v3.1	11/05/2015	TRM v3.1 Volume 4 origin.
v4.0	10/10/2016	Clarified language related to applying the adjustment factor to the High 5 of 10 baseline and additional data provision details.
v5.0	10/10/2017	Updated equation, figure, and table references.
v6.0	10/2018	No revisions.
v7.0	10/2019	Transferred metering and rounding guidance from Vol 5.
v8.0	10/2020	Added guidance on rounding.
v9.0	10/2021	Added eligibility exclusion for critical load customers, updated links to program manuals and updated for winter peak.

APPENDIX A: **M&V METERING SCHEDULE**

1.0 Arrive on site and meet customer

1.1 Turn unit on to stabilize and make sure the unit is in full cooling mode (Variable speed blowers are on high and all compressors in multi-compressor systems are operating).

1.2 Record customer information:

a. Address
b. City
c. Zip
d. County
e. Email
f. Utility acount number (from utility bill)
g. Altitude (ft)
h. Residential program or commercial program
i. Building type
j. Phone number

2.0 Test In: Perform TI procedure to determine system's baseline cooling capacity and energy efficiency ratio (EER).

2.1 Record Unit Information

2.2 Measure and record airflow using 1 of the following methods:

a. Air Flow Method 1: Handheld Anemometer
b. Air Flow Method 2: Generic Fan Chart

2.3 Air Flow Power Consumption

a. Determine the blower motor type as either "PSC" or "ECM."
b. Measure and record the blower voltage and current.

2.4 Condenser and Compressor Measurements

a. Compressor Type (Scroll or Reciprocating)
b. Refrigerant Type (R22 or R410)
c. Metering Device (Fixed Orifice, TXV or Capillary Tube)
d. Condenser Model Number
e. Condenser Serial Number
f. Compressor Phase (Single or Three)
g. Multiple Compressor System (Check box for participating utilities)
h. Measure and Record Compressor Volts
i. Measure and Record Compressor Current
j. Measure and Record Ambient Air Dry-Bulb Temperature
k. Measure and Record Ambient Air Wet-Bulb Temperature if Required

2.5 Enter Information from Refrigerant Analyzer:

a. Suction Pressure (PSI)
b. Discharge Pressure (PSI)
c. Evaporator Temperature (ºF)
d. Condenser Temperature (ºF)
e. Vapor Line Temperature (VLT) (ºF)
f. Liquid Line Temperature (LLT) (ºF)
g. Superheat (ºF)
h. Subcooling (ºF)

2.6 Measure and Record Supply and Return Air Conditions:

a. Return Air Dry-Bulb Temperature (ºF)
b. Return Air Wet-Bulb Temperature (ºF)
c. Supply Air Dry-Bulb Temperature (ºF)
d. Supply Air Wet-Bulb Temperature (ºF)

2.7 Review System Performance

3.0 Perform Corrective Measures as Needed

3.1 Clean Condenser—required
3.2 Clean Evaporator—required
3.3 Clean Blower—required
3.4 Verify clean filter: change or clean as needed—required
3.5 Verify Airflow within range (+/- 15% of 400 cfm/ton)—required
3.6 Check refrigerant charge; adjust to Manufacturer's Spec's as needed

4.0 Test Out: The Test Out (TO) procedure requires measurements that are used to determine the performance characteristics of the cooling system after all corrective measures have been implemented.

4.1 Air Flow—Use same method as Test In
4.2 Air Flow Power Consumption
  a. For ECMs, make sure it is operating in full cooling mode during the entire tune-up.
  b. Measure and record the blower voltage and current.
4.3 Measure and record Supply and Return Air Conditions:
  a. Return Air Dry-Bulb Temperature (ºF)
  b. Return Air Wet-Bulb Temperature (ºF)
  c. Supply Air Dry-Bulb Temperature (ºF)
  d. Supply Air Wet-Bulb Temperature (ºF)
4.4 Condenser and Compressor Measurements
  a. Compressor Volts
  b. Compressor Current
  c. Ambient Air Dry-Bulb Temperature
  d. Ambient Air Wet-Bulb Temperature
4.5 Information from Refrigerant Analyzer:
  a. Suction Pressure (PSI)
  b. Discharge Pressure (PSI)
  c. Evaporator Temperature (ºF)
  d. Condenser Temperature (ºF)
  e. Vapor Line Temperature (VLT) (ºF)
  f. Liquid Line Temperature (LLT) (ºF)
  g. Superheat (ºF)
  h. Subcooling (ºF)
4.6 Review System Performance

5.0 Generate invoice: A customer signed invoice is required for participation in the program. The following information must be shown on the invoice:

5.1 Customer Address
5.2 Contractor Name and Address
5.3 Project Number Listed on the DCVF
5.4 Corrective Measures Performed
5.5 Charge for Services Performed
5.6 Rebate Amount Applied to Charges

APPENDIX B: **COUNTIES BY WEATHER ZONE ASSIGNMENT**

County name	Zone	County name	Zone	County name	Zone	County name	Zone
Anderson	2	Brown	2	Cooke	2	Falls	2
Andrews	2	Burleson	3	Coryell	2	Fannin	2
Angelina	2	Burnet	2	Cottle	1	Fayette	3
Aransas	4	Caldwell	3	Crane	2	Fisher	2
Archer	2	Calhoun	4	Crockett	2	Floyd	1
Armstrong	1	Callahan	2	Crosby	1	Foard	1
Atascosa	3	Cameron	4	Culberson[62]	2 & 5	Fort Bend	3
Austin	3	Camp	2	Dallam	1	Franklin	2
Bailey	1	Carson	1	Dallas	2	Freestone	2
Bandera	2	Cass	2	Dawson	2	Frio	3
Bastrop	3	Castro	1	De Witt	3	Gaines	1
Baylor	2	Chambers	3	Deaf Smith	1	Galveston	3
Bee	3	Cherokee	2	Delta	2	Garza	1
Bell	2	Childress	1	Denton	2	Gillespie	2
Bexar	3	Clay	2	Dickens	1	Glasscock	2
Blanco	2	Cochran	1	Dimmit	3	Goliad	3
Borden	2	Coke	2	Donley	1	Gonzales	3
Bosque	2	Coleman	2	Duval	4	Gray	1
Bowie	2	Collin	2	Eastland	2	Grayson	2
Brazoria	3	Collingsworth	1	Ector	2	Gregg	2
Brazos	3	Colorado	3	Edwards	2	Grimes	3
Brewster	2	Comal	3	El Paso	5	Guadalupe	3
Briscoe	1	Comanche	2	Ellis	2	Hale	1
Brooks	4	Concho	2	Erath	2	Hall	1

[62] El Paso Electric may treat residents of Van Horn, TX in Culberson County as climate zone 5 even though the rest of the county is classified as climate zone 2.

County name	Zone	County name	Zone	County name	Zone	County name	Zone
Hamilton	2	Jasper	2	Leon	2	Montague	2
Hansford	1	Jeff Davis	2	Liberty	3	Montgomery	3
Hardeman	1	Jefferson	3	Limestone	2	Moore	1
Hardin	3	Jim Hogg	4	Lipscomb	1	Morris	2
Harris	3	Jim Wells	4	Live Oak	3	Motley	1
Harrison	2	Johnson	2	Llano	2	Nacogdoches	2
Hartley	1	Jones	2	Loving	2	Navarro	2
Haskell	2	Karnes	3	Lubbock	1	Newton	2
Hays	2	Kaufman	2	Lynn	1	Nolan	2
Hemphill	1	Kendall	2	Madison	3	Nueces	4
Henderson	2	Kenedy	4	Marion	2	Ochiltree	1
Hidalgo	4	Kent	1	Martin	2	Oldham	1
Hill	2	Kerr	2	Mason	2	Orange	3
Hockley	1	Kimble	2	Matagorda	3	Palo Pinto	2
Hood	2	King	1	Maverick	3	Panola	2
Hopkins	2	Kinney	3	McCulloch	2	Parker	2
Houston	2	Kleberg	4	McLennan	2	Parmer	1
Howard	2	Knox	1	McMullen	3	Pecos	2
Hudspeth	5	La Salle	3	Medina	3	Polk	3
Hunt	2	Lamar	2	Menard	2	Potter	1
Hutchinson	1	Lamb	1	Midland	2	Presidio	2
Irion	2	Lampasas	2	Milam	3	Rains	2
Jack	2	Lavaca	3	Mills	2	Randall	1
Jackson	3	Lee	3	Mitchell	2	Reagan	2

County name	Zone	County name	Zone	County name	Zone	County name	Zone
Real	2	Shackelford	2	Titus	2	Wharton	3
Red River	2	Shelby	2	Tom Green	2	Wheeler	1
Reeves	2	Sherman	1	Travis	2	Wichita	2
Refugio	4	Smith	2	Trinity	3	Wilbarger	1
Roberts	1	Somervell	2	Tyler	3	Willacy	4
Robertson	2	Starr	4	Upshur	2	Williamson	2
Rockwall	2	Stephens	2	Upton	2	Wilson	3
Runnels	2	Sterling	2	Uvalde	3	Winkler	2
Rusk	2	Stonewall	1	Val Verde	3	Wise	2
Sabine	2	Sutton	2	Van Zandt	2	Wood	2
San Augustine	2	Swisher	1	Victoria	3	Yoakum	1
San Jacinto	3	Tarrant	2	Walker	3	Young	2
San Patricio	4	Taylor	2	Waller	3	Zapata	4
San Saba	2	Terrell	2	Ward	2	Zavala	3
Schleicher	2	Terry	1	Washington	3		
Scurry	2	Throckmorton	2	Webb	4		