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 1 below, are calculated annually based on a rolling three-year average of the previous three years of tune-up data. Full M&V data (where units are tested both before and after the tune-up) are collected for a random sample of 10 percent of all tune-ups. Implementers are required to work with the evaluation team to determine an appropriate methodology to select which 10 percent of tune-up projects require full M&V data and analysis.

For units not receiving full M&V, photo documentation showing the before and after condition of the components must be provided for all residential units and a representative sample of commercial units. Implementers are required to work with the evaluation team to determine an appropriate methodology to select the representative sample of commercial units.

The stipulated efficiency loss values are dependent on whether a refrigerant charge adjustment was made to the air conditioning unit as part of the tune-up or whether the unit is a residential or commercial unit. These factors are considered the primary variables influencing efficiency loss. Therefore, efficiency losses are developed separately for those with and without a refrigerant charge and residential versus commercial units.

The evaluation team will collect data to regularly assess the validity of this conclusion.

Table 2. AC Tune-Up Efficiency Loss Factors

Market sector	Refrigerant charge adjusted
Residential	No
	Yes
Commercial	No
	Yes

Atmospheric Air Pressure

The average atmospheric air pressure for each climate zone is listed in Table 3 below, which was derived from the average pressure from TMY3 weather data during tune-up season (defined in *Eligibility Criteria* above).

Table 3. Atmospheric Pressure

Climate zone	Pressure (psia)
Climate Zone 1: Amarillo	12.94
Climate Zone 2: Dallas	14.53
Climate Zone 3: Houston	14.67
Climate Zone 4: Corpus Christi	14.68
Climate Zone 5: El Paso	12.80

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 4.

Table 4. 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 18. There are three 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 ft²)x (airspeed in feet per minute)*].

- Method 2: The technician may select an estimate of airflow using the manufacturer's fan charts.

- Method 3: The technician uses a manufacturer fan chart to select an estimate of airflow. The fan chart used must be provided in the documentation.

The three methods for determining AC system airflow values following completion of the AC tune-up at test out are summarized in Table 5 below.

Table 5. AC Air low Determination Methods for Estimating Cooling Capacity at Test-Out

Method for estimating AC airflow	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 fan charts	Use a generic fan chart to select airflow (CFM) value based on the closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower
Method 3: Manufacturer fan charts	Use the manufacturer fan chart to select airflow (CFM) value based on the closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower

Table 6. EER Adjustment Factor and Capacity Adjustment Factor Constants

EER adjustment factor and capacity adjustment factor constants[4]	
$C_1 = 1.013421588$	$D_1 = 1.003933337$
$C_2 = 0.017697661$	$D_2 = 0.016648337$
$C_3 = -0.006686796$	$D_3 = -0.017096426$
$C_4 = -0.000931159$	$D_4 = -0.000933205$
$C_5 = 8.04838 \times 10^{-5}$	$D_5 = 0.000222327$
$C_6 = -3.59283 \times 10^{-5}$	$D_6 = -0.000169511$

Table 7. Constants for Saturation Pressure Over Liquid Water Calculation

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

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

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein 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 8 for reference.

Table 8. 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 Superheat 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 the 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 9.

Table 9. 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]	Airflow 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

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[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.

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

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: Operation and maintenance (O&M)
- Most recent tune-up service date or confirmation that the system has not been serviced within the previous five years
- Climate zone or county
- Building type
- Equipment type
- Equipment manufacturer, model number, and serial number
- Equipment manufacture year (eligible systems must be at least five years old)
- Equipment-rated cooling and heating capacities
- Equipment cooling and heating efficiency ratings
- 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
- Motor type for condenser and blower
- All other operating measurements and parameters listed in the M&V protocol
- Implementer inspection reports

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[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.

- Before and after tune-up pictures of components illustrating condition change due to cleanings for all residential units, representative sample of commercial units not receiving a test-in
- If Method 2 is used for measuring airflow, a copy of the generic fan chart with an annotation or description of how it was read
- If Method 3 is used for measuring airflow, a copy of the manufacturer's fan chart, with an annotation or description of how it was read

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.
- 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 Fundamentals 2021 – Chapter 1: Psychrometrics
- 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 10. 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,

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TRM version	Date	Description of change
		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 revision.
v7.0	10/2019	No revision.
v8.0	10/2020	No revision.
v9.0	10/2021	No revision.
v10.0	10/2022	No revision.
v11.0	10/2023	Added age requirement to eligibility. Removed pressure correlation equation and replaced with deemed pressure by climate zone. Added language describing efficiency loss factor determination in more detail and implementer/evaluator responsibilities. Added an additional airflow rate determination method. Added additional tracking system and documentation requirements. Added reference to ASHRAE Fundamentals Chapter 1.

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. The baseline case is defined by the existing system manufacturer, model number, AHRI efficiencies, and operating parameters.

High-Efficiency Condition

High-efficiency conditions for GSHP equipment must meet applicable standards. AHRI ratings for EER and COP must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 11.

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 11. 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

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[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 Core Concepts EVO 10000-1:2022.

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 18

Where:

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

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

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

Equation 19

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.

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

Equation 20

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[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 21

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

Equation 22

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

Equation 23

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

Equation 24

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 25

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 11) [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 11) [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)*

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$CF_{C/H}$	=	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 24 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.

- Climate zone or county
- Decision/action type: ER, ROB, and system type conversion (yes, no)
- Building type
- Baseline equipment type
- Baseline equipment number of units

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[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 rated cooling and heating capacities

- Baseline equipment cooling and heating efficiency ratings

- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)

- New equipment type (water-to-air, brine-to-air, water-to-water, brine-to-water)

- New equipment loop type (water, ground, groundwater)

- New equipment number of units

- New equipment rated cooling and heating capacities

- New equipment make and model

- ENERGY STAR or AHRI certificate matching new unit model number

- Installed cooling and heating efficiency ratings

References and Efficiency Standards

Petitions and Rulings

- 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 12. 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 revision.
v5.0	10/10/2017	No revision.
v6.0	10/2018	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.
v7.0	10/2019	No revision.
v8.0	10/2020	No revision.
v9.0	10/2021	Estimated useful life changed from 15 to 20 years for consistency with Volume 2.
v10.0	10/2022	No revision.
v11.0	10/2023	Updated program tracking and documentation requirements.

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

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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

Replace-on-Burnout (ROB) and New Construction (NC):

For retrofit applications, the baseline condition assumes the replacement of an existing direct expansion (DX) HVAC system with a new VRF system. For new construction applications, the baseline condition acknowledges the customer's option of installing a baseline DX HVAC system in lieu of the VRF system. Therefore, the baseline condition should align with the early retirement, replace-on-burnout, and new construction baselines defined in the equivalent DX HVAC measure in this TRM. Refer to Volume 3 Measure 2.2.2 Split and Packaged Air Conditioners and Heat Pumps to determine baseline efficiency values using applicable baseline type, system type, capacity, and existing system age.

High-Efficiency Condition

High-efficiency conditions for VRF equipment must meet applicable standards as specified in Table 13. Minimum efficiency requirements are established in ASHRAE 90.1-2013.[16] The minimum part-load efficiency requirements have been increased to reflect the current federal standard, effective May 30, 2023, with a manufacturing compliance date of January 1, 2024.[17] Units < 65,000 Btuh are expected to comply with current federal standards for consumer products.

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 13. Both air-cooled and water-cooled systems are rated per AHRI Standard 1230.

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[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/.

[16] ASHRAE Standard 90.1-2013. Table 6.8.1-9.

[17] US Department of Energy (DOE) federal minimum efficiency standard for 65,000-759,000 Btuh systems. 10 CFR 431.97. https://www.regulations.gov/document/EERE-2018-BT-STD-0003-0080.

[18] US Department of Energy (DOE) federal minimum efficiency standard for < 65,000 Btuh systems, 10 CFR 430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

Table 13. Federal Standard for Electrically Operated VRF ACs and HPs

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[19]
VRF air conditioners, air-cooled	< 45,000	All	VRF multi-split system	11.7 EER2 14.3 SEER2	DOE Standards
	≥ 45,000 and < 65,000	All		11.2 EER2 13.8 SEER2	
	≥ 65,000 and < 135,000	None or electric resistance		11.2 EER 15.5 IEER	DOE Standards and ASHRAE 90.1-2013
	≥ 135,000 and < 240,000			11.0 EER 14.9 IEER	
	≥ 240,000 and < 760,000			10.0 EER 13.9 IEER	
	≥ 760,000			10.0 EER 11.6 IEER	ASHRAE 90.1-2013
VRF air-cooled (cooling mode)	< 65,000	All	VRF multi-split system	11.7 EER2 14.3 SEER2	DOE Standards
	≥ 65,000 and < 135,000	None or electric resistance	VRF multi-split system	11.0 EER 14.6 IEER	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system with heat recovery	10.8 EER 14.4 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system	10.6 EER 13.9 IEER	
			VRF multi-split system with heat recovery	10.4 EER 13.7 IEER	
	≥ 240,000 and < 760,000		VRF multi-split system	9.5 EER 12.7 IEER	
			VRF multi-split system with heat recovery	9.3 EER 12.5 IEER	
	≥ 760,000		VRF multi-split system	9.5 EER 10.6 IEER	ASHRAE 90.1-2013
			VRF multi-split system with heat recovery	9.3 EER 10.4 IEER	

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[19] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR 430.32 for < 65,000 Btuh and 10 CFR 431.97 for 65,000-759,999 Btuh.

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[19]
VRF water source (cooling mode)	< 65,000	All	VRF multi-split system 86°F entering water	12.0 EER 16.0 IEER	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system with heat recovery 86°F entering water	11.8 EER 15.8 IEER	
	≥ 65,000 and < 135,000		VRF multi-split system 86°F entering water	12.0 EER 16.0 IEER	
			VRF multi-split system with heat recovery 86°F entering water	11.8 EER 15.8 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system 86°F entering water	10.0 EER 14.0 IEER	
			VRF multi-split system with heat recovery 86°F entering water	9.8 EER 13.8 IEER	
	≥ 240,000 and < 760,000		VRF multi-split system 86°F entering water	10.0 EER 12.0 IEER	
			VRF multi-split system with heat recovery 86°F entering water	9.8 EER 11.8 IEER	
	≥ 760,000		VRF multi-split system 86°F entering water	10.0 EER	ASHRAE 90.1-2013

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[19]
			VRF multi-split system with heat recovery 86^{0}F entering water	9.8 EER	
VRF air-cooled (heating mode)	< 65,000 (cooling capacity)		VRF multi-split system	7.5 HSPF2	DOE Standards
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multi-split system 47^{0}F db/43^{0}F wb outdoor air	3.3 COP$_H$	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system 17^{0}F db/15^{0}F wb outdoor air	2.25 COP$_H$	
	≥ 135,000 (cooling capacity)		VRF multi-split system 47^{0}F db/43^{0}F wb outdoor air	3.2 COP$_H$	
			VRF multi-split system 17^{0}F db/15^{0}F wb outdoor air	2.05 COP$_H$	
VRF water source (heating mode)	< 135,000 (cooling)	None	VRF multi-split system 68^{0}F entering water with and without heat recovery	4.3 COP$_H$	DOE Standards and ASHRAE 90.1-2013
	≥ 135,000 and < 240,000 (cooling)			4.4 COP$_H$	
	≥ 240,000 and < 760,000 (cooling)			3.9 COP$_H$	
	≥ 760,000 (cooling)			3.9 COP$_H$	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 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 Core Concepts EVO 10000-1:2022.

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:

$$Peak\ Demand\ Savings\ (kW)^{20} = kW_{Baseline} - kW_{New}$$

<div align="right">**Equation 26**</div>

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*

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

<div align="right">**Equation 27**</div>

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.

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

<div align="right">**Equation 28**</div>

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

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

<div align="right">**Equation 29**</div>

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

<div align="right">**Equation 30**</div>

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

<div align="right">**Equation 31**</div>

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

<div align="right">**Equation 32**</div>

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:

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

<div align="right">**Equation 33**</div>

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 13) [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 13) [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 13 as the baseline efficiencies for the new construction and replace on burnout energy and demand savings methodology.

No M&V plan or report is required when using the deemed savings path.

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.[21]

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[21] 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.

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: ER, ROB, NC, system type conversion
- Building type
- System type (VRF AC, VRF HP air-cooled, VRF HP water-source)
- 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
- 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 14. 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 revision.
v8.0	10/2020	Added DOE CCMS certification to eligibility list
v9.0	10/2021	No revision.
v10.0	10/2022	Clarify no M&V plan requirement for deemed path. Add system type to tracking requirements.
v11.0	10/2023	Updated baseline conditions to match federal regulations.

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[22]
- Ekotrope
- REM Rate

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

- 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.)[23]

Utilities looking to use new software not included in this list should work with the EM&V team for approval.

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 secrets 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 meets 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.[24]

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[25]

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

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[23] Applicable for the modeling of multifamily buildings or portions thereof.
[24] In limited cases, townhomes that are constructed as part of a larger multifamily property may qualify under this measure.
[25] Baseline parameters are subject to change with updates to the relevant energy code.

manufacturing standards are reflected in the equipment efficiency requirements for space conditioning and water heating equipment. Additionally, the program requirements of reference programs for this market, such as the ENERGY STAR® New Homes, inform some baseline requirements.

Accordingly, baseline parameters and key model input values for new single-family detached homes and residential multifamily buildings three stories or less are detailed in Table 15. 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 16.

Exception:[26] Multifamily buildings with 4 or 5 stories above-grade[27] 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 15 and Table 16: 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. Baseline studies will be reviewed periodically to ensure they remain relevant to the current Texas market and new data may be required for continued use.

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 15 and Table 16 or changes to the implementation of baseline conditions within an approved modeling package are allowable and subject to EM&V team approval.

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

[27] 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 15. 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

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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[28]
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[29]
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[30]
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

[28] 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

[29] 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.

[30] 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)[31]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[32] 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[33]) as of April 16, 2015

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[31] 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.

[32] ANSI/RESNET/ICC 301-2019 Addendum B-2020, Clarifications, HVAC Quality Installation Grading, and Dehumidification – Mandatory January 1, 2022

[33] 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 ANSI/RESNET/ICC 30 (most recent published version and ANSI addenda) reference default values, equivalent to federal standard efficiency appliances. As-built for homes without high-efficiency appliances should also use the ANSI/RESNET/ICC 301 (most recent published version and ANSI addenda) 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 16. 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

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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)[34]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[35] 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

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[34] 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.

[35] ANSI/RESNET/ICC 301-2019 Addendum B-2020, Clarifications, HVAC Quality Installation Grading, and Dehumidification – Mandatory January 1, 2022.

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 or raters certified by other evaluated approved EPA-recognized Home Certification Organization.

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)

- o Wall insulation grade
- o Door material (wood, metal, vinyl, and whether solid core or hollow)—when available
- o Rim joist
- o Window U-factor
- o Window SHGC
- o Air infiltration
- o Mechanical ventilation
- o Slab edge insulation—only for houses located in IECC Climate Zone 4
- HVAC equipment
  - o HVAC equipment type
  - o 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.
  - o Cooling capacity
  - o Heating capacity
  - o Cooling efficiency (SEER)
  - o Heating efficiency (AFUE for gas, HSPF for heat pumps)
  - o Duct location
  - o Duct insulation R-value
  - o Duct leakage to outside (CFA)
  - o Heating set-point temperature(s) (°F)
  - o Cooling set-point temperature(s) (°F)
  - o Thermostat type (setback or no setback)
  - o Supply fan power (W/CFM)
- Water heating system
  - o Water heating systems
  - o 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
  - o DHW fuel type
  - o DHW capacity (gallons)
  - o Energy factor
  - o DHW set-point temperature

- o DHW pipe insulation
- o Number of low-flow showerheads and flow rate
- o Number of low-flow faucets and flow rate
- Lighting
  - o Number of sockets with high efficacy lamps or lighting power density, as appropriate.
- Appliances
  - o Number of ceiling fans
  - o Refrigerator model number
  - o Dishwasher model number
  - o Clothes washer presence
  - o Clothes washer model number
- HVAC commissioning
  - o Grade
- Dehumidification system
  - o Type
  - o Capacity
  - o Efficacy
  - o 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 17. 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 revision.
v3.0	3/13/2015	No revision.
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 revision.
v7.0	10/2019	Added provision for multifamily new construction, updated baseline to reflect the adoption of IECC 2015.
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.

TRM version	Date	Description of change
v10.0	10/2022	Updated references to current relevant standards.
v11.0	10/2023	Added clarification on baseline study usage and clarified that RESNET accreditation is not required and utilities can request EM&V review and approval of new software.

2.2.2 Smart Home Energy Management System (SHEMS) Measure Overview

TRM Measure ID: R-HS-SH

Market Sector: Residential

Measure Category: Whole house

Applicable Building Types: Single-family; manufactured

Fuels Affected: Electricity and gas

Decision/Action Types: New construction and retrofit

Program Delivery Type: Custom

Deemed Savings Type: Look-up tables

Savings Methodology: M&V and whole-house simulation modeling

This measurement and verification (M&V) protocol details energy and demand savings associated with smart home energy management systems (SHEMS). SHEMS are combinations of smart home devices and software that can be monitored and controlled through a single platform interface. Users typically interact with SHEMS through a dashboard on a computer, hand-held device, or voice assistant, though certain components of SHEMS are sometimes deployed through other utility demand side management (DSM) energy efficiency programs (e.g., occupancy sensors, smart thermostats). The combination of smart home devices and occupancy monitoring provides an emerging opportunity to save energy through residential controls with SHEMS.

Measure Description

This measure involves the installation of a SHEMS to manage multiple end-uses in a residential residence. The SHEMS system includes a remote consumer interface with energy savings control actions through automated and suggested actions based on information (e.g., room occupancy, schedule, related device loads, weather, or other dependent variable) collected by connected devices.

Eligibility Criteria

The measure applies to all residential applications.

Baseline Condition

The baseline condition is assumed to be uncontrolled loads.

High-Efficiency Condition

The high-efficiency condition is loads controlled by SHEMS.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

Annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = (kWh_{connected} \times ERP \times IEF_E \times ISR) - kWh_{SHEMS}$$

Equation 34

Where:

$kWh_{connected}$	=	*Average annual energy consumption of lighting and plug loads connected to SHEMS (see Table 18)*
ERP	=	*Energy reduction percentage (see Table 18)*
IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see*

Table 19)

ISR	=	*In-service rate, the percentage of incentivized units that are rebated, installed and in use; default = 0.97*
kWh_{SHEMS}	=	*Average annual standby energy consumption from hub and smart devices products. Default per hub = 7 kWh, and default per smart product = 2.2 kWh.*

Table 18. SHEMS: Default Total Kilowatt–hour Connected and ERP Results[36]

Equipment	Average total kWh connected (kWh/yr)	Energy reduction percentage (ERP)
TV system	594	49.1%
Computer system	373	48.1%
Other plugs	168	48.8%
Lighting	506	48.7%
Whole home	1,641	48.7%

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[36] CenterPoint Energy Smart Home Energy Management System Pilot, April 2022.

Equipment	Average total kWh connected (kWh/yr)	Energy reduction percentage (ERP)
Upstream/midstream—smart switch	42	48.9%
Upstream/midstream—smart plug	189	48.9%

Table 19. SHEMS: Interactive Effects for Cooling Energy Savings & Heating Energy Penalties[37]

IEF_E					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.06	1.13	1.17	1.15	1.12
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.91	1.00	1.05	1.11	0.97
Electric resistance heat with AC	0.65	0.80	0.90	1.00	0.75
Electric resistance heat with no AC	0.57	0.69	0.76	0.83	0.65
No heat with AC	1.06	1.13	1.17	1.15	1.12
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[38]	0.88	0.98	1.04	1.07	0.95

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

Demand Savings

Summer and winter demand savings are determined by applying a coincidence factor associated with each season.

$$\Delta kW = \frac{\Delta kWh}{Hours} \times CF$$

Equation 35

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[37] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60 W watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: 1 + HVACsavings/Lightingsavings.

[38] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

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Where:

$Hours$	=	*Annual hours per year controlled by SHEMS (Default = 4,380[39])*
CF	=	*Coincidence factor (see Table 20)*

Table 20. SHEMS: Coincidence Factors[40]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.33	0.43	0.36	0.30	0.66
Winter	0.89	0.88	0.86	0.85	0.87

Upstream/Midstream Program Assumptions

Upstream/midstream delivery of SHEMS should generally follow the same guidance to calculate savings using the Unknown (per Smart Switch) and Unknown (per Smart Plug) default assumptions for $kWh_{connected}$ and ERP, provided in Table 18.

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

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for SHEMS is 10 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:

- Climate zone or county
- Quantity of smart products installed

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[39] Estimated based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hours/day, or 1,936 hours/year) and half during standby hours (8,760-1,936 = 6,824 hours/year). The resulting weighted average is 4,380 hours/year. Same as APS measure.
[40] See Volume 1, Section 4. Values taken from residential *advanced power strips* measure.

- Kilowatt-hours of connected or system group type
- Heating system type (gas, electric resistance, heat pump), if known
- Cooling system type (air conditioner, evaporative, none), if known
- Program delivery type
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 21. SHEMS: Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM 10.0 origin.
v11.0	10/2023	No revision.

2.3 M&V: BUILDING ENERGY CODES

2.3.1 Residential Energy Code Compliance Enhancement Measure Overview

TRM Measure ID: R-EC-RC

Market Sector: Residential

Measure Category: Energy code compliance enhancement

Applicable Building Types: All residential

Fuels Affected: Electricity

Decision/Action Types: New construction

Program Delivery Type: Custom

Deemed Savings Type: For this measure, a deemed menu of recommended utility activities scales based on market potential as well as utility contributions to energy code compliance enhancement efforts

Savings Methodology: Custom

Measure Description

The *residential energy code compliance* measure captures the holistic efforts of utilities to improve adherence to the relevant energy code(s) within their communities. The energy savings estimates are designed to efficiently estimate electric energy and demand savings attributable to new construction buildings and major renovations whose energy code compliance improvements result from utility efforts. The measure savings methodology details the framework to estimate savings achieved by utility energy code compliance enhancement efforts on a cyclical basis.

Eligibility Criteria

This measure applies to residential new construction and major renovation projects completed in an energy code evaluation cycle are eligible to be included in the potential savings calculations. Furthermore, only program activities operating within the state will be considered for attributable savings.

Baseline Condition

Baseline conditions for the energy-code-related measures are determined by the historical compliance rate to the existing energy code within the relevant jurisdiction(s).

High-Efficiency Condition

The high-efficiency condition is the current compliance rate to the existing energy code within the relevant jurisdiction(s).

Energy and Demand Savings Methodology

An implementation plan will be developed for each evaluation cycle and geographic location to document the necessary variables described below.

Market Baseline

The proposed market baseline attempts to estimate a prospective prediction of the overall energy code compliance level without the influence of utility and other related stakeholder programs.

The baseline is established through an in-field study or studies to examine the current state of newly constructed buildings and major renovations by conducting site visits to collect information that assesses building practices and energy-consuming equipment. The baseline study must target single-family and multifamily residential building types for that evaluation cycle, maintaining relative precision values below 20 percent (85 percent confidence interval) for relevant building types.[41]

Potential Energy Savings

The potential energy savings calculation represents all savings that could be achieved if the compliance rate with the current energy code(s) was increased to 100 percent (i.e., the delta between the baseline and 100 percent compliance). The difference represents the total pool of savings that may be gained under the current energy code cycle. This value will likely not be achieved; it is necessary to calculate so that a specific portion of these savings may be attributed to the utility in future steps.

The potential energy unit savings estimation is developed in the baseline study through building simulation modeling for estimating whole building energy usage and savings potential by building type. Third-party industry experts may develop these models as part of the implementation plan development. The models will use the TMY3 weather-normalized files detailed in Volume 1 of the TRM. The potential savings for each housing type will be extrapolated across the entire new construction and major renovation population to estimate the potential savings assumption in the implementation plan.

Compliance Adjustment Factor (CAF)

The CAF scales directly with the rate of code compliance; this factor aims to eliminate buildings from the "savings pool" that are not currently compliant. If every building fully complies with the code, then the gross code energy savings will equal the potential energy savings.

This factor is determined through a baseline study or studies that assess building compliance with the energy code. This could be performed utilizing a Delphi process or through analytical methods by calculating granular energy savings at the measure level and extrapolating to the whole building population. The implementation plan will detail the CAF and the supporting methods to support the assumption.

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[41] For more information on the baseline study process, visit this Pacific Northwest National Laboratory (PNNL) website: https://www.pnnl.gov/building-energy-codes.

Gross Code Energy Savings

The gross code energy savings represents the energy savings achieved through increases in energy code compliance. These savings result from increased code compliance above the market baseline regardless of influence.

The gross code savings is determined using the current end-of-cycle compliance rates and the pre-existing market baseline from the beginning of the evaluation cycle. On a unit basis, the gross code savings will be the delta in energy consumption between these two scenarios. The unit energy consumption delta should be extrapolated to the relevant new building stock resulting in overall gross code savings. The unit savings and extrapolation should be detailed in the implementation plan.

Naturally Occurring Market Adoption (NOMA)

The NOMA is the savings the market would have achieved naturally through compliance increases of its own subtracted from the gross code energy savings.

NOMA is estimated by extrapolating historical increases in compliance over time for the relevant jurisdiction(s). The implementation plan should detail comparable jurisdictions' baseline compliance trend data to support the claimed NOMA.

Net Code Energy Savings

After determining the net code savings, the fraction of these savings resulting from utility energy code compliance efforts is determined. This assessment will examine the evidence of efforts from utility participants and other potential market influences, such as government agencies, local advocacy groups, or even national marketing campaigns. The net code energy savings is the delta between gross code energy savings minus NOMA.

Attribution Factor (AF)

The attribution factor determines what fraction of savings realized from an increase in energy code compliance are the direct result of utility code program activities.

This factor will compare the relative influence of utility activities with other organizations that may have influenced code compliance. It will detail evidence and program data collected by the utility over the evaluation cycle.

Allocation

The allocation score divides the energy savings between utilities when more than one utility is collaborating in a code program in a shared jurisdiction or separately providing complementary energy code compliance enhancement activities. If necessary, the implementation plan will include detail of the allocation framework.

Delphi Panel Overview

A Delphi panel is an acceptable data collection method to inform the development of factors in the savings framework. The panel is expected to consist of 10–15 industry experts, including builders, raters, engineers, code officials, consultants, and academics, preferably from the relevant jurisdiction(s). The panel should access all relevant and necessary information in the implementation plan and supporting documentation; including baseline study results, new construction and major renovation data, survey responses, and all evidence collected by the utility to support its energy compliance enhancement efforts. For more information on the Delphi process, see the Illinois TRM v10, Vol. 4, Section 6.6.[42]

Energy Savings Methodology

Potential energy savings per residential building are determined through market research, typically through primary or secondary research. This includes an in-field market baseline study, building simulation modeling, and/or measure characterization used in combination with market data (number and type of buildings).

$$Potential\ Energy\ Savings = Market\ Baseline\ Consumption - Code\ Compliant\ Consumption$$

Equation 36

$$Gross\ Code\ Energy\ Savings = Potential\ Energy\ Savings \times CAF$$

Equation 2

$$Net\ Code\ Energy\ Savings = Gross\ Code\ Energy\ Savings - NOMA$$

Equation 3

$$Program\ Net\ Code\ Energy\ Savings = Net\ Code\ Energy\ Savings \times AF$$

Equation 4

$$Energy\ Savings = Program\ Net\ Code\ Energy\ Savings \times Allocation$$

Equation 5

Where:

CAF	=	_Compliance adjustment factor_
NOMA	=	_Naturally occurring market adoption_
_AF_	=	_Attribution factor_

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[42] 2022 Illinois Statewide Technical Reference Manual, v10.0, Volume 4, Section 6.6: Structured Expert Judgment Approaches. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010122_v10.0_Vol_4_X-Cutting_Measures_and_Attach_09242021.pdf.

Summer Demand Savings Methodology

Summer peak demand savings are estimated using whole-building simulation modeling based on historical meter data collection and load shape profiles for the specific climate zone. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Winter Demand Savings Methodology

Winter peak demand savings are estimated using whole-building simulation modeling based on historical meter data collection and load shape profiles for the specific climate zone. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Building Population

The building population for this measure is the number of residential buildings that completed construction in the program year. The number of completed projects in a jurisdiction can be estimated using construction data sources that utilize building permit applications to identify active projects. The building permit data needs to be augmented to determine the building population to estimate the building completion date for each residential building.

The US Census Bureau releases monthly reports on new residential construction across the country and includes a section titled Length of Time, which estimates the length of time for Authorization to Start and Start to Completion. Combining these two values for the "South" region can estimate the building population of completed projects based on the amount of building permits issued in the jurisdiction.

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings tied to activities is a potential for future development of this measure. The initial savings framework and documentation will be assessed to create a potential activity table with deemed savings amounts in future years.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The Codes and Standard program will use the estimated useful life (EUL) of a new home or major renovation measure: 23 years.

Program Tracking Data and Evaluation Requirements

The primary inputs and supporting documentation below should be specified and tracked within the program to inform the evaluation and apply the savings properly. Many factors will need to be tracked per building type, code jurisdiction, and climate zone.

- Climate zone or county
- Building type

- Building population

- Building area

- Building code jurisdiction

- Compliance enhancement activity log

The following tracked values require documentation to support the value used in the framework. An implementation plan detailing the supporting data collection, documentation, and analysis used to develop the values below is required before implementation. The evaluator will review this implementation plan to verify energy savings assumptions prior to delivery and assess the claimed savings after delivery.

- Market baseline

- Relevant standards

- Potential energy savings

- Gross energy savings

- Net energy savings

- Compliance adjustment factor

- Naturally occurring market adoption

- Allocation factor

- Allocation

- Building population factors

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 22. Residential Energy Code Compliance Revision History

TRM version	Date	Description of change
v10.0	11/2022	TRM 10.0 origin
v11.0	10/2023	Adjusted calculation process to estimate building population.

2.4   M&V: RENEWABLES

2.4.1 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[43], 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 customers' 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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[43] 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®.[44] 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 the 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.

  o 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 23. Module Type Options

Type	Approximate efficiency	Module cover	Temperature coefficient of power
Standard (crystalline silicon)	19 percent	Anti-reflective	-0.37 %/°C
Premium (crystalline silicon)	21 percent	Anti-reflective	-0.35 %/°C
Thin film	18 percent	Anti-reflective	-0.32 %/°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.

- Shading: Accept the PVWatts default values as the minimum shading[45] or adjust the shading percentage only if the actual conditions exceed this value.

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[44] PVWatts Calculator: https://pvwatts.nrel.gov/.
[45] Three percent default shading, PVWatts Calculator accessed on August 8, 2023.

- DC to AC size ratio: Adjust to match the equipment or use the default.

- Bifacial: Adjust to match installed equipment.

- All other input variables: Accept the PVWatts default values.

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 20 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
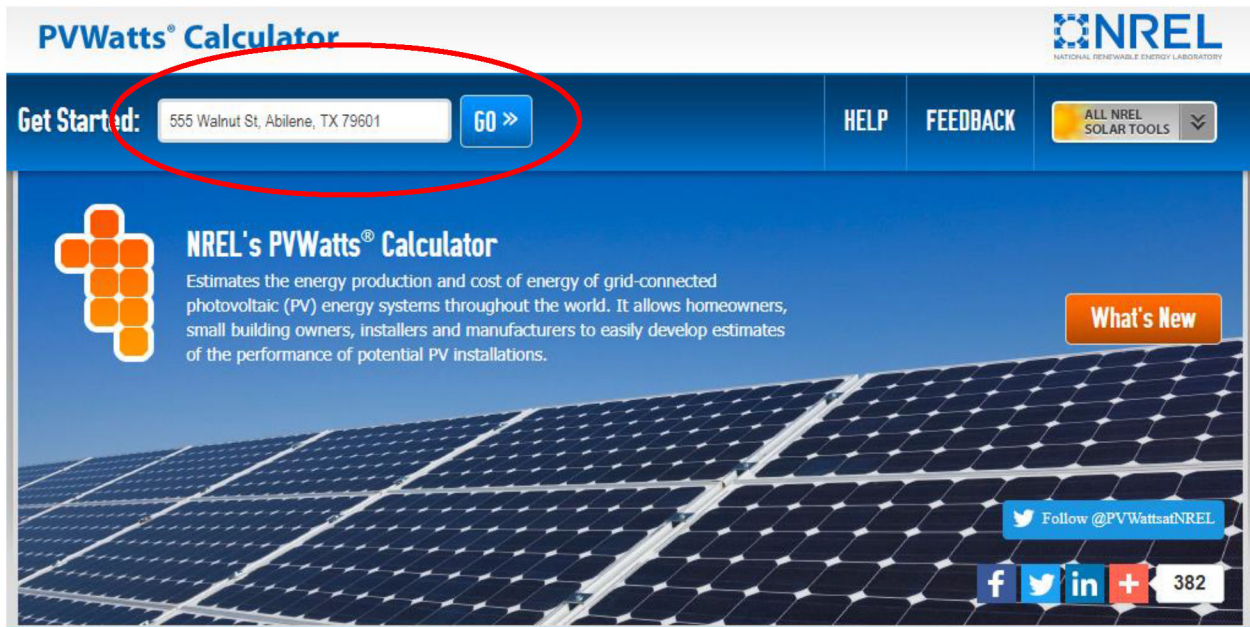
- **Step 2.** PVWatts automatically identifies the nearest weather data source, defaulting to the NREL NSRDB grid cell for your location (see Figure 2). Confirm the resulting location and proceed to system info, as shown in Figure 3.

Figure 2. PVWatts Resource Data Map
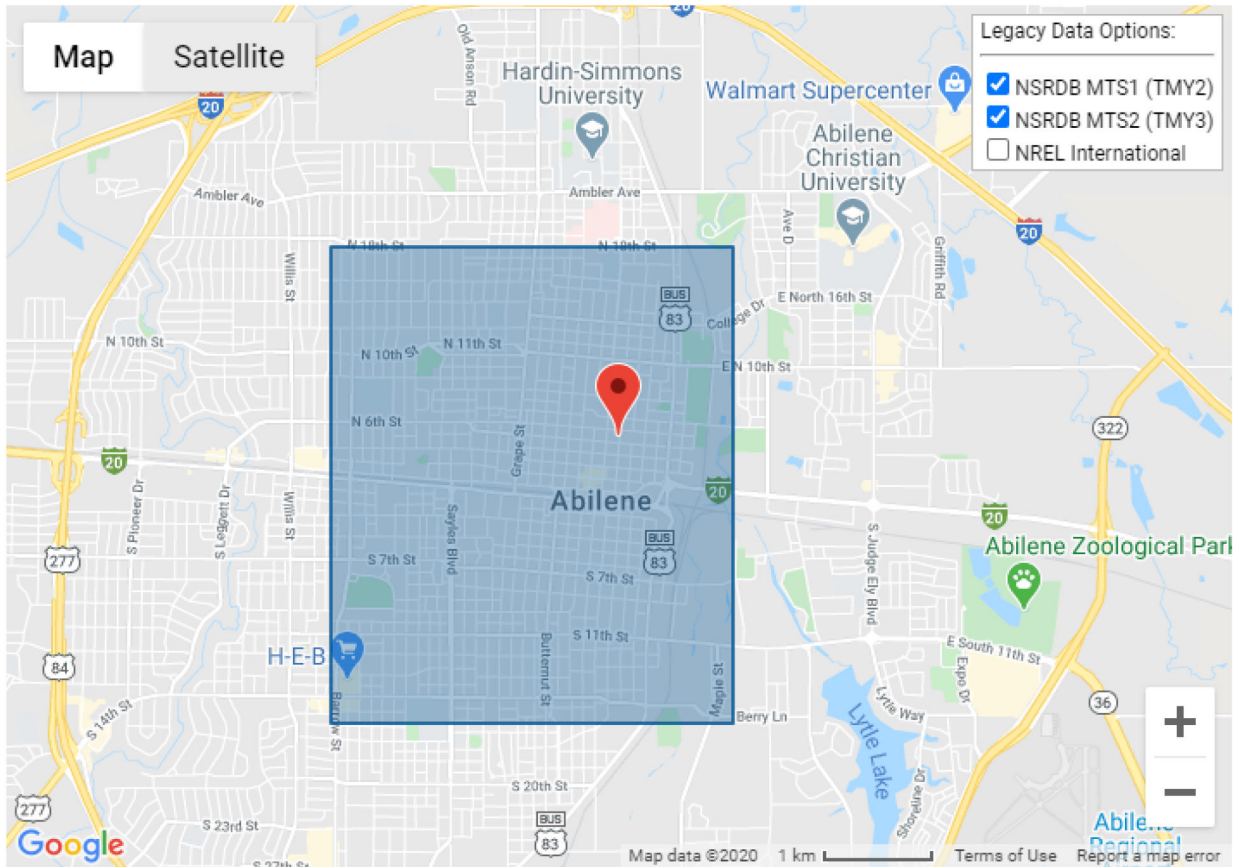
Figure 3. PVWatts Input Screen for Step 2
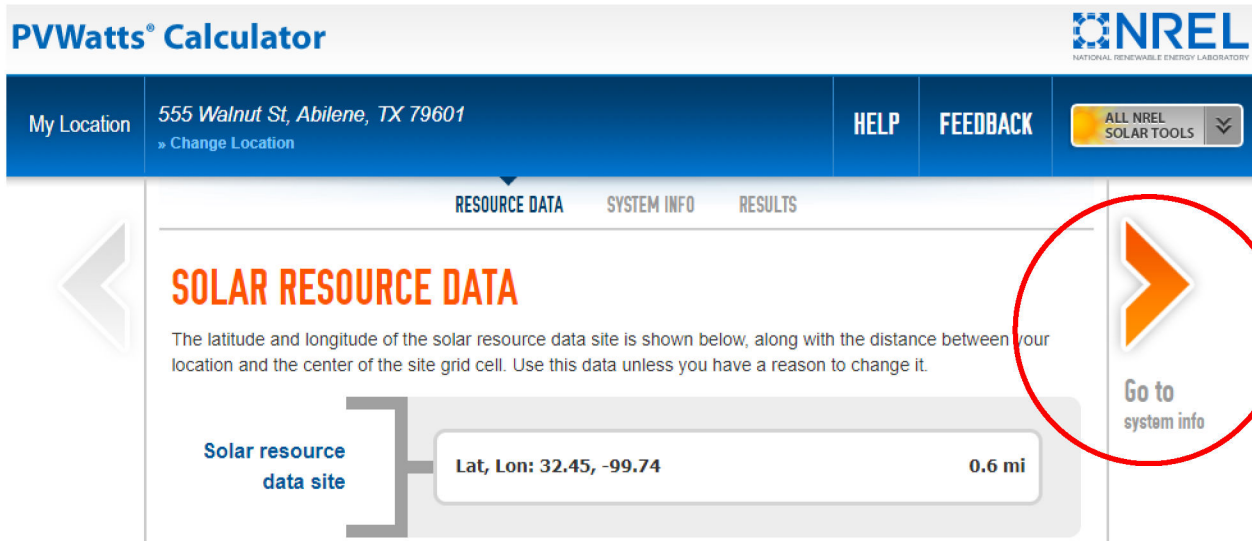
- **Step 3.** The user enters system info as follows:
  - DC system size (kW): 5.00
  - Module type: Standard
  - Array type: Fixed (roof mount)
  - Tilt (deg): 20
  - Azimuth (deg): 200

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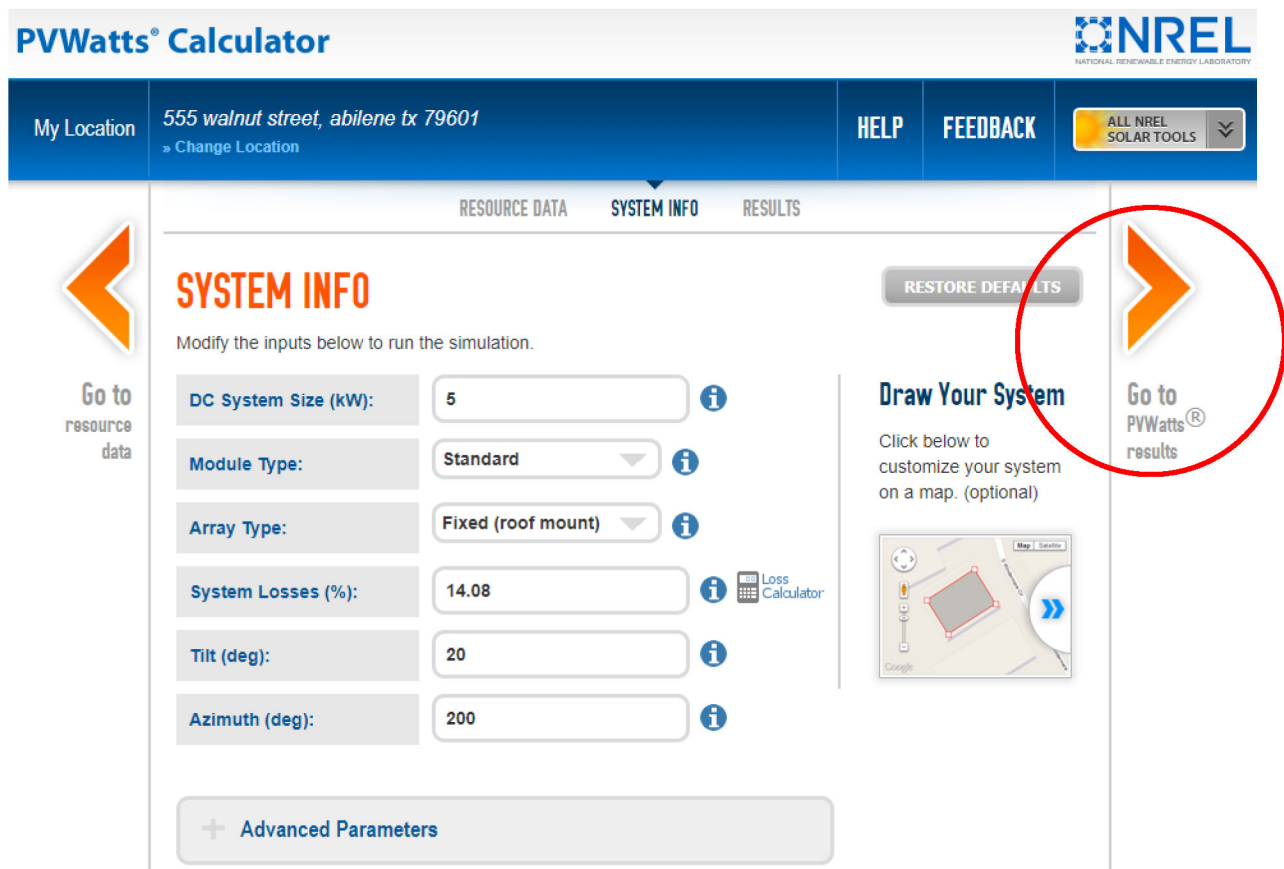
- **Step 4.** PVWatts returns an estimate of annual energy production (kWh), in this case 7,904 kWh. See Figure 5.

Figure 5. PVWatts Output Screen for Step 4

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)*

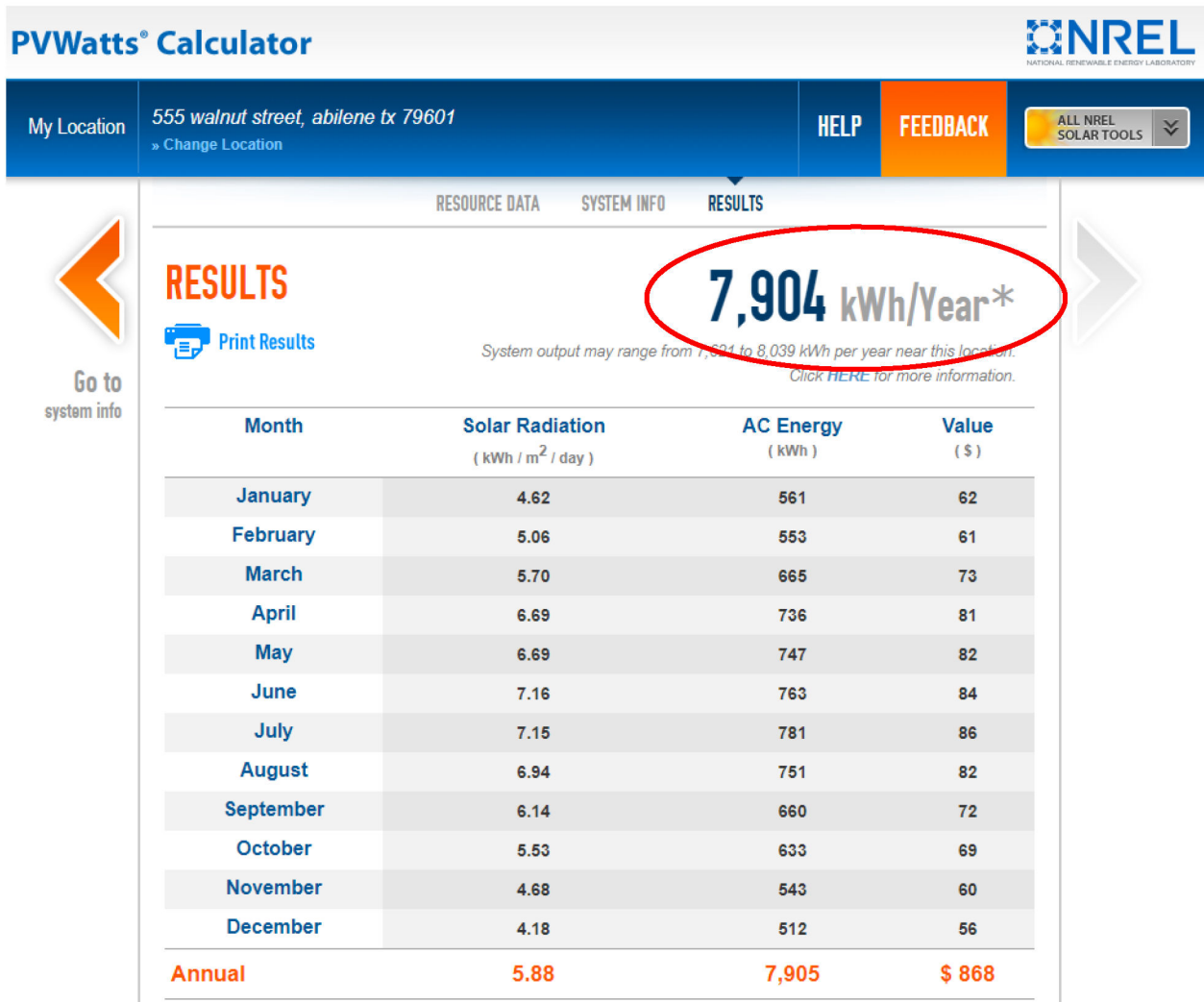|	
DC System Size	5 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	20°
Array Azimuth	200°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

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 37

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.

Residential systems using trackers may use the maximum tilt or azimuth value that the tracking system can reach.

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 24 through Table 33) 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 38

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.

Residential systems using trackers may use the maximum tilt or azimuth value that the tracking system can reach.

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[46]
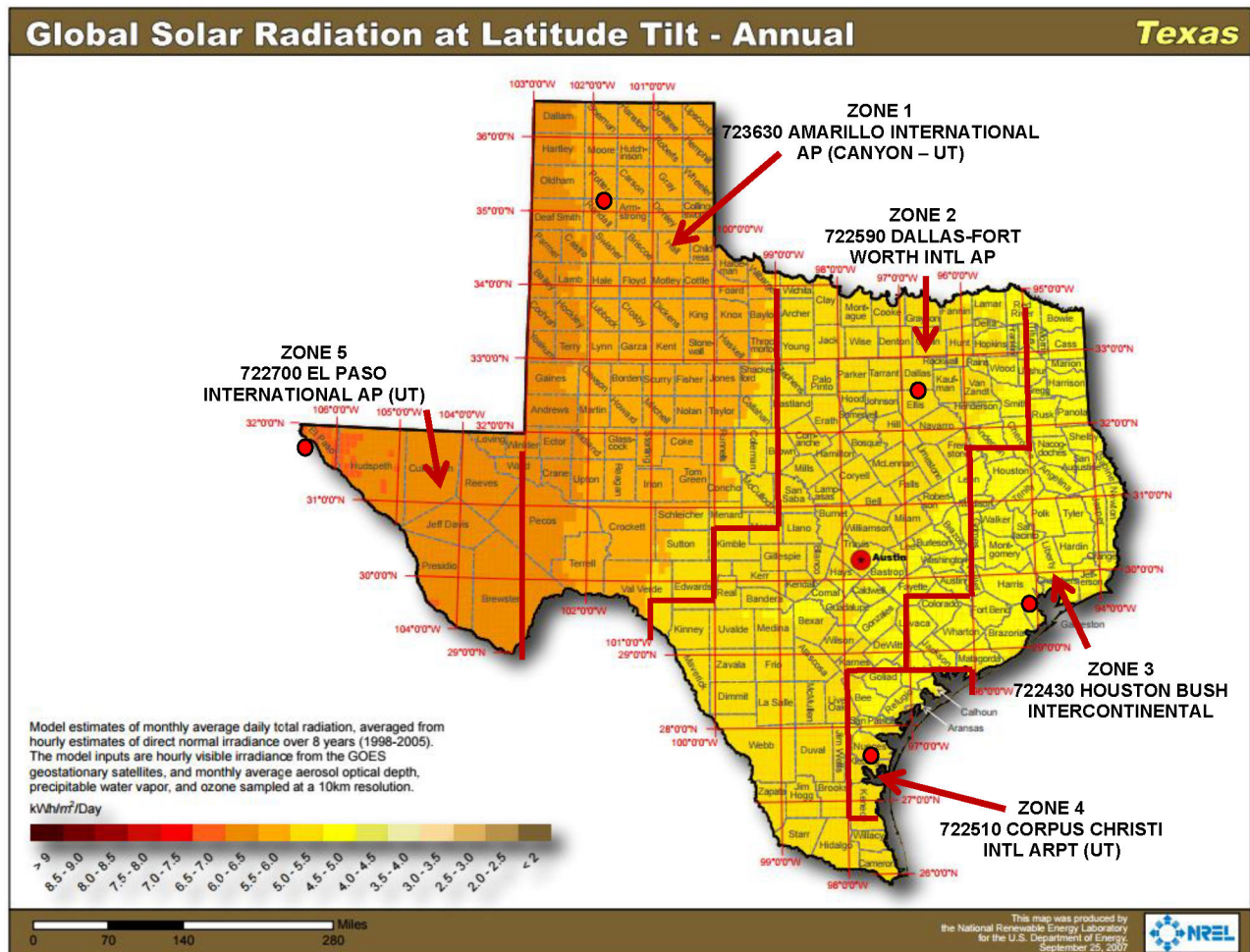
Deemed Summer and Winter Demand Savings—Lookup Value Tables

The tables below provide lookup values used to calculate deemed summer and winter demand savings based on the weather zone, tilt, and azimuth. Table 24 through Table 33 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 24.

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

Table 24. 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 25. 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 26. 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 27. 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 28. 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 29. 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 30. 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 31. 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 32. 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 33. 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
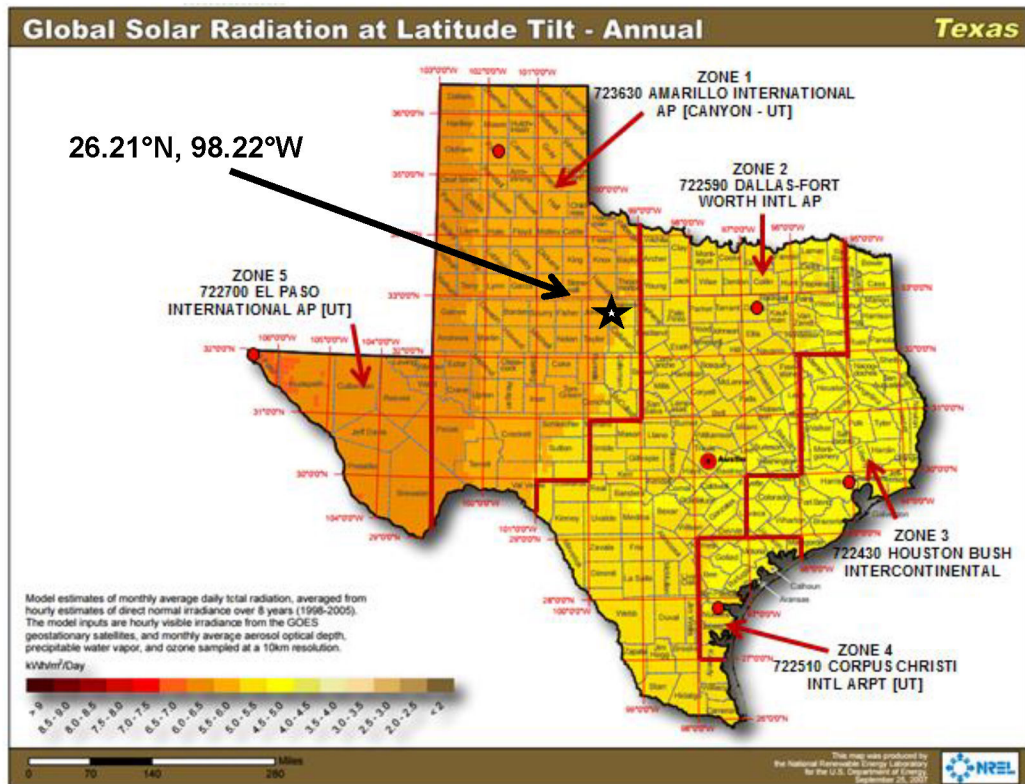
- **Step 2.** Calculate summer and winter demand savings. From the zone 1 lookup table, 20-degree tilt falls within the 7.5- to 22.5-degree tilt range, and 200-degree azimuth falls within the 157.5–202.5 azimuth range. The summer lookup value is 49 percent, and the winter lookup value is 2 percent.

Applying Equation 37,

$$Deemed\ summer\ demand = DC\ system\ size\ (kW) * lookup\ value$$

$$Deemed\ summer\ demand = 5.000\ kW * 49\%$$

$$Deemed\ summer\ demand = 5.000\ kW * 0.49$$

$$Deemed\ summer\ demand = 2.450\ kW$$

Applying Equation 38,

$$Deemed\ winter\ demand = DC\ system\ size\ (kW) * lookup\ value$$

$$Deemed\ summer\ demand = 5.000\ kW * 2\%$$

$$Deemed\ summer\ demand = 5.000\ kW * 0.02$$

$$Deemed\ summer\ demand = 0.100\ kW$$

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 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
- Shading study, if not using PVWatts default values

- 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 34. 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 revision.
v3.0	04/10/2015	No revision.
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 revision.
v7.0	10/2019	No revision.
v8.0	10/2020	Updated instructions for new version of PVWatts and references to NREL National Solar Radiation Database (NSRD) (previously TMY3).

TRM version	Date	Description of change
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.
v10.0	10/2022	No revision.
v11.0	10/2023	Eliminated alternate savings method and adjusted premium module type requirements to match PVWatts. Clarified assumptions to use in PV Watts analysis.

2.4.2 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,[47] 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.

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[47] 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.[48] 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 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 10).

- DC system size (kilo-watt): 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.

  o 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 35. Module Type Options

Type	Approximate efficiency	Module cover	Temperature coefficient of power
Standard (crystalline silicon)	19 percent	Anti-reflective	-0.37 %/°C
Premium (crystalline silicon)	21 percent	Anti-reflective	-0.35 %/°C
Thin film	18 percent	Anti-reflective	-0.32 %/°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.

- Shading: Accept the PVWatts default values as the minimum shading[49] or adjust the shading percentage only if the actual conditions exceed this value.

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[48] PVWatts Calculator: https://pvwatts.nrel.gov/.
[49] Three percent default shading, PVWatts Calculator accessed on August 8, 2023.

- DC to AC size ratio: Adjust to match the equipment or use the default.

- Bifacial: Adjust to match installed equipment.

- All other input variables: accept the PVWatts default values.

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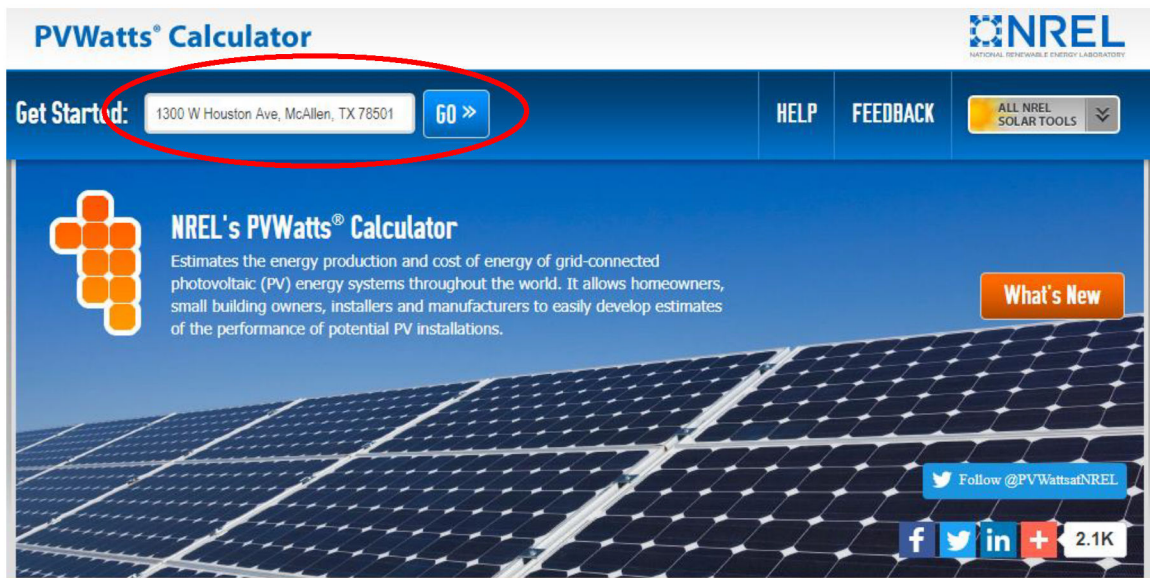
> **Step 2.** PVWatts automatically identifies the nearest weather data source, defaulting to the NREL grid cell for your location. The user should change the default weather data source, as shown in Figure 10. Confirm the resulting location and proceed to system info, as shown in Figure 11.

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Figure 10. PVWatts Resource Data Map
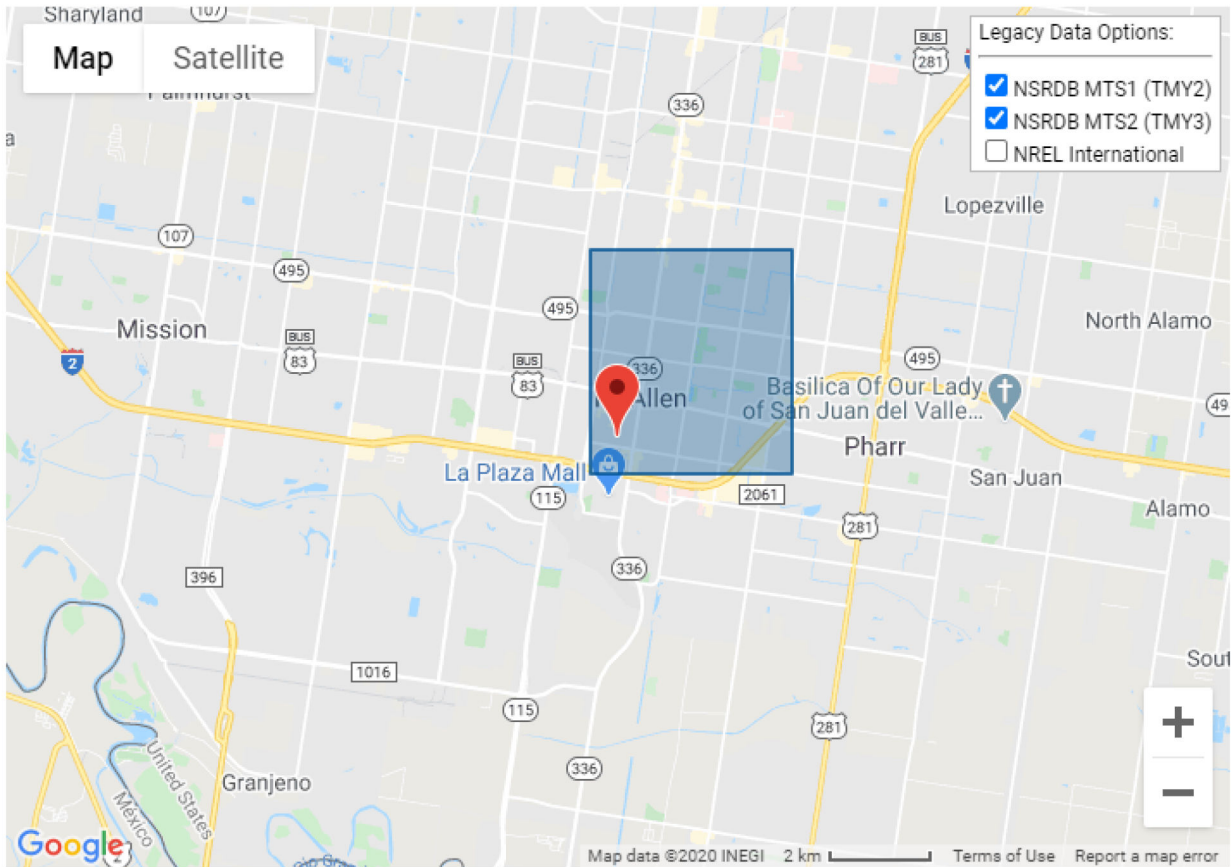
Figure 11. PVWatts Input Screen for Step 2
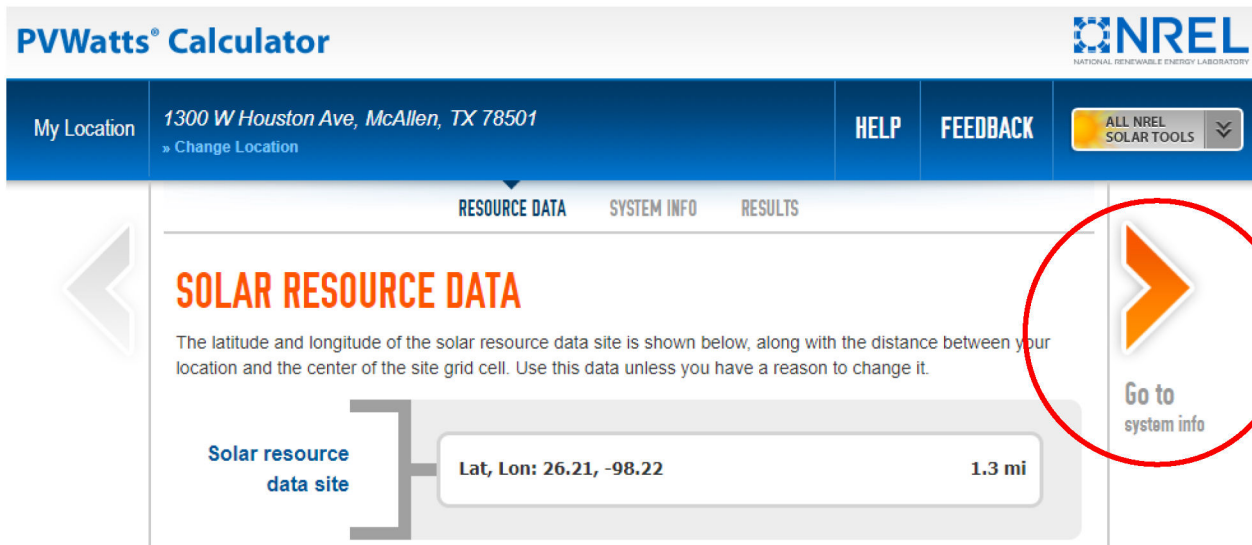
Step 3. The user enters system info as follows:

- 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

PVWatts® Calculator | NREL NATIONAL RENEWABLE ENERGY LABORATORY

My Location | 1300 W. Houston Avenue, McAllen, TX 78501 » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

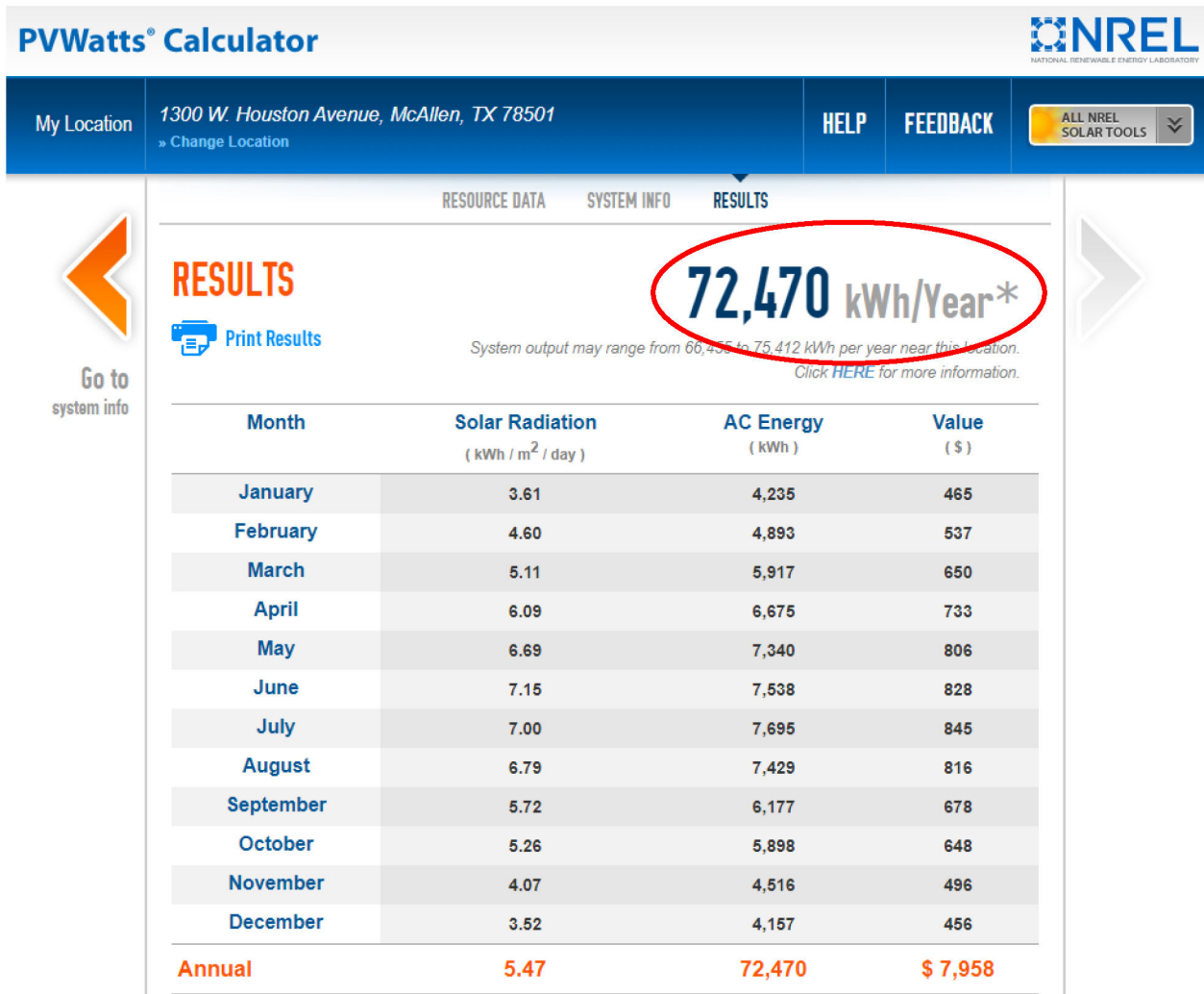RESOURCE DATA SYSTEM INFO **RESULTS**

RESULTS

🖨 Print Results

Go to system info

72,470 kWh/Year*

System output may range from 66,455 to 75,412 kWh per year near this location.
Click HERE for more information.

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.

Summary Demand Savings Methodology

Deemed summer demand savings are determined using the weather zone map (Figure 15) and summer demand savings lookup values (Table 36) 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

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 36 through Table 45) 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

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 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[50]
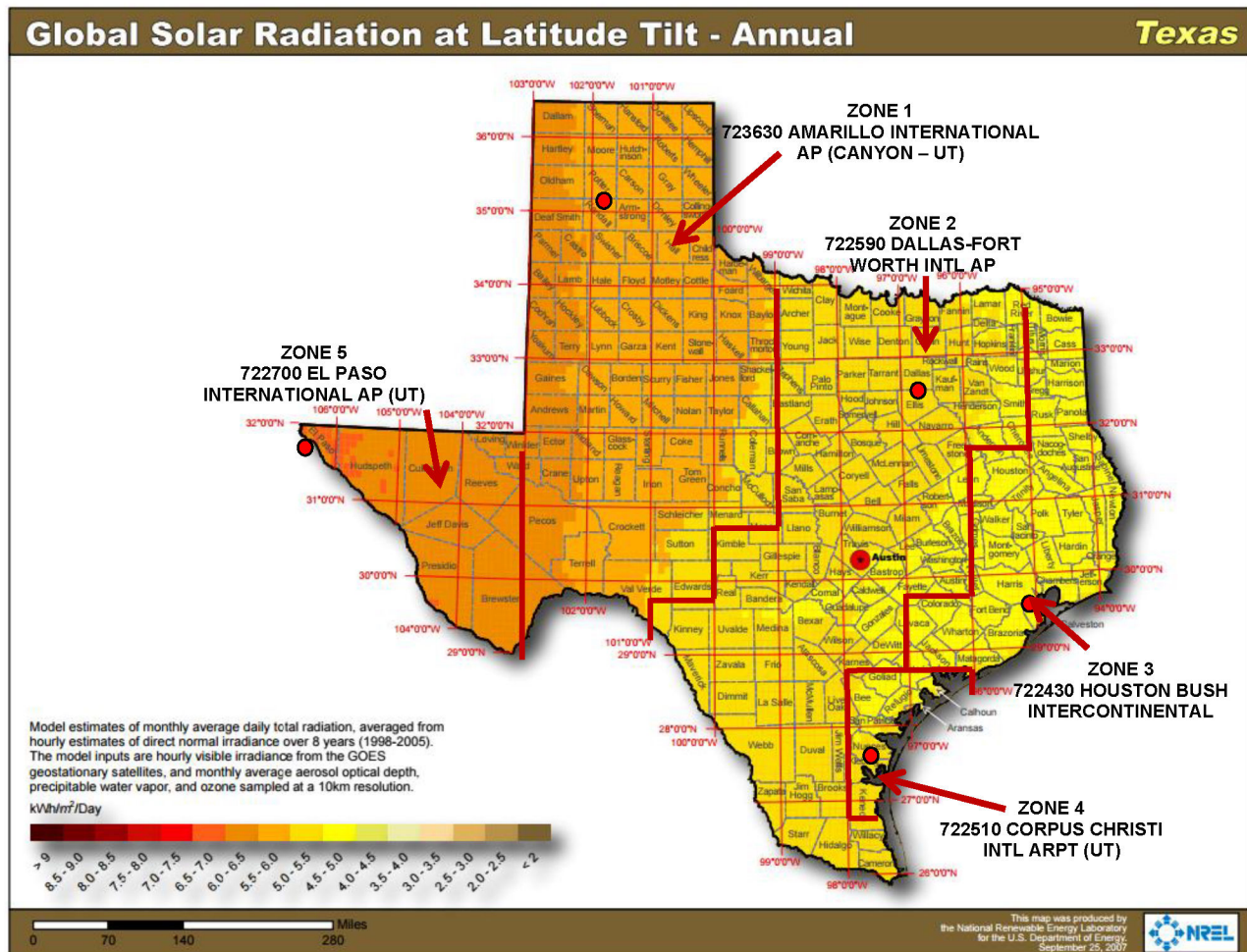
Deemed Summer and Winter Demand Savings—Lookup Value Tables

The tables below provide lookup values used to calculate deemed summer and winter demand savings based on the weather zone, tilt, and azimuth. Table 36 through Table 45 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 36.

---

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

Table 36. 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 37. 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 38. 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 39. 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 40. 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 41. 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 42. 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 43. 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 44. 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 45. 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
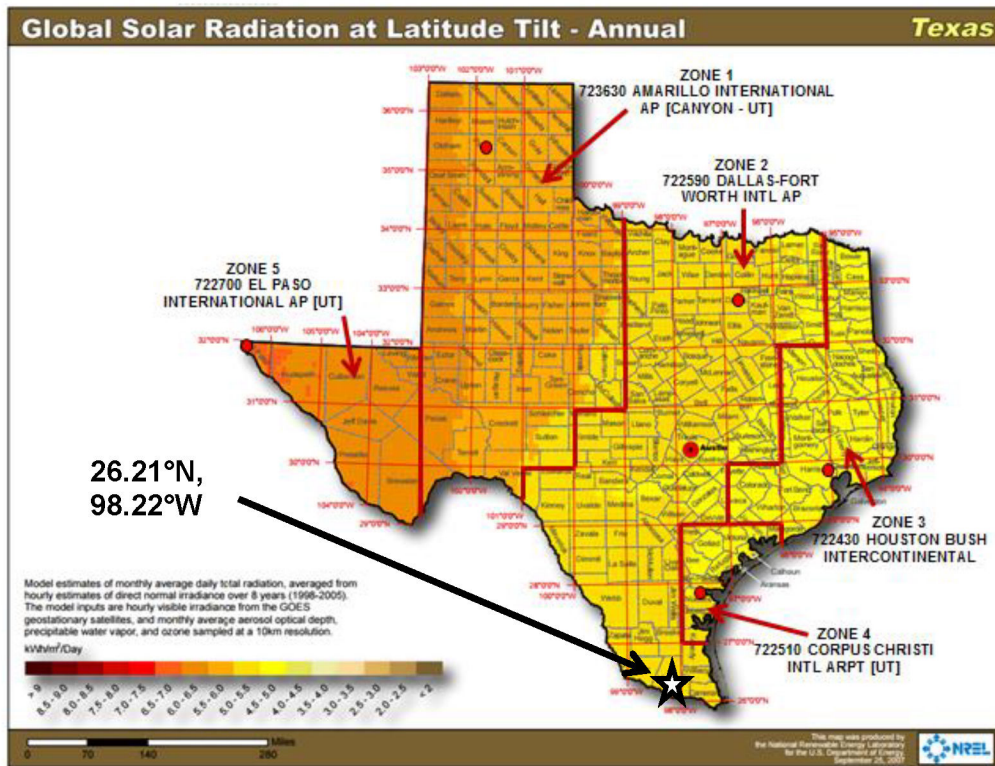
Step 2. Calculate the summer and winter demand savings. From the zone 2 lookup tables, 5 degree tilt falls within the 0-7.5 degree tilt range, and 175 degree azimuth falls within the 157.5-202.5 azimuth range. The summer lookup value is 46 percent, and the winter lookup value is 3 percent.

Applying Equation 39,

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

$$Deemed\ summer\ demand = 50.000\ kW * 46\%$$

$$Deemed\ summer\ demand = 50.000\ kW * 0.46$$

$$Deemed\ summer\ demand = 23.000\ kW$$

Applying Equation 40,

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

$$Deemed\ summer\ demand = 50.000\ kW * 3\%$$

$$Deemed\ summer\ demand = 50.000\ kW * 0.03$$

$$Deemed\ summer\ demand = 1.500\ kW$$

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.

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
- Shading study, if not using PVWatts default value

- 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 46. 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 a 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 revision.
v7.0	10/2019	No revision.
v8.0	10/2020	Updated instructions for the new version of PVWatts and references to NREL National Solar Radiation Database (NSRD) (previously TMY3)
v9.0	10/2021	Clarified PVWatts kilowatt-hour modeling instructions and documentation requirements. Provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges.

TRM version	Date	Description of change
v10.0	10/2022	No revision.
v11.0	10/2023	Eliminated alternate savings method and adjusted premium module type requirements to match PVWatts. Clarified assumptions to use in PVWatts analysis.

2.4.3 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.[51]

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 47, 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.

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[51] 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 47. 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
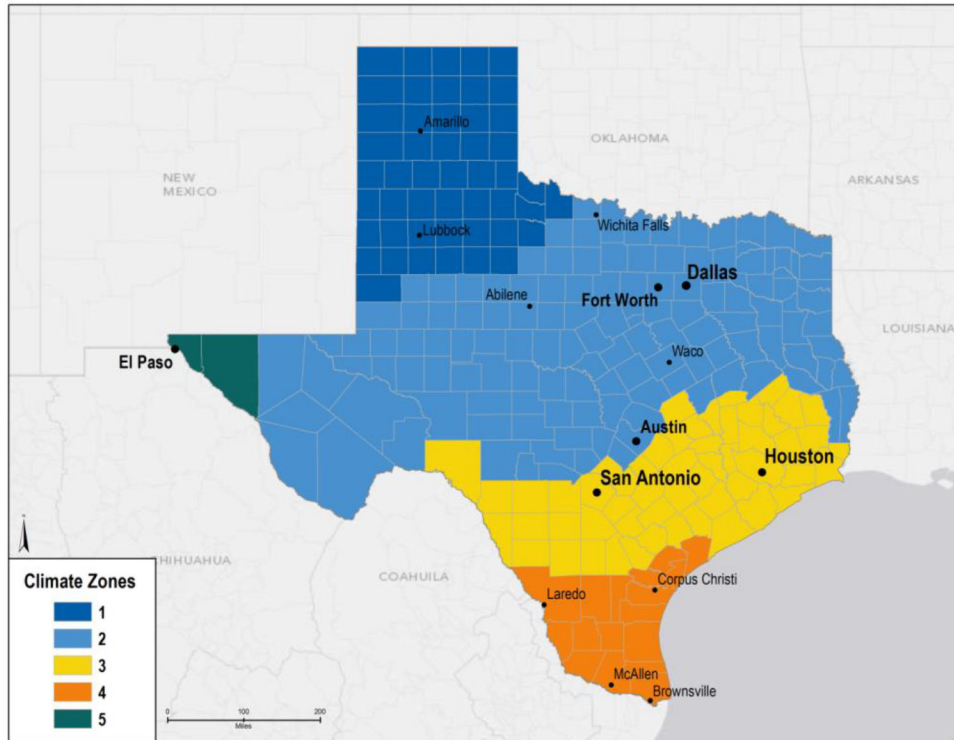
Module. The default action in the Module screen allows users to select a product with required performance data pre-loaded into SAM. Several CertainTeed Apollo modules and Dow DPS-XXX modules can be specified in this window. However, modeling options for the PV Module can be modified in SAM 2015.6.30 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.

- Climate zone or county
- Decision/action type: retrofit, new construction
- Building type
- 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 48. 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 the latest version of SAM software and removal of TMY2 weather data file use. Revised measure details to match the 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 revision.
v5.0	10/10/2017	No revision.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	No revision.

TRM version	Date	Description of change
v9.0	11/2021	TRM v9.0 update. Updated EUL.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.

2.4.4 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 floor space. 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

The attic temperature for each hour is estimated according to the following equation for both the baseline and high-efficiency conditions:[52]

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

Equation 41

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)*

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[52] 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/ft³)
c_p	=	Specific heat of air (Btu/lb-°F)
A_c	=	Ceiling surface area (ft²)
U_c	=	U-factor of the ceiling between the conditioned space and the unconditioned attic (Btu/ft²-hr-°F)
A_d	=	Surface area of supply ducts in the attic (ft²); set to zero if there are no supply ducts in the attic
U_d	=	U-factor of the insulation on the ducts, (Btu/ft²-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:

$$Hourly\ Energy\ Savings\ (kWh) = \frac{(A_c * U_c + A_d * U_d)}{1000 * EER} * \left(T_{a,b} - T_{a,he}\right) * 1\ hr$$

Equation 42

Where:

A_c	=	Ceiling surface area (ft²)
U_c	=	U-factor of the ceiling between the conditioned space and the unconditioned attic (Btu/ft²-hr-°F)
A_d	=	Surface area of supply ducts in the attic (ft²); set to zero if there are no supply ducts in the attic
U_d	=	U-factor of the insulation on the ducts (Btu/ft²-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 49. 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 43

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 50. 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 44

Where:

The *Summer Peak Demand Savings* are the appropriate value from Table 50.

> *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 or county
- 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 the 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-installation spot measurements (near insulation level and underside of the roof)

  - Post-installation 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 51. Residential Solar Attic Fans Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	Removed measure due to lack of M&V data collection to refine preliminary deemed savings estimates.
v9.0	10/2021	Reinstated measure requiring M&V data collection.
v10.0	10/2022	No revision.
v11.0	10/2023	No revision.

2.5 M&V: MISCELLANEOUS

2.5.1 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: M&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 and comply with IPMVP Option C. Projects shall meet the model fit metrics based on one year of pre-installation and one year of post-installation hourly consumption data. Alternate methodologies or data availability of less than hourly increments will be considered on a case-by-case basis with prior approval from the evaluation team.

For projects with smaller savings (typically < 20 kW) where standard M&V efforts may be cost prohibitive, the simplified M&V energy and demand savings may be used with prior evaluation-team 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

Savings Algorithms and Input Variables

Not applicable.

M&V Methodology

The evaluation, measurement, and verification (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. Whole facility guidance is found in IPMVP Core Concepts EVO 10000-1:2022. CalTRACK 2.0 technical appendix should be used to support the development of consistent normalized energy consumption models.

A measurement and verification (M&V) plan and M&V report shall document the methodology selected and include assumptions and details regarding model development, testing, handling of errors, and information to validate regression model(s).

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.