Where:

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

Public Utility Commission of Texas

Texas Technical Reference Manual

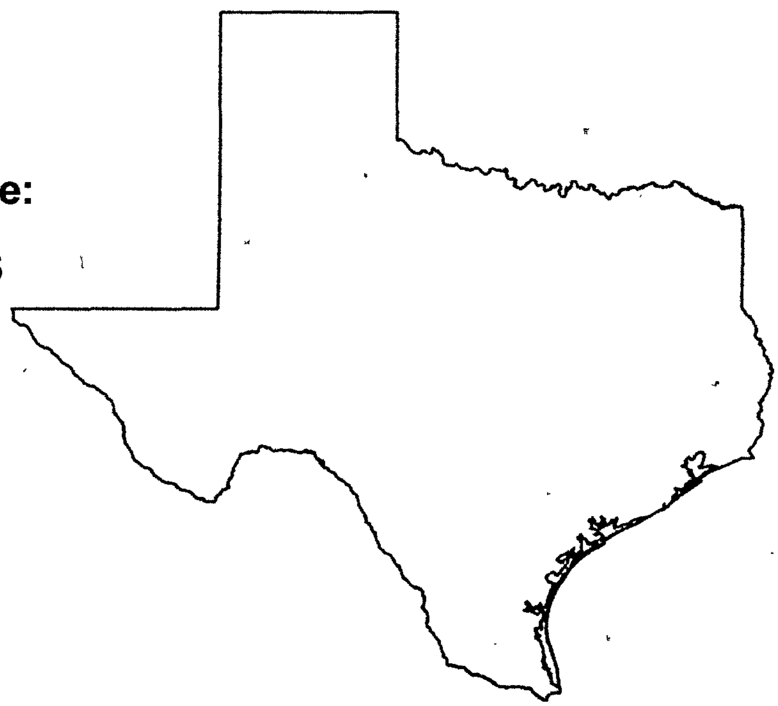
Version 4.0

Volume 4: Measurement & Verification Protocols

Program Year (PY) 2017

Last Revision Date:

November 1, 2016



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

TRM Technical Support

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

1. INTRODUCTION

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

M&V protocols are included for the following measures:

- HVAC: Air Conditioning Tune-up
- HVAC: Ground Source Heat Pump
- Whole House: New Homes
- Renewables: Solar Shingles
- Miscellaneous: Behavioral
- Demand Response: Residential Load Curtailment
- Demand Response: Nonresidential Load Curtailment

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

Please consult Volume I: Overview and User Guide, Section 4: Structure and Content, for details on the organization of the measure templates presented in this volume.

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

Sector	Measure Category	Measure Description	4.0 Update
Residential & Nonresidential	HVAC	Air Conditioning Tune-Up	Revised efficiency loss factors based on 2015 results. Added VFD motor types.
Nonresidential	HVAC	Ground Source Heat Pump	TRM v3.1 origin.
Residential	Whole-House	New Homes	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.
Residential & Nonresidential	Renewables	Solar Photovoltaics	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. Moved to Volume 4 from Volumes 2 and 3.
Residential & Nonresidential	Renewables	Solar Shingles	Major methodology updates include revising the reference to latest version of SAM software and removal of TMY2 weather data file use. Revised measure details to match format of TRM volumes 2 and 3. This included adding detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
Nonresidential	Miscellaneous	Behavioral	TRM v3.1 origin.
Residential	Demand Response	Residential Load Curtailment	Addendum memo to TRM 2.1, TRM v3.1 origin
Nonresidential	Demand Response	Nonresidential Load Curtailment	Moved this measure from TRM Volume 3 to TRM Volume 4. The baseline calculation methodology was modified in TRM 3.0 to be the highest 5 of 10 prior days for all the programs. In addition, a new day-of adjustment factor was added with an adjustment cap.

2. M&V MEASURES

2.1 M&V: HVAC

2.1.1 Air Conditioning Tune-Up Measure Overview

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

Market Sector: Residential and Commercial

Measure Category: HVAC

Applicable Building Types: Residential; Commercial

Fuels Affected: Electricity

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

Program Delivery Type(s): Custom

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

Savings Methodology: Algorithms, EM&V and deemed efficiency loss corresponding to whether on not refrigerant charge was adjusted.

AC tune-ups promote a holistic approach to improving the operational efficiency of existing air conditioners under 300,000 Btu/hour (≤ 25 tons) in size by completing six tune-up service measures. This protocol is used to estimate savings for tune-up measures through an M&V approach that relies on test-out measurements of key AC performance indicators following completion of all tune-up service measures.

The M&V protocols included here are for air conditioner tune-ups (AC tune-up) for equipment under 25 tons where the six tune-up service measures are completed by professional air conditioning technicians. Tuned air conditioners are then performance tested under protocol conditions to ensure the AC system is under significant load and at steady-state conditions prior to recording measurements. Compliance with these M&V protocols ensures reliable performance measurements from which to estimate the energy savings impacts from the combined effects of all six tune-up service measures.

Measure Description

AC tune-ups must be professionally completed by qualified air conditioning service technicians using measurement tools and equipment. This protocol covers assumptions made for baseline equipment efficiencies based on previous M&V tune-ups in Texas from 2011-2014. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating AC tune-up unit.

Following completion of the six service measures, the M&V methodology for tune-ups require in-field measurement and recording of AC performance parameters under protocol conditions to record *in situ*, post tune-up, performance to calculate estimated energy impacts.

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

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

Applicable equipment types include:

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

Eligibility Criteria

This measure only applies to existing air conditioning equipment, which includes service, to split and packaged air conditioner and heat pump systems under 300,000 Btu/hour (25 tons). For an AC tune-up to be eligible to use the deemed efficiency loss factors and savings approach, the AC tune-up must include completion of the six tune-up service measures and the following conditions must be met:

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

Baseline Condition

The baseline efficiency conditions are calculated (see Equation 7) based on the stipulated efficiency loss (see Table 2-1).

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 1

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

Equation 2

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

Equation 3

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

Equation 4

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

Equation 5

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

Equation 6

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

Equation 7

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

Equation 8

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

Equation 9

---

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

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

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

Equation 10

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

Equation 11

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

Equation 12

$$Specific\ Heat\ of\ Moist\ Air, [C_p] = -2.0921943x10^{-14} \times t_{db}^4 + 2.5588383x10^{-11} \times t_{db}^3 + \ldots$$

$$\ldots + 1.2900877x10^{-8} \times t_{db}^2 + 5.8045267x10^{-6} \times t_{db} + 0.23955919$$

Equation 13

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

Equation 14

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

Equation 15

The Saturation Over Liquid Water equation is:

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

Equation 16

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

Equation 17

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

Equation 18

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

Equation 19

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

Equation 20

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

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

Equation 21

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

Equation 22

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

Equation 23

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

Equation 24

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

Equation 25

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

Equation 26

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

Equation 27

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

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

Equation 28

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

Equation 29

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

Equation 30

Where:

Cap_{Rated}	=	*Rated nominal equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh*
$Cap_{TO,C}$	=	*Measured cooling capacity after tune-up [Btuh]; 1 ton = 12,000 Btuh*
$\eta_{pre,C}$	=	*Cooling efficiency of existing equipment before tune-up [Btuh/W]*
$\eta_{post,C}$	=	*Cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI standard conditions [Btuh/W]*
$\eta_{TO,C}$	=	*Cooling efficiency of existing equipment measured after tune-up [Btuh/W]*
$\eta_{pre,H}$	=	*Heating efficiency of existing equipment before tune-up [HSPF]*
$\eta_{post,H}$	=	*Heating efficiency of existing equipment after tune-up and adjusted to AHRI standard conditions [Btuh/W]. For this protocol $\eta_{post,H}$ is a mathematical estimate based on the proxy for cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI standard conditions (i.e. $\eta_{post,C}$).*

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

$EFLH_{C/H}$	=	*Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Residential Volume 2 Table 2-30, Equation 46 and Table 2-33); Nonresidential Volume 3 Table 2-16 through Table 2-20)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Equations 48 and 49); Nonresidential Volume 3 Tables 2-16 through Table 2-20)*
Volts	=	*Measured voltage (Volts) on single-phase electric power leads to AC components*
Amps	=	*Measured current flow (Amps) on single-phase electric power leads to AC components*

PF	=	*Power factor stipulated based on motor type (see Table 2-2)*
V_1, V_2, V_3	=	*Measured voltage, line to line on each of the three electric power leads (V_1, V_2, V_3) to AC components for 3-phase loads*
A_1, A_2, A_3	=	*Measured current flow (Amps) on each line (A_1, A_2, A_3) of the three power leads to AC components for 3-phase loads*
efficiency loss	=	*Efficiency loss factor (see Table 2-1)*
P	=	*Measured total pressure of moist air [inches Mercury]*
P_{ws}	=	*Saturation pressure over liquid water [psia]*
P_{atm}	=	*Atmospheric pressure [psia]*
v	=	*Specific volume of air [cu.ft./lb]*
Ln.	=	*Natural Logarithm*
e	=	*Natural Log constant (2.7182818284590452353602874713527)*
Z	=	*Elevation-Altitude [feet]*
T	=	*Absolute temperature, Rankine scale* [$°R = °F + 459.67$]
t_{db}	=	*Measured dry bulb temperature [ºF]*
t_{wb}	=	*Measured wet bulb temperature [ºF]*
$Wet\ Bulb_{Return\ Air}$	=	*Wet-bulb temperature of return air (load) to AC evaporator [°F]*
$Wet\ Bulb_{Supply\ Air}$	=	*Wet-bulb temperature of cooled supply air to indoor space [°F]*
$Dry\ Bulb_{Outdoor}$	=	*Dry-bulb temperature of outdoor air at time of tune-up [°F]*
$h_{Return\ Air}$	=	*Measured enthalpy of return air (load) to AC evaporator [Btu/lb]*
$h_{Suppy\ Air}$	=	*Measured enthalpy of cooled supply air to indoor space [Btu/lb]*
Mass Flow Rate	=	*Measured heat carrying capacity of moist return air [lb/hr.]*
CFM	=	*AC supply/return air flow [cu.ft./min.] (Method 1 see Table 2-3)*
Length	=	*Measured length of duct grill long side [inches] (Method 2)*
Width	=	*Measure width of duct grill short side [inches) (Method 2)*
Air Speed	=	*Measured air velocity at duct grille [feet per second] (Method 2)*

95ºF	=	*95 degrees Fahrenheit is the outdoor dry bulb temperature at AHRI test conditions*
10ºF	=	*10 degrees Fahrenheit is the typical wet bulb temperature change across an evaporator coil at AHRI conditions*

Deemed Energy and Demand Savings Tables

Deemed 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 stipulated *efficiency loss* value for that tune-up. The deemed efficiency loss factor to be used is provided in Table 2-1 below and is dependent on whether a refrigerant charge adjustment was made to the air conditioning unit as part of the tune-up. Tune-ups that do not follow all measure protocols are not eligible to use the deemed efficiency loss factors. In these cases, pre tune-up measurements must be taken to determine the unit's efficiency loss and provided to the EM&V team.

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

Refrigerant Charge Adjusted	Efficiency Loss Factor[4]
No	0.110
Yes	0.149

Deemed Power Factors

Deemed power factors are presented by motor type for packaged and split system AC and heat pump units in Table 2-2.

Table 2-2: Deemed 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

[4] Values for Texas derived by CLEAResult using 2011-2015 program year data.

Deemed Energy and Demand

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

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

Cooling Load Calculation

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

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

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

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

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

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

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

Saturation Pressure Over Liquid Water Constants[6]	
$C_8 = -1.0440397\text{ E}+04$	$C_{11} = 1.2890360\text{ E}-05$
$C_9 = -1.1294650\text{ E}+01$	$C_{12} = -2.4780681\text{ E}-09$
$C_{10} = -2.7022355\text{ E}-02$	$C_{13} = 6.5459673\text{ E}+00$

Metering Plan

Equipment Required

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

[5] EER and Capacity AHRI adjustment factors and algorithms initially developed by Cadmus for Tune-Up programs in Texas.

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

Table 2-6 for reference.

Table 2-6: AC Tune-Up Toolkit Components

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

Metering Schedule

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

Equipment Accuracy

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

Table 2-7: Measurement Resolution and Accuracy

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

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

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable

Measure Life and Lifetime Savings

The estimated useful life (EUL) of residential and commercial AC tune-ups is 5 years.[7]

Program Tracking Data and Evaluation Requirements

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

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

[7] 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.

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. Items covered by this petition and applicable to the tune-up measure include the following:
- Updated demand and energy coefficients for all commercial HVAC systems.
- PUCT Docket 41070 – Provides energy and demand savings coefficients for an additional climate zone, El Paso, TX. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/77.

Document Revision History

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

TRM Version	Date	Description of Change
v3.0	4/10/2015	TRM v3.0 origin
v3.1	11/05/2015	TRM v3.1 update. Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Revised efficiency loss factors based on 2015 results. Added VFD motor types.

2.1.2 Ground Source Heat Pump Measure Overview

TRM Measure ID: NR-HV-GH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET)

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V and Whole Facility Measurement

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

Measure Description

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

Applicable GSHP efficient measure types include:

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

High-efficiency conditions for GSHP equipment must meet applicable standards. AHRI energy ratings for EER and COP by manufacturer model numbers are established following required test protocols and parameters, and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 2-9 and Table 2-10.

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

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

Table 2-9: Minimum Efficiency Levels for Commercial Package GSHPs[8]

System Type	Capacity (Btuh)	Cooling Mode EER	Heating Mode COP
Small Commercial Packaged Heat Pump Equipment (Water cooled and Water source)	< 17,000	11.2	4.2
	≥ 17,000 and < 65,000	12.0	4.2
	≥ 65,000 and < 135,000	11.9	4.2
Small Commercial Packaged Air-Conditioning and Heating Equipment (Water Source)	≥ 65,000 and < 135,000	11.9	4.2
Large Commercial Packaged Water Source Heat Pumps	≥135,000 and < 240,000	12.3	3.2
Very Large Commercial Packaged Water Source Heat Pumps	≥240,000 and < 760,000	12.2	3.2
Variable Refrigerant Flow Multi-Split Water Source Heat Pumps	< 17,000 no heat recovery	12.0	4.2
	< 17,000 with heat recovery	11.8	4.2
	≥ 17,000 and < 65,000	12.0	4.2
	≥ 65,000 and < 135,000	12.0	4.2
	≥ 135,000 and < 760,000 no heat recovery	10.0	3.9
	≥ 135,000 and < 760,000 with heat recovery	9.8	3.9

8 https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/77

Table 2-10: Minimum Efficiency Levels for Commercial Single Stage GSHPs[9]

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

Energy and Demand Savings Methodology

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

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

M&V Plan and M&V Report

Preparation of an M&V plan and ultimately an M&V report is a required part of the savings determination. Advanced planning ensures that all data collection and information necessary for savings determination will be available after implementation of the measure(s). The project's M&V plan and M&V report provide a record of the data collected during project development

[9] Values from ASHRAE 90.1-2013.

and implementation. These documents may also serve multiple purposes throughout a project including recording critical assumptions and in case conditions change. Documentation should be complete, readily available, clearly organized and easy to understand.

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

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

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

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

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

Equation 31

Where:

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

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

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

Equation 32

Where:

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

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

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

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

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

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

Equation 33

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

Equation 34

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

Equation 35

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

Equation 36

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 37

Where:

$Cap_{pre,C/H}$	=	*Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [BTU/h];*
$Cap_{post,C/H}$	=	*Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh];*
$\eta_{pre,C}$	=	*Cooling efficiency of existing equipment [Btu/W](i.e., EER_{pre})*
$\eta_{post,C}$	=	*Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post}) – (Must exceed baseline efficiency standards in Table 1-1) [Btu/W]*
$\eta_{pre,H}$	=	*Heating efficiency of existing equipment [COP]*
$\eta_{post,H}$	=	*Rated heating efficiency of the newly installed equipment – (Must exceed baseline efficiency standards in Table 1-1) [COP]*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Nonresidential Volume 3 Table 2-16 through Table 2-20)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Nonresidential Volume 3 Tables 2-16 through Table 2-20)*
$HSPF_{pre,H}$	=	*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: There are no deemed savings for this measure.

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779 – Provides EUL for HVAC equipment.
- PUCT Docket 40885 – Provides a petition to revise deemed savings values for Commercial HVAC replacement measures.
- PUCT Docket 41070 – Provides energy and demand savings coefficients for an additional climate zone, El Paso, TX. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.

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

- Code of Federal Regulations. Title 10. Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/77.

Document Revision History

Table 2-11: M&V Ground Source Heat Pump History

TRM Version	Date	Description of Change
v3.1	11/05/2015	TRM v3.1 origin
v4.0	10/10/2016	No revisions

2.2 M&V: WHOLE HOUSE

2.2.1 New Homes 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 protocol is to estimate savings for new homes through a M&V approach. The development of the new homes 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 new homes program implementers to utilize the tools and systems they have developed. The protocol allows for flexibility in implementation while developing verified energy savings and balancing the risk associated with the uncertainty in the expected savings. The M&V methodology supports the following M&V goals for the new homes programs:

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

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

- REM/Rate
- DOE-2
- EnergyPlus
- Beacon PST

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

New homes built to energy efficient program protocols in Texas should be designed and built to standards well above most other homes on the Texas market. A new, energy efficient Texas home should have undergone a process of inspections, testing, and verification that meet strict program requirements.

Measure Description

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

Eligibility Criteria

This measure does not apply to existing construction. Only new construction homes are eligible.

Baseline Condition[12]

For a list of baseline parameters and key model input values, see

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

Table 2-12. When a new statewide energy code is adopted by the State Energy Conservation Office (SECO), the baseline parameters for residential whole-house measures must be updated to reflect this change. Recognizing that it takes time for new energy codes to be locally adopted and enforced, this M&V methodology requires the new code as baseline in those jurisdictions required to meet or exceed the statewide energy code for the next program year cycle, but not less than twelve months from the energy code effective date. Effective September 1, 2016, Texas is adopting 2015 IECC.[13] From a TRM perspective, the new construction baseline condition will change 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.

Ideally, the relevant energy code will be tracked in the program tracking system. Alternatively, it may be tracked as part of project documentation made available to evaluators upon request. Changes to baseline conditions from

[13] On June 16, 2015, Texas Governor Greg Abbott signed HB 1736 into Texas law. This will move the state's single-family residential code from the 2009 code to the 2015 IECC.

Table 2-12 or changes to the implementation of baseline conditions within an approved modeling package is allowable, and subject to EM&V team approval.

Table 2-12: New Home – Baseline Characteristics

Baseline Home Parameters and Characteristics	Baseline Specification / Value
House Envelope	
Unit Type	Single- Family Detached
Number of Stories Above Grade 1	Same as As-Built
Foundation Type	Same as As-Built
Number of Bedrooms	Same as As-Built
Total Conditioned Floor Area	Same as As-Built
Total Conditioned Volume	Same as As-Built
Wall Height Per Floor	Same as As-Built
Window Distribution (N,S,E,W)	Same as As-Built
Percentage Window to Floor Area	Same as As-Built
Front Door Orientation	Same as As-Built
Aspect Ratio (Length / Width)	Use the same estimated average aspect ratio for both baseline and as-built. However, it is recommended to use actual aspect ratio when actual house footprint dimensions are available.
Roof Solar Absorptivity	Same as As-Built. When as-built data is not available, use 0.75.
Attic Insulation R-Value	See IECC 2009, Table 402.1.1
Cathedral Ceiling Insulation R-Value	R-19
Percentage Cathedral Ceilings	Same as As-Built
Wall Construction	2x4-16 inch on center spacing
Wall Framing Fraction	23%
Wall Insulation	See IECC 2009, Table 402.1.1
Wall Sheathing	Plywood
Wall Insulation Grade	3
Door R-Value	Same as As-Built.
Floor Insulation	See IECC 2009, Table 402.1.1
Rim Joist	Same as wall insulation
Window U Factor	Maximum 0.4
Window SHGC	Maximum 0.3
Air Infiltration	7 ACH50
Mechanical Ventilation	None
Slab Edge Insulation	See IECC 2009, Table 402.1.1
HVAC Equipment	
HVAC Equipment Type	Same as As-Built
Cooling Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Heating Capacity	Same as As-Built or Simulated to Reflect Reference Home Load, not to exceed 20% difference
Cooling Efficiency (SEER)	14
Heating Efficiency (AFUE)	80

Baseline Home Parameters and Characteristics	Baseline Specification / Value
Heating Efficiency (HSPF) – Heat Pump	8.2
Duct Location	100% Attic
Duct R-Value	R-6
Duct Leakage to Outside	8 CFM per 100 ft² of Conditioned Floor Area
Total Duct Leakage	12 CFM per 100 ft² of Conditioned Floor Area or Equivalent Leakage Based on Standard Assumption
Thermostat Type	Same as As-Built
Heating Setpoint	68°F
Cooling Setpoint	78°F
Water Heating System	
DHW Fuel Type	Same as As-Built
DHW Capacity (Gallons)	Same as As-Built for Storage. Assume a 50-gallon storage water heater when as-built water heater is instantaneous.
Energy Factor (EF)	Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[14]) as of April 16, 2015
DHW Temperature	120°F
DHW Pipe Insulation	None
Low Flow Shower Heads	None
Lighting	
High efficacy lamps	20% of permanently installed fixtures
Appliances	
Ceiling fans	70.4 CFM per Watt

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

House Simulation Modeling

Two house simulation models should be developed for each home utilizing an appropriate residential 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

[14] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

demand savings are the difference in annual energy use between the as-built home and the baseline home.

Energy Savings Methodology

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

Summer Demand Savings Methodology

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

Winter Demand Savings Methodology

Winter peak demand savings are estimated utilizing whole-house 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 baseline and as-built homes for all energy end uses for each home. Electricity consumption and savings shall be expressed in kilowatt hours (kWh) to the nearest whole kWh.

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

Deemed Energy and Demand Savings Tables

This section is not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

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

- Relevant Energy Code under which the House was Built–especially in cases where the local jurisdiction has adopted an energy code more stringent than the statewide code.
- House Envelope
    - Dwelling Unit Type
    - House Footprint Dimensions
    - Number of Stories Above Grade 1
    - Foundation Type
    - Number of Bedrooms
    - Total Conditioned Floor Area
    - Total Conditioned Volume
    - Wall Height Per Floor
    - Window Distribution (N,S,E,W)
    - Front Door Orientation
    - Aspect Ratio (Length / Width) – when available
    - Roof Solar Absorptivity – when available
    - Attic Insulation R-Value
    - Cathedral Ceiling Insulation R-Value
    - Percentage Cathedral Ceilings
    - Ceiling Insulation Grade
    - Wall Construction
    - Wall Framing Fraction
    - Wall Insulation (R-Value)
    - Wall Insulation Grade
    - Door Material (Wood, Metal, Vinyl, and whether Solid Core or Hollow) – when available
    - Rim Joist
    - Window U Factor
    - Window SHGC
    - Air Infiltration
    - Mechanical Ventilation
    - Slab Edge Insulation – only for houses located in IECC climate zone 4

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

Files to Submit for EM&V Review

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

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

References and Efficiency Standards

Petitions and Rulings

Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 2-13: M&V New Homes Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Updated baseline conditions due to federal standard updates for HVAC and water heating equipment. Modified program tracking requirements and requirements surrounding the relevant baseline code.
v2.1	1/30/2015	No revisions
v3.0	3/13/2015	No revisions
v3.1	11/05/2015	TRM v3.1 update. 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 new IECC baseline

2.3 M&V: RENEWABLES

2.3.1 Nonresidential Solar Photovoltaic (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: N/A

Program Delivery Type: Prescriptive

Deemed Savings Type: Simulation Software (kWh), Deemed Values (kW)

Savings Methodology: Model-Calculator (PVWatts®)

Measure Description

This section summarizes the savings calculations of the Solar Photovoltaic Standard Offer, Market Transformation, and Pilot programs. These programs are offered by the Texas utilities, with the primary objective to achieve cost-effective energy savings and peak demand savings. Participation in the Solar Photovoltaic program involves the installation of a solar photovoltaic system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator15 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 and/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.

[15] See http://pvwatts.nrel.gov/ last accessed January 20, 2016.

Energy and Demand Savings Methodology

All 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 (currently TMY2) offered by PVWatts®.[16] Demand savings utilize deemed savings lookup tables with values derived from PVWatts® using TMY3 weather data sources applicable to defined weather zones; an Alternative Method is also available for commercial systems.

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 ZIP code: Use the 5-digit ZIP code of the installation address.
- Weather data file: Accept the default (currently TMY2) weather data source offered by PVWatts®.
- DC System Size (kW): Input the sum of the DC (direct current) power rating of all photovoltaic modules in the array at standard test conditions (STC) in kilowatts DC.
  - For AC modules, refer to the module specification sheet to obtain the DC(STC) power rating.
- Module Type: Standard, Premium, or Thin Film. Use the nominal module efficiency, cell material, and temperature coefficient from the module data sheet to choose the module type, or accept the default provided by PVWatts®.

Table 2-14: Module Type Options

Type	Approximate Efficiency	Module Cover	Temperature Coefficient of Power
Standard (crystalline Silicon)	15%	Glass	-0.47 %/°C
Premium (crystalline Silicon)	19%	Anti-reflective	-0.35 %/°C
Thin film	10%	Glass	-0.20 %/°C

- Array Type: Fixed (open rack), Fixed (roof mount), 1-Axis Tracking, 1-Axis Backtracking, 2-Axis Tracking.
- Tilt (deg): Enter the angle from horizontal of the photovoltaic modules in the array.
- Azimuth (deg): Enter the angle clockwise from true north describing the direction that the array faces.
- All other input variables: Accept the PVWatts® default values.

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[16] Applying the PVWatts® default weather input file simplifies estimating and promotes consistency between customers/contractors, program implementers, and evaluators. If or when NREL updates the PVWatts® default to TMY3, the TRM method will follow in the subsequent year, but during the year of the change will continue to rely on TMY2 for consistency. NREL has stated that TMY2 will be "the standard for the foreseeable future." See http://pvwatts.nrel.gov/pvwatts.php, accessed January 25, 2016.

Annual Energy Savings (kWh)

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

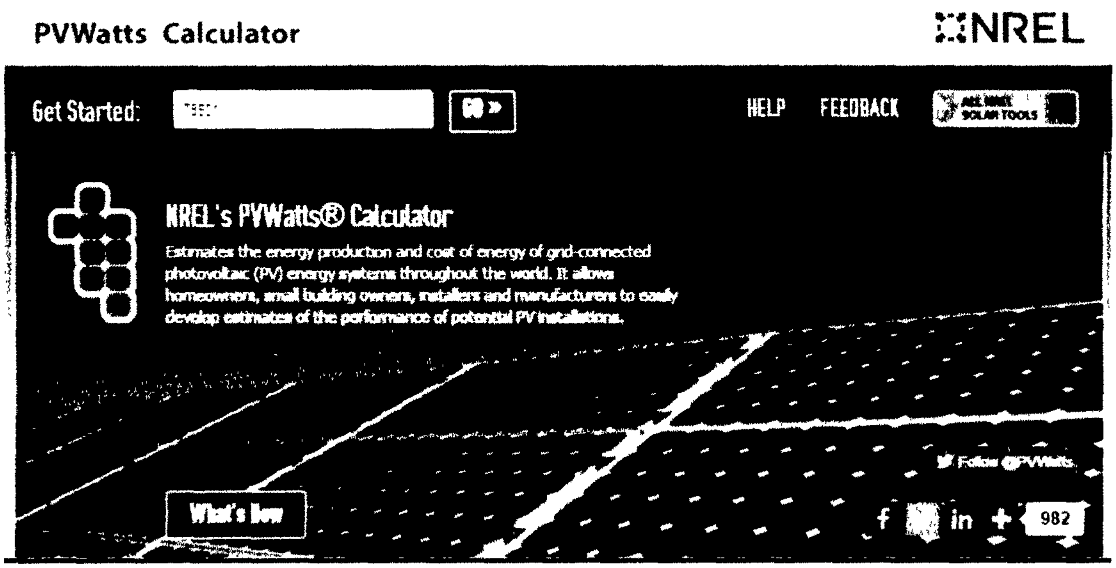
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain the total annual energy savings.

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

Example: A commercial customer in McAllen (zip code 78501) installs a 50 kWdc 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. The user enters the zip code of the proposed PV system in PVWatts® calculator and presses "Go". See Figure 2-1.

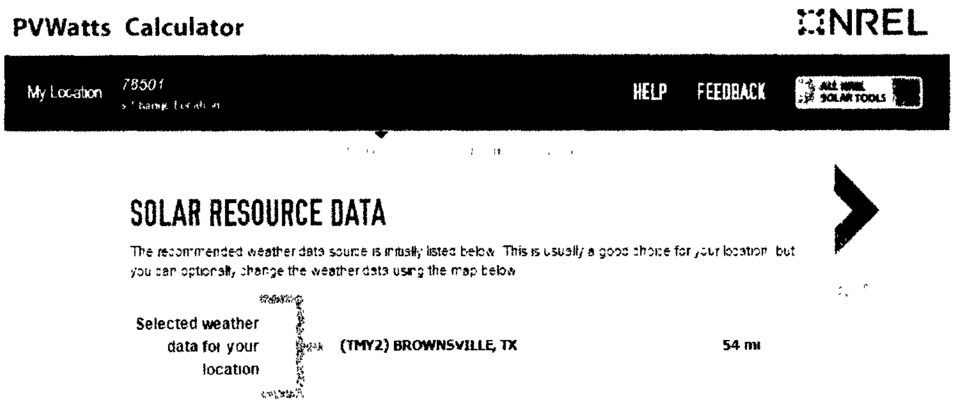
Figure 2-1. PVWatts® Input Screen for Step 1



Step 2. PVWatts® automatically identifies the nearest weather data source (currently TMY2). The user does not change the default weather data source and presses "Go to system info". See

Figure 2-2.

Figure 2-2. PVWatts® Input Screen for Step 2

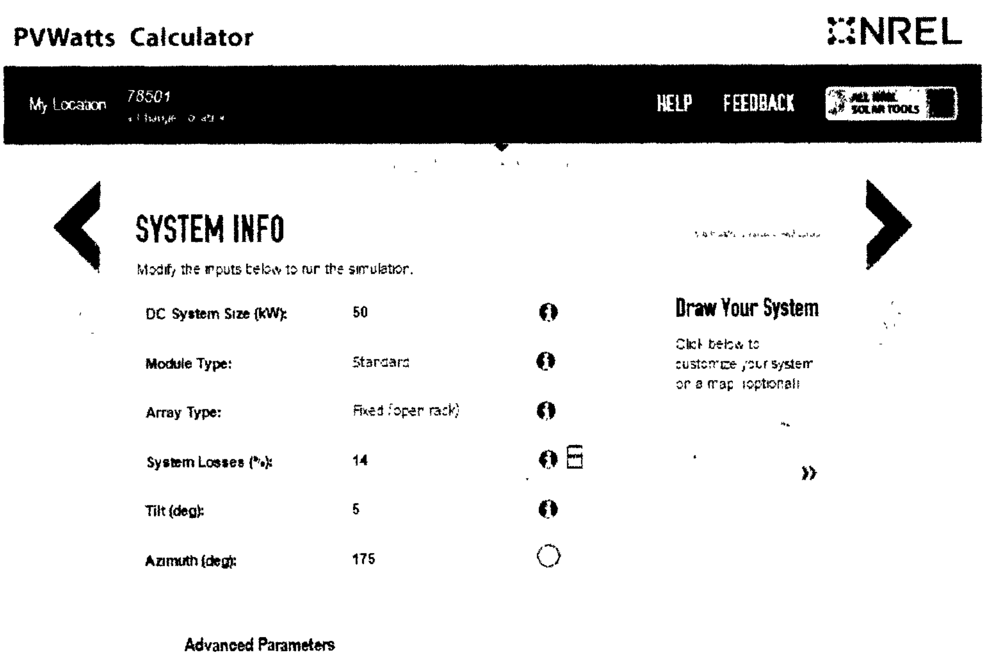


Step 3. The user enters System Info as follows:

- 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 2-3.

Figure 2-3. PVWatts® Input Screen for Step 3



Step 4. PVWatts® returns an estimate of annual energy production (kWh), in this case 68,022 kWh. See Figure 2-4.

Figure 2-4. PVWatts® Output Screen for Step 4

PVWatts® Calculator NREL

My Location 78501 » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA SYSTEM INFO RESULTS

Go to system info

RESULTS Print Results

68,022 kWh per Year *

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Energy Value ($)
January	3.21	3,975	N/A
February	3.80	4,214	N/A
March	4.73	5,758	N/A
April	5.14	5,944	N/A
May	5.96	7,063	N/A
June	6.31	7,145	N/A
July	6.49	7,533	N/A
August	5.91	6,846	N/A
September	5.19	5,880	N/A
October	5.01	5,902	N/A
November	3.67	4,289	N/A
December	2.81	3,472	N/A
Annual	4.85	68,021	0

Further down this output page PVWatts® returns a summary of model inputs (Figure 2-5).

Figure 2-5. PVWatts® Output Screen for Step 4 (continued)

Location and Station Identification	
Requested Location	78501
Weather Data Source	(TMY2) BROWNSVILLE, TX 54 mi
Latitude	25.9° N
Longitude	97.43° W
PV System Specifications (Residential)	
DC System Size	50 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	5°
Array Azimuth	175°
System Losses	14%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1
Initial Economic Comparison	
Average Cost of Electricity Purchased from Utility	No utility data available
Initial Cost	3.30 $/Wdc
Cost of Electricity Generated by System	not determined

The coordinates (latitude and longitude) of the proposed system are also presented. These are useful in determining 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 suffices as documentation of the annual energy savings estimate.

Summer Demand Savings Methodology

Deemed summer demand savings are determined using the weather zone map (Figure 2-6) and summer demand savings lookup values (Table 2-15) 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 38

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

Commercial systems may instead be modeled using the Alternative Method described below.

Winter Demand Savings Methodology

Deemed winter demand savings are determined using the weather zone map (Figure 2-6) and winter demand savings lookup values tables (Table 2-16. Winter Demand Savings Lookup Values) provided below. Deemed winter demand savings is the product of the system's DC system size and the appropriate lookup table value.

Deemed Winter Demand Savings

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

Equation 39

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.

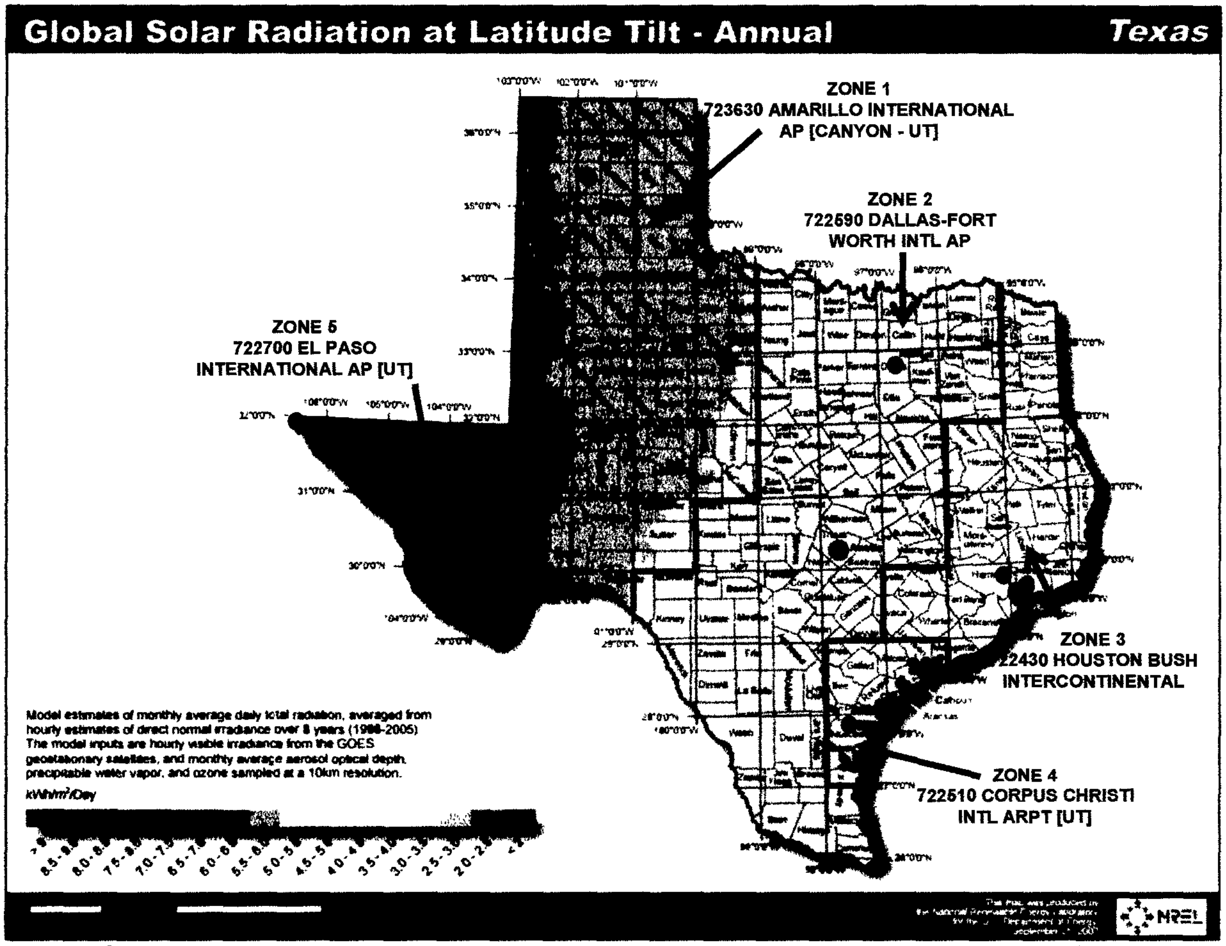
Deemed Energy Savings Tables

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 2-6, 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 2-6. Weather Zone Determination for Solar PV Systems



Source: http://apps1.eere.energy.gov/states/images/maps/map_large_pv_TX.jpg, accessed January 20, 2016.

Deemed Summer and Winter Demand Savings – Lookup Value Tables

The tables below provide lookup values used for calculating deemed summer and winter demand savings based on the weather zone, tilt and azimuth. Table 2-15 presents lookup values for determining deemed summer demand savings, and Table 2-16 presents lookup values for determining deemed 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).

Table 2-15 Summer Demand Savings Lookup Values

Zone 1 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 2 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 3 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 4 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 5 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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 2-16. Winter Demand Savings Lookup Values

Zone 1 Winter Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 2 Winter Demand Savings Factors

90		Azimuth (deg, 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%

Zone 3 Winter Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 4 Winter Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 5 Winter Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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 in McAllen (zip code 78501) installs a 50 kWdc fixed array comprised of standard crystalline Silicon modules on their rooftop with a tilt of 5 degrees and an azimuth of 175 degrees.

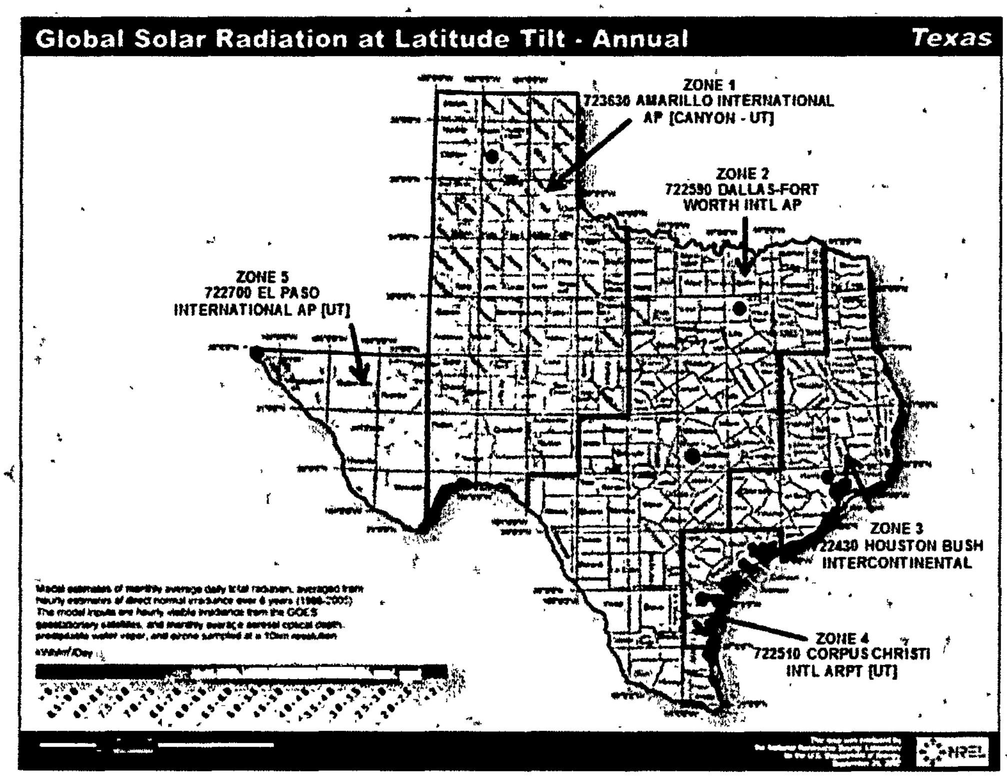
Step 1. Determine the appropriate weather zone. Geographic coordinates for this system (25.9°N, 97.43°W) were derived when determining the annual energy savings (kWh). See Figure 2-7.

Table 2-17. PVWatts® Output Showing Geographic Coordinates

Location and Station Identification		
Requested Location	78501	
Weather Data Source	(TMY2) BROWNSVILLE, TX	54 mi
Latitude	25.9° N	
Longitude	97.43° W	

From the weather zone map, this location is in Zone 2. See Figure 2-7.

Figure 2-7. 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%, and the winter lookup value is 3%.

Applying Equation 38,

*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 39,

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

*Deemed summer demand = 50.000 kW * 3%*

*Deemed summer demand = 50.000 kW * 0.03*

Deemed summer demand = 1.500 kW

Summer and Winter Demand Savings – Alternative Method

An alternative method for estimating summer and winter demand savings is also available. To utilize the alternative method, follow these steps:

Step 1. Determine the applicable weather zone of the proposed system using Figure 2-6, above.

Step 2. Use PVWatts® to model the proposed system as described in the Annual Energy Savings (kWh) section above. However, instead of using the zip code/default weather file, select the TMY3 reference location and weather file associated with the applicable weather zone of the proposed system. (For example, a system in McAllen, weather zone 1, would be modeled based on the DALLAS-FORT WORTH INTL AP, TX TMY3 weather file. Leave all other inputs the same.

Step 3. On the PVWatts Results page, select Download Results: Hourly. Save the **pvwatts_hourly.csv** output file to your computer and open it using Microsoft Excel.

Step 4. Open the provided calculation tool **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field) on your computer, and select the Alt. Method Inputs tab.

Step 5. From the PVWatts hourly output file, highlight and copy the output data (A1:K8780). Paste this data to cell M1 on the Alt. Method Inputs tab in **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field).

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

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 photovoltaic system is established at 30.0 years. This value is consistent with engineering estimates based on manufacturers' warranties and historical data.

Additional Calculators and Tools

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

Program Tracking Data & Evaluation Requirements

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

- Project location (city) and zip code
- Module type: Standard, premium, or thin film
- Array Type: Fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking, etc.
- Tilt, azimuth and DC system size rating for each array
- Date of PVWatts® run, and PVWatts® report (retained with project documentation)

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: http://pvwatts.nrel.gov/pvwatts.php.Document Revision History

Document Revision History

Table 2-18: Nonresidential Solar Photovoltaic History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v3.1	11/05/2015	Updated to reflect EPE's 2016 program, and revised Maximum Incentivized Size for EPE from 50 to 10 kW.
v4.0	10/10/2016	Removed deemed savings option for energy. Provided new method for calculating summer and winter demand savings and provided deemed summer and winter demand savings lookup tables.

2.3.2 Residential Solar Photovoltaic (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

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 the savings calculations of the Solar Photovoltaic Standard Offer, Market Transformation, and Pilot programs. The primary objective of these programs is to achieve cost-effective reduction in energy savings and peak demand savings. Participation in the Solar Photovoltaic program involves the installation of a solar photovoltaic system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator[17] 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 and/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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[17] See http://pvwatts.nrel.gov/, accessed January 20, 2016.

Energy and Demand Savings Methodology

All 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 (currently TMY2) offered by PVWatts®.[18] Demand savings utilize deemed savings lookup tables with values derived from PVWatts® using reference TMY3 weather data sources applicable to defined weather zones; an Alternative Method is available for residential systems utilizing trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth.

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 ZIP code: Use the 5-digit ZIP code of the installation address.
- Weather data file: Accept the default (currently TMY2) weather data source offered by PVWatts®.
- DC System Size (kW): Input the sum of the DC (direct current) power rating of all photovoltaic modules in the array at standard test conditions (STC) in kilowatts DC.
    - For AC modules, refer to the module specification sheet to obtain the DC(STC) power rating.
- Module Type: Standard, Premium, or Thin Film. Use the nominal module efficiency, cell material, and temperature coefficient from the module data sheet to choose the module type, or accept the default provided by PVWatts®.

Table 2-19. Module Type Options

Type	Approximate Efficiency	Module Cover	Temperature Coefficient of Power
Standard (crystalline Silicon)	15%	Glass	-0.47 %/°C
Premium (crystalline Silicon)	19%	Anti-reflective	-0.35 %/°C
Thin film	10%	Glass	-0.20 %/°C

- Array Type: Fixed (open rack), Fixed (roof mount), 1-Axis Tracking, 1-Axis Backtracking, 2-Axis Tracking.
- Tilt (deg): Enter the angle from horizontal of the photovoltaic modules in the array.
- Azimuth (deg): Enter the angle clockwise from true north describing the direction that the array faces.
- All other input variables: Accept the PVWatts® default values.

[18] Applying the PVWatts® default weather input file simplifies estimating and promotes consistency between customers/contractors, program implementers, and evaluators. If or when NREL updates the PVWatts® default to TMY3, the TRM method will follow in the subsequent year, but during the year of the change will continue to rely on TMY2 for consistency. NREL has stated that TMY2 will be "the standard for the foreseeable future." See http://pvwatts.nrel.gov/pvwatts.php, accessed January 25, 2016.

Annual Energy Savings (kWh)

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

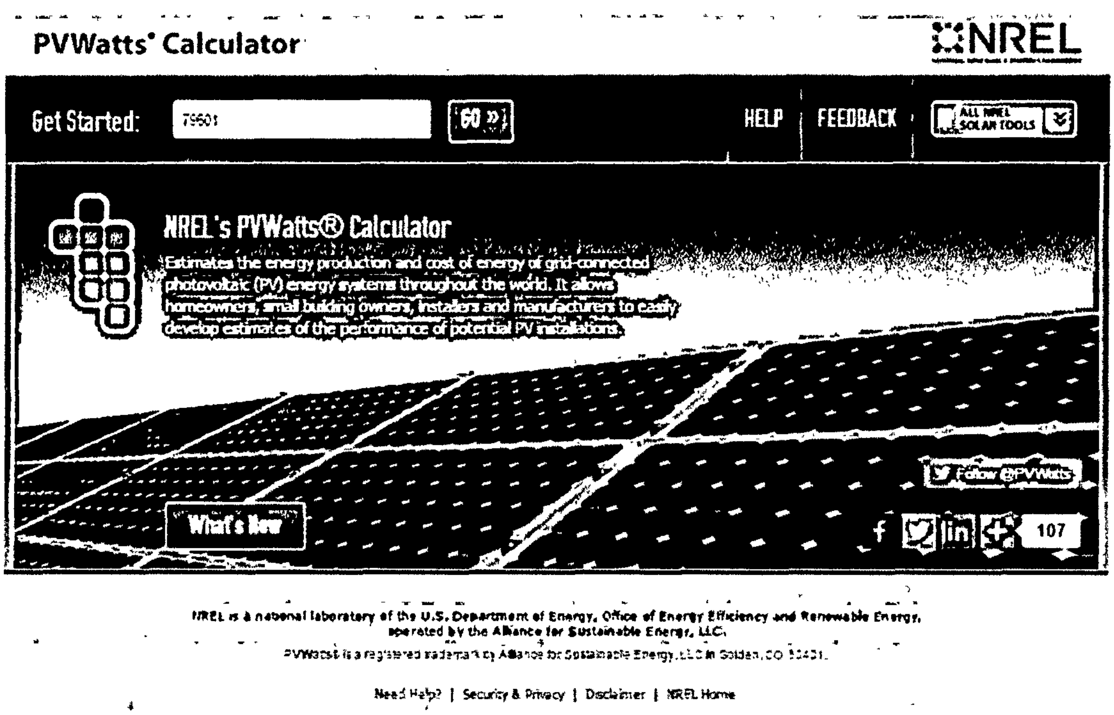
For systems with multiple arrays, users should derive annual energy savings for each array separately, and sum them to obtain the total annual energy savings.

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 suffices as documentation of the annual energy savings estimate.

Example: A residential customer in Abilene (zip code 79601) installs a 5 kWdc fixed array comprised of standard crystalline Silicon modules on their rooftop with a tilt of 15 degrees and an azimuth of 200 degrees.

Step 1. The user enters the zip code of the proposed PV system in PVWatts® calculator and presses "Go". See Figure 2-8.

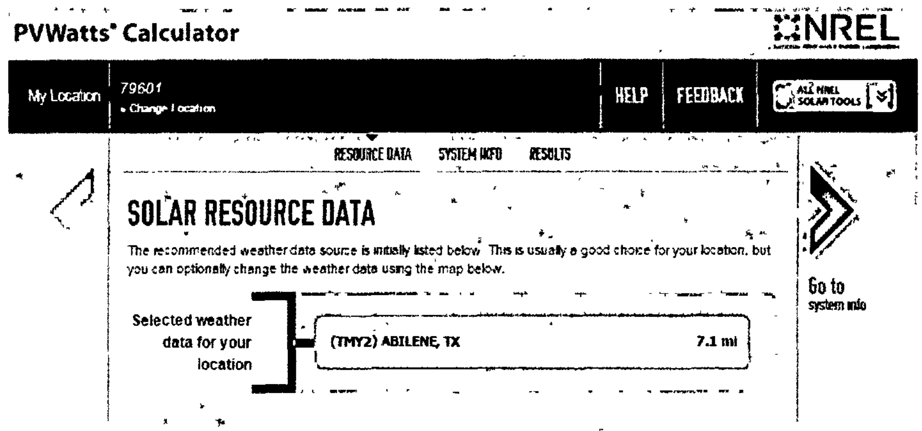
Figure 2-8. PVWatts® Input Screen for Step 1



Step 2. PVWatts® automatically identifies the nearest weather data source (currently TMY2). The user does not change the default weather data source and presses "Go to system info". See

Figure 2-9.

Figure 2-9. PVWatts® Input Screen for Step 2

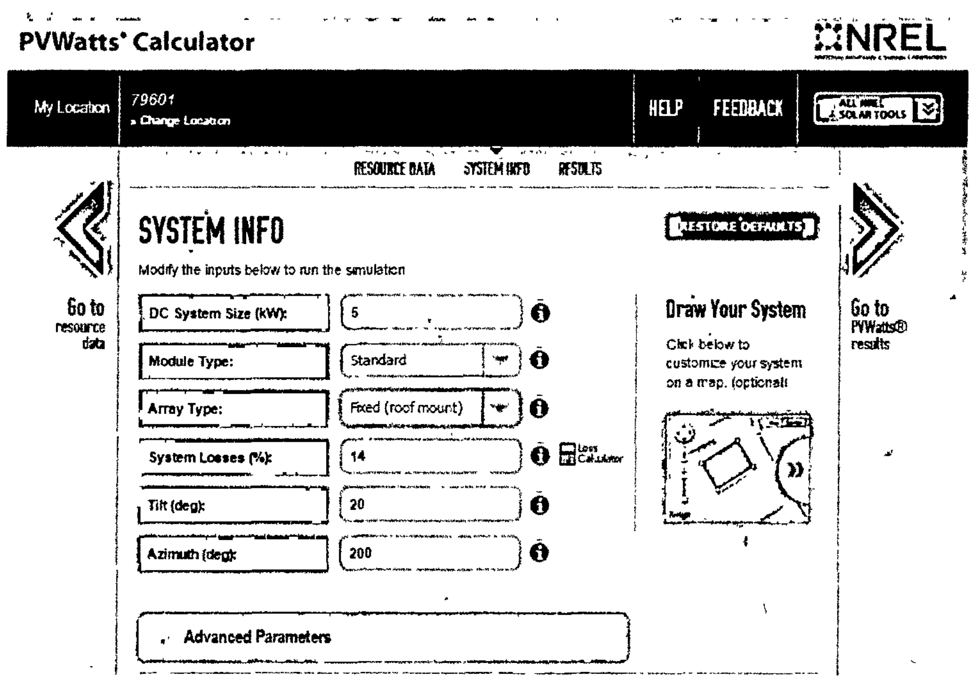


Step 3. The user enters System Info as follows:

- DC System Size (kW): 5.00
- Module Type: Standard
- Array Type: Fixed (roof mount)
- Tilt (deg): 20
- Azimuth (deg): 200

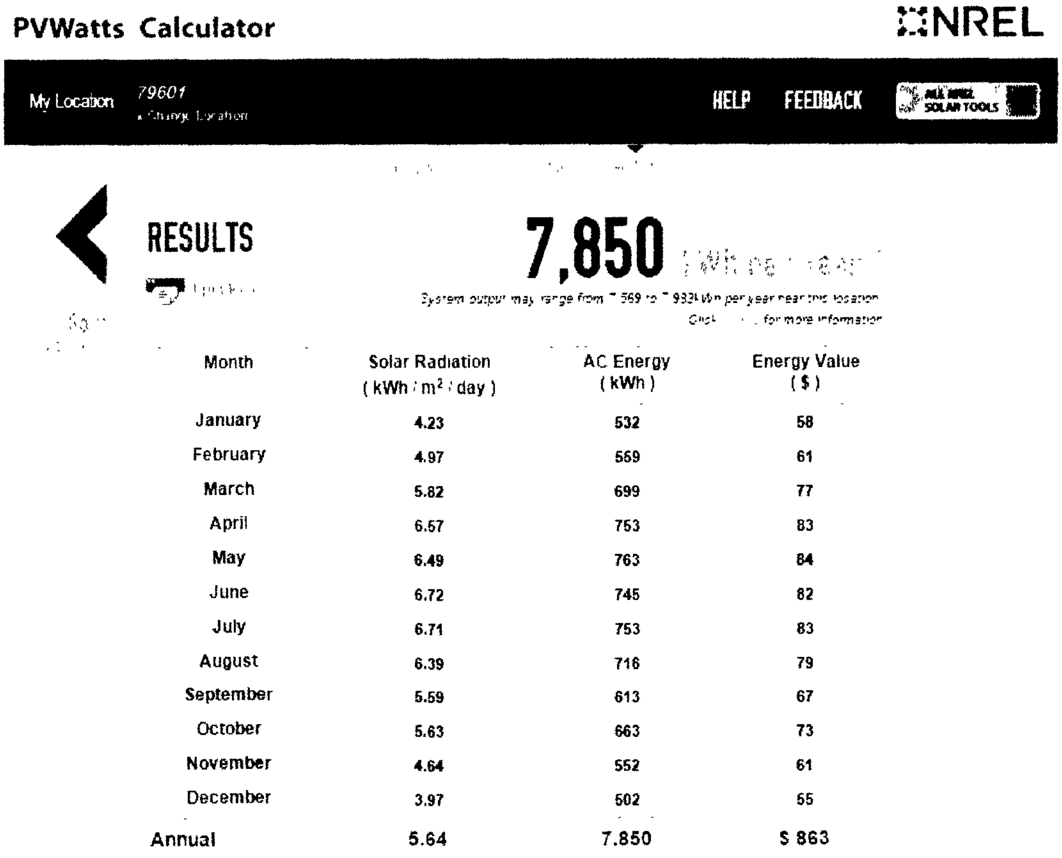
All other details (System Losses, Advanced Parameters, and Initial Economics) are left at default values. Once entered, the user presses "Go to PVWatts® results". See **Figure 2-10**.

Figure 2-10. PVWatts® Input Screen for Step 3



Step 4. PVWatts® returns an estimate of annual energy production (kWh), in this case 7,850 kWh. See Figure 2-11.

Figure 2-11. PVWatts® Output Screen for Step 4


PVWatts Calculator

NREL

My Location 79601

HELP FEEDBACK

RESULTS

7,850

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Energy Value ($)
January	4.23	532	58
February	4.97	569	61
March	5.82	699	77
April	6.57	753	83
May	6.49	763	84
June	6.72	745	82
July	6.71	753	83
August	6.39	716	79
September	5.59	613	67
October	5.63	663	73
November	4.64	552	61
December	3.97	502	55
Annual	5.64	7,850	$ 863

Further down this output page PVWatts® returns a summary of model inputs (Figure 2-12).

Figure 2-12. PVWatts® Output Screen for Step 4 (continued)

Location and Station Identification		
Requested Location	79601	
Weather Data Source	(TMY2) ABILENE, TX	7.1 mi
Latitude	32.43° N	
Longitude	99.68° 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%	
Inverter Efficiency	96%	
DC to AC Size Ratio	1.1	
Initial Economic Comparison		
Average Cost of Electricity Purchased from Utility	0.11 $/kWh	
Initial Cost	3.30 $/Wdc	
Cost of Electricity Generated by System	0.17 $/kWh	

The coordinates (latitude and longitude) of the proposed system are also presented. These are useful in determining 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 suffices as documentation of the annual energy savings estimate.

Summer Demand Savings Methodology

Deemed summer demand savings are determined using the weather zone map (Figure 2-13) and summer demand savings lookup values tables (Figure 2-14) 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 40

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

In rare cases, residential systems utilizing trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may utilize the Alternative Method described below.

Winter Demand Savings Methodology

Deemed winter demand savings are determined using the weather zone map (Figure 2-13) and winter demand savings lookup values tables (Figure 2-15) provided below. Deemed winter demand savings is the product of the system's DC system size and the appropriate lookup table value.

Deemed Winter Demand Savings

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

Equation 41

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

In rare cases, residential systems utilizing trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may utilize the Alternative Method described below.

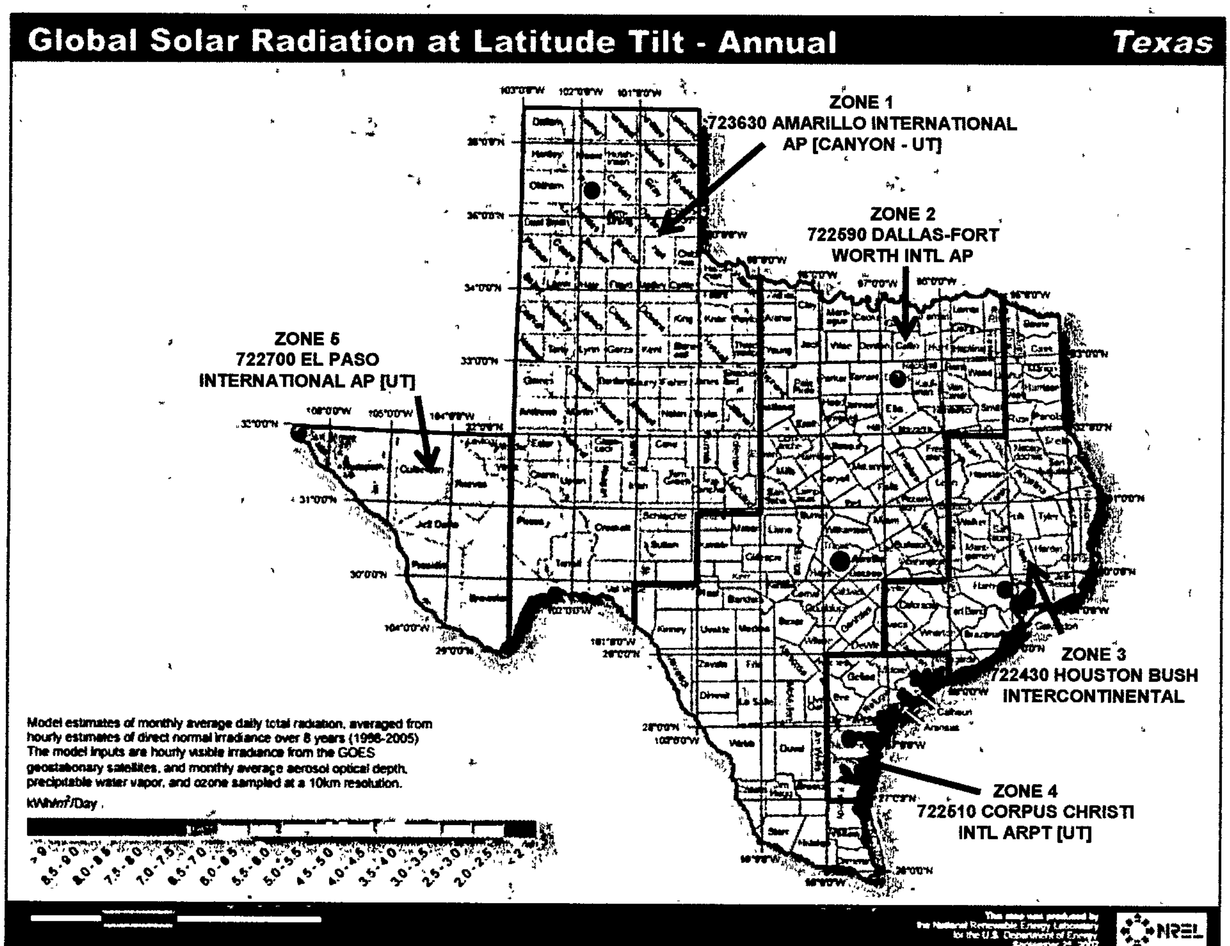
Deemed Energy Savings Tables

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 2-13, 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 2-13. Weather Zone Determination for Solar PV Systems



Source: http://apps1.eere.energy.gov/states/images/maps/map_large_pv_TX.jpg, accessed January 20, 2016.

Deemed Summer and Winter Demand Savings – Lookup Value Tables

The tables below provide lookup values used for calculating deemed summer and winter demand savings based on the weather zone, tilt and azimuth. Figure 2-14 presents lookup values for determining deemed summer demand savings, and Figure 2-15 presents lookup values for determining deemed 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).

Figure 2-14. Summer Demand Savings Lookup Values

Zone 1 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 2 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 3 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 4 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Zone 5 Summer Demand Savings Factors

Tilt (deg)		Azimuth (deg, 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%

Figure 2-15. Winter Demand Savings Lookup Values

Zone 1 Winter Demand Savings Factors						
		Azimuth (deg, center and range)				
Tilt (deg)		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%

Zone 2 Winter Demand Savings Factors						
		Azimuth (deg, center and range)				
90		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%

Zone 3 Winter Demand Savings Factors						
		Azimuth (deg, center and range)				
Tilt (deg)		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%

Zone 4 Winter Demand Savings Factors						
		Azimuth (deg, center and range)				
Tilt (deg)		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%

Zone 5 Winter Demand Savings Factors						
		Azimuth (deg, center and range)				
Tilt (deg)		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 in Abilene (zip code 79601) installs a 5 kWdc fixed array comprised of standard crystalline Silicon modules on their rooftop with a tilt of 15 degrees and an azimuth of 200 degrees.

Step 1. Determine the appropriate weather zone. Geographic coordinates for this system (32.43°N, 99.68°W) were derived when determining the annual energy savings (kWh). See Figure 2-16.

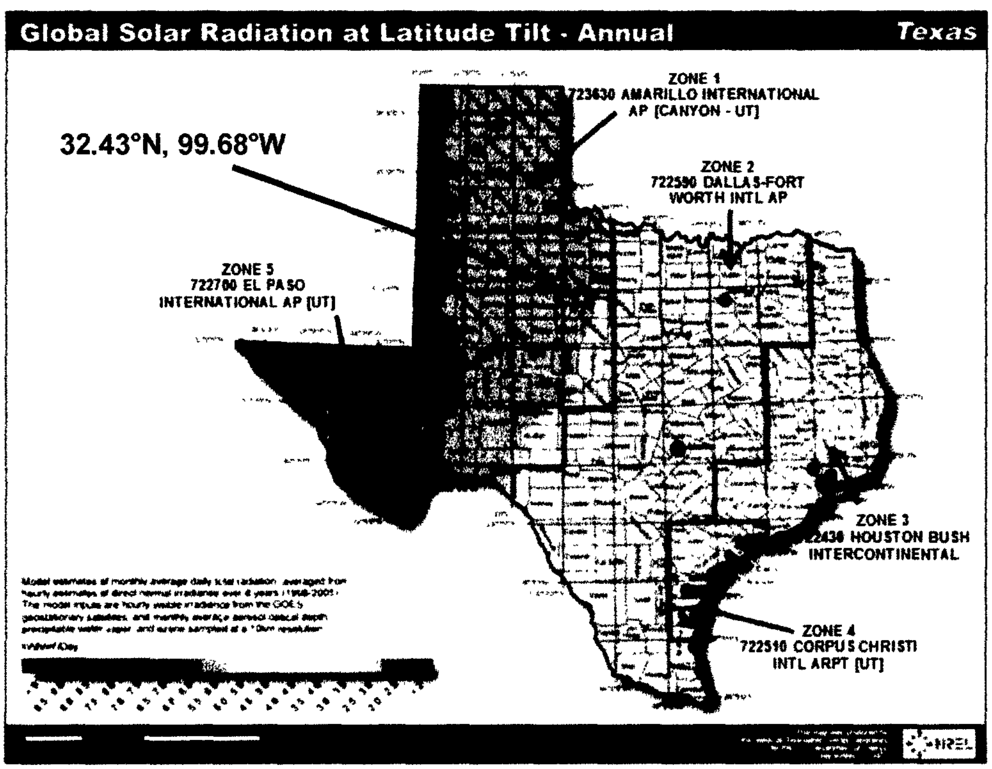
Figure 2-16. PVWatts® output showing geographic coordinates.

Location and Station Identification

Requested Location	79601
Weather Data Source	(TMY2) ABILENE, TX 7.1 mi
Latitude	32.43° N
Longitude	99.68° W

From the weather zone map, this location is in Zone 1. See Figure 2-17.

Figure 2-17. Application of the Weather Zone Map



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

Applying Equation 40,

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

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

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

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

Applying Equation 41,

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

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

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

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

Summer and Winter Demand Savings – Alternative Method

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

Step 1. Determine the applicable weather zone of the proposed system using Figure 2-13, above.

Step 2. Use PVWatts® to model the proposed system as described in the Annual Energy Savings (kWh) section above. However, instead of using the zip code/default weather file, select the TMY3 reference location and weather file associated with the applicable weather zone of the proposed system. (For example, a system in Abilene, weather zone 1, would be modeled based on the AMARILLO INTERNATIONAL AP [CANYON-UT], TX TMY3 weather file. Leave all other inputs the same.

Step 3. On the PVWatts Results page, select Download Results: Hourly. Save the **pvwatts_hourly.csv** output file to your computer and open it using Microsoft Excel.

Step 4. Open the provided calculation tool **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field) on your computer, and select the Alt. Method Inputs tab.

Step 5. From the PVWatts hourly output file, highlight and copy the output data (A1:K8780). Paste this data to cell M1 on the Alt. Method Inputs tab in **TRM 4.0 PV tool YYYYMMDD_locked.xlsx** (in which the version date is indicated by the YYYYMMDD field).

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) of photovoltaic systems is established at 30.0 years. This value is consistent with engineering estimates based on manufacturers' warranties and historical data.

Program Tracking Data & Evaluation Requirements

The following information will be required to be collected.

- Project location (city) and zip code
- Module type: Standard, premium, or thin film
- Array Type: Fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking, etc.
- Tilt, azimuth and DC system size rating for each array
- Date of PVWatts® run, and PVWatts® report (retained with project documentation) for each array
- 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: http://pvwatts.nrel.gov/pvwatts.php.Document Revision History

Table 2-20: Residential Solar Electric (Photovoltaic) Energy Systems Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	TRM v2.0 update. Minor edits to language and structure.
v2.1	01/30/2015	No revisions
v3.0	04/10/2015	No revisions
v4.0	10/10/2016	TRM v4.0 update. Removed deemed savings option for energy. Provided new method for calculating summer and winter demand savings and provided deemed summer and winter demand savings lookup tables.

2.3.3 Solar Shingles Measure Overview

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

Market Sector: Residential and Commercial

Measure Category: Renewables

Applicable Building Types: All

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET), New Construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: Prescribed Simulation Software EM&V

Savings Methodology: Software Modeling Tool and Calculator-SAM

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

Measure Description

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

Eligibility Criteria

Solar shingle systems consisting of connected arrays, sub-arrays and inverter(s).

The installation must meet the following requirements in order 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/or 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

Savings Algorithms and Input Variables

SAM solar shingle installation data, modeling and analysis

SAM can be downloaded from the NREL website.[19]

SAM Data Input

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

1. Create a new solar PV project in SAM.
2. Specify a Solar PV project and select a market segment (e.g. residential/commercial).
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 2-14, according to where in Texas the solar shingles are being installed. The map in Figure 2-18 indicates the delineation of the weather zones, by county.

NOTE: It is critical that the TMY3 files be 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.

[19] 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 2-21: 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]

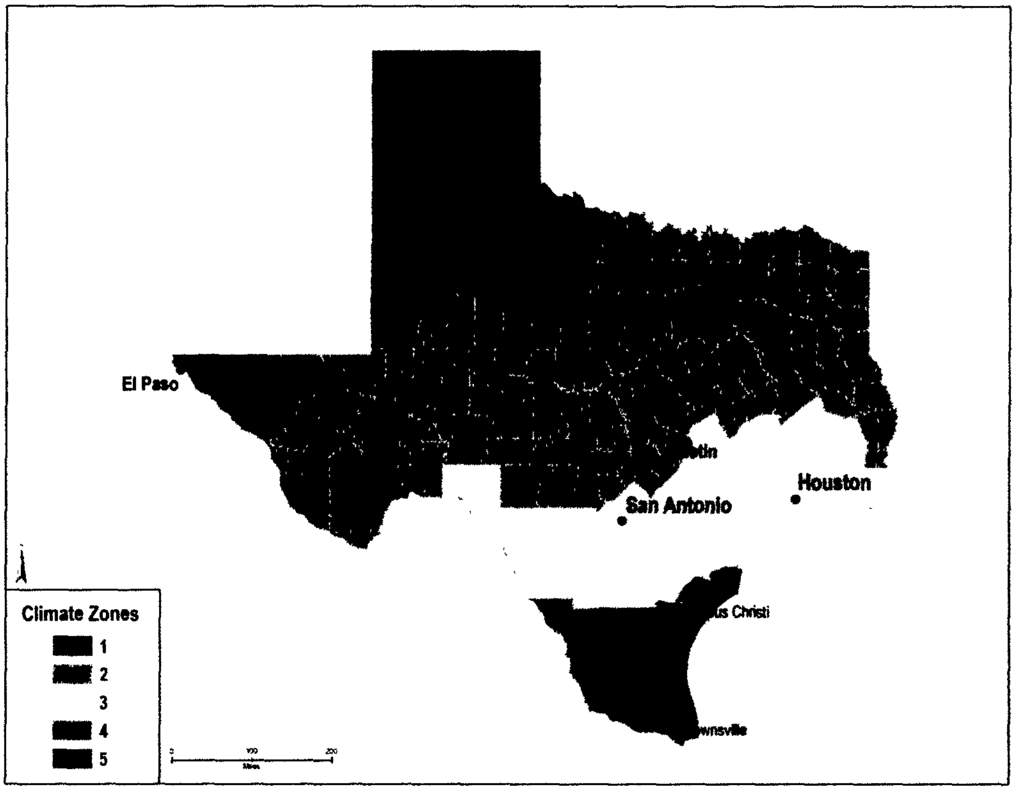


Figure 2-18: Texas Technical Reference Manual Weather Zones

Module. The default action in the Module screen allows the user to select a product for which required performance data has been pre-loaded into the 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, by default, is set to " CEC Performance Model with Module Database" (at the top of this window). Other modeling options provide the flexibility needed 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 the fact that, by their nature, solar shingles are integrated into the buildings on which they are installed.

Inverter. Inverter-specific information must be provided. Similarly, to the functioning of the Module screen, an inverter can be selected from the Inverter CEC Database (default), or, for inverters not in the CEC database, by specifying data from the manufacturer's datasheet (Inverter Datasheet mode) or by specifying inverter efficiency at different loading rates (Inverter Part Load Curve mode), from which the inverter part load curve can be constructed. Any of these methods should be 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 for modeling of up to 4 subarrays. If the system being modeled has only one array, the data for this array are entered in the column for subarray 1, and 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 provided. 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 a large number of output data fields: create an 8760 hourly output file by selecting "Time Series" at the top of the screen (option appears only after clicking "Simulate") and then selecting "Power generated by system (kW)" from the options on the right hand side of the screen. Output data can be sent to either 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 for calculating 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 definition of peak demand incorporated in TRM 3.0 and the associated methods for extracting peak demand savings from models producing 8,760 hourly savings using Typical Meteorological Year (TMY) data. See TRM volume 1 section 4.

Additional Calculators and Tools

Not applicable

Measure Life and Lifetime Savings

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: Retrofit, New Construction
- Building Type
- Climate/Weather Zone
- System Latitude
- System Tilt from horizontal
- System Azimuth

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

- SAM model file (*.zsam format)
- 8760 hourly output file (csv or similar format)
- Calculator with annual energy savings and peak demand savings estimate.

References and Efficiency Standards

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 2-22: M&V Solar Shingles History

TRM Version	Date	Description of Change
v3.0	4/10/2015	TRM v3.0 origin
v3.1	11/05/2015	TRM v3.1 update. Major methodology updates include revising the reference to latest version of SAM software and removal of TMY2 weather data file use. Revised measure details to match format of TRM volumes 2 and 3. This included adding detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	No revisions

2.4 M&V: MISCELLANEOUS

2.4.1 Behavioral Measure Overview

TRM Measure ID: NR-MS-BC

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Operation & Maintenance (O&M)

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V and Whole Facility Measurement

This protocol is used to estimate savings for various behavioral or practice changes that may be implemented on an ongoing (i.e., permanent) basis such that savings remain persistent and reliable long term. The development of the M&V methodology is driven by the desire to create and implement a framework to provide high quality verified savings—keeping within the standards currently applied to commercial energy savings measures—to enable the opportunity to implement measures and report energy savings from a wide variety of energy optimization practices and behaviors.

Measure Description

This measure is not defined, but requires that any behavioral measure develop an M&V plan and report. These documents shall include a complete description of the proposed behavioral changes, how the changes will save energy, and why the behavioral change should be considered as a permanent change on par with high efficiency equipment retrofits. One example is establishing an authorized and enforced facility-wide energy policy with implementation and quality assurance processes.

The projects M&V plan and report shall describe the current case, and proposed new case, that define changes in operations and/or sequence of operations. These documents should fully discuss, describe, and document the logic of the proposed changes and how those changes translate into energy savings impacts.

The measure description should describe how the initial energy savings estimates will be determined to estimate energy and demand savings impacts that will then be verified by measurement and verification analysis following IPMVP criteria.

Eligibility Criteria

This measure applies to implementing behavioral measures that establish processes to ensure persistent energy reductions that are measurable at the facility level.

Baseline Condition

The baseline condition for each behavioral measure included in a plan has two facets: 1) to establish the existing operating parameters (e.g., temperatures, hours of operation, loads, etc.) and existing energy use for each behavior change included in the plan, and; 2) establish the proposed new case operating parameters resulting from each behavior change and present the equations proposed to quantify energy savings impact estimates.

The plan should document the source and accuracy/confidence of the various parameters used in the proposed equations to estimate baseline and new case energy use, for each behavior impact (e.g. if interior lights are to be turned off, there may be two sources of energy savings, one attributable directly to the light fixture energy use, the other attributable to reduced internal heat gain and load on the air conditioning system). The plan shall explain all assumptions employed for both baseline and behavior change cases noting source and applicability—logic reasoning.

High-Efficiency Condition

Demonstrated by conclusive energy savings results of M&V plan following IPMVP protocols.

Energy and Demand Savings Methodology

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

Savings equations, algorithms and input variables should be used as an initial means to estimate energy savings prior to measure implementation. These must adhere to standard engineering practices and accepted energy efficiency engineering methods. Initial savings estimates must identify energy savings calculations, algorithms and all pertinent factors used to calculate the estimated energy impacts of the project. Project M&V plans shall appropriately cite technical sources and resources used to develop initial energy savings estimates. These initial savings estimates, although to be replaced with final whole facility EM&V determined savings, should be included in the final M&V report of savings.

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

A whole facility EM&V methodology presents a plan for determining energy savings due to significant and persistent facility-wide behavioral changes 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 to verify commercial measures. The Whole Facility guidance is found in the latest version of the IPMVP Volume 1 EVO 10000-1:2012.

The Option C methodology should be documented in a M&V report and include detail regarding model development, testing, handling of errors, and the information for validating the 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. Particular procedures to be taken and their respective results should be documented and may include:

- Describe the process taken for how the review of outliers was completed, whether outliers were identified, and how those outliers were addressed in the modeling. Describe how any missing data points or data entry errors were addressed and document what was missing, corrected, or erroneous data were changed from the original data for purposes of the model. Any data that are ultimately removed or changed from the original data set should be annotated with the assignable cause.
- Present the guidelines used to test for the statistical significance of each independent variable and overall model fitment. The results of these statistical tests and results should be presented as part of the presentation of individual model results.

M&V Plan and M&V Report

Preparation of an M&V plan and ultimately an M&V report is a required part of the savings determination. Advanced planning ensures that all data collection and information necessary for savings determination will be available after implementation of the behavioral change(s). The projects M&V plan and M&V report provide a record of the initial energy savings impact estimates, and the data collected during project development and implementation. These documents may also serve multiple purposes throughout a project including recording critical assumptions and conditions, and any changes that may emerge during project implementation. For example, the M&V plan shall describe how major energy drivers will be documented and recorded. The M&V report shall document such findings. Also, other energy savings influences (e.g. equipment retrofits, changes to occupancy) that may have occurred during the baseline and/or reporting periods are to be accounted for and quantified. Such savings development and assumptions should be clearly documented within the M&V report. Documentation should be complete, readily available, clearly organized, and easy to understand.

Changes to the required level of documentation may be possible if a viable comparison group can be used for the analysis, but in using a comparison group, the EM&V team needs to review the make-up and selection of the group and that using a comparison group in lieu of other documentation should be presented in a draft M&V plan.

The methodology described herein involves use of whole facility electric meter data. An important component of a 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.

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

Refer to TRM volume 1, section 4.2: Approach to Identifying Peak Hours for further details on peak demand savings and methodology derived using the whole facility EM&V process. This should be presented in the project M&V plan.

Additional Calculators and Tools

The project M&V Plan shall describe analysis calculators or software tools employed and their applicability for project analysis.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is one year.

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: O&M
- Building Type
- Climate Zone
- Baseline Equipment Types Affected by Behavior Change

- Baseline Equipment Capacities
- Baseline Equipment Efficiency Ratings
- Baseline Number of Units
- Baseline Operating Practice
- Efficient Operating Practice.

References and Efficiency Standards

Not Applicable

Petitions and Rulings

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

Relevant Standards and Reference Sources

- Unique to each project and to be documented in M&V plan and report.

Document Revision History

Table 2-23: M&V Behavioral History

TRM Version	Date	Description of Change
v3.1	11/05/2015	TRM v3.1 origin
v4.0	10/10/2016	Updated documentation of methodology and measure life.

2.5 M&V: LOAD MANAGEMENT

2.5.1 Residential Load Curtailment Measure Overview

TRM Measure ID: R-LM-LM

Market Sector: Residential

Measure Category: Demand Response

Applicable Building Types: Single Family, Multifamily, and Manufactured Homes

Fuels Affected: Electricity

Decision/Action Types: Operation & Maintenance (O&M)

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V

Utilities operate residential load management programs to obtain demand savings: to the extent energy savings are also estimated, they are estimated as a function of the estimated demand savings.[20] Demand savings calculations are performed using utility customer interval energy demand data from IDRs or Advanced Meters. Measured and verified Demand Savings for the curtailment period is presented here.

Measure Description

Measures participating in a residential load management program may be air-conditioners, heat pumps, swimming pool pumps, or other electricity loads as specified by utility program designs. Specific methods of load management for this measure are not defined and are determined by individual programs. The savings reflect the cumulative effect of all participant actions to reduce residence-wide demand during a load management event.

Eligibility Criteria

A project will be eligible for incentives and reporting demand and energy savings when continuous demand interval recording capability (30-minute intervals or less) and sufficient interval data exists to measure and verify sufficient comparison-days to establish demand baselines as well as interval demands during load management events.

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

Baseline Condition

The baseline condition is an individual participants' load that would have occurred had the load management event and subsequent demand response activities not taken place.[21]

High-Efficiency Condition

Not applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 42

Where:

Baseline Period kW	=	*Baseline average demand calculated according to the High 3 of 5 Baseline Method*
Curtailment kW	=	*Average demand measured during the curtailment period*

High 3 of 5 Baseline with Day-of Adjustment

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

Applying this concept to the residential load management measure, the high 3 of 5 baseline for a given curtailment event is estimated by first identifying the five non-holiday weekdays immediately preceding the event in which no prior program curtailment events were called, and calculating each participant's average demand during the same hours as the hours for which the curtailment event was implemented on each of those five days. The three highest of these five average like day demand values are then averaged to estimate the "unadjusted high three baseline".

The day-of baseline adjustment is estimated by comparing participants' average demand for electricity on the day of the event during the two hours prior to notification of the pending event (the "adjustment period") to participants' average demand for electricity on the "high three" days during those same two hours. In the situation where notification may not be

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

given, the two hours preceding one hour before the event begins on the event day and baseline days will be used as the adjustment period. The average load of the adjustment period on the event day are compared to the average load of the adjustment periods from the baseline days. The difference (positive or negative) between day-of demand and high three baseline day demand in the adjustment period is the uncapped additive adjustment. To apply the adjustment period to the unadjusted baseline, one of two options are selected in the following steps:

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

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

Example Calculation

Table 2-24 illustrates the steps of the High 3 of 5 baseline calculation method. Specific participant's results may vary. Numbers from the table in bold font represent data selected for the calculation.

Table 2-24. High 3 of 5 Example Load Management Event Data

Event Day and Potential Baseline Days	Potential Baseline Day 5	Potential Baseline Day 4	Potential Baseline Day 3	Potential Baseline Day 2	Potential Baseline Day 1	Load Management Event Date
Event Hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600
Average kW During Event Hours	**5.67**	**5.96**	4.95	4.58	**6.01**	5.12
Notification Hour						1400
Adjustment Period Hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400
Adjustment Period Avg. kW	**5.54**	**5.87**	4.86	4.44	**5.89**	6.03

Calculation Steps:

1)

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

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

2)

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

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

3)

Adjustment Cap = 80% of Unadjusted High Three Baseline (kW)

Adjustment Cap = 0.8 * 5.88 = 4.7 kW

4)

Choose Additive Adjustment = Minimum {Absolute value of Uncapped Additive Adjustment, Adjustment Cap} (kW)

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

5)

Final Baseline = Additive Adjustment + Unadjusted High Three Baseline (kW)

Final Baseline = 0.26 + 5.88 = 6.14 kW

6)

kW Savings = Final Baseline – Curtailment kW (kW)

kW Savings = 6.14 – 5.12 = 1.02 kW

Additional Calculation Considerations

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

- Less than one percent of participating residential customers experience meter recording failures
- The customer can be confirmed as having participated via the practices of the sponsor operating the program or lack of opt-out notification

- The EM&V team is engaged to discuss applying the average savings and any program participation segmentation, and the specific cases are documented
- Savings for the residential segment will be calculated using the average savings of the segment as calculated via the High 3 of 5 method for the balance of the program or segment

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

Program year kW load management event savings will be calculated as the average savings of all events. Rounding of savings should occur only at the total program event level or program year average event savings level. Program year kWh load management event savings will be calculated as the average event kW savings multiplied by the total number of event hours in the program year. Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Lifetime

Not applicable.

Program Tracking Data and Evaluation Requirements

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

- For each participant for which savings are being claimed, kWh consumption at intervals no greater than 30-minutes for each event day and for no less than five non-holiday and non-weekend days prior to each event day. Interval data shall be time-stamped with the date and no less than the time period ending the interval.
- Documentation describing the time stamp and whether the time stamp reflects the forward looking period or period preceding the time stamp
- A list of all load management events affecting residential participants, describing their date, the time the event started, and the time the event ended.
- A list of all participants and addresses with a variable linking to the load or energy consumption interval data and that describes their enrollment date, load management control commissioning date, and any events in which the participant did not participate due to

enrollment or equipment installation timing, equipment failures, or other factors known to the implementer or utility.

- Tools, calculators or other datasets that may be useful to the EM&V Team, based on discussion between the EM&V Team, utilities, and/or program implementer. The process for calculating kW and kWh savings should be provided in the program documentation, including any summation and rounding practices.
- Memos, reports, or results of any equipment test or metering data that provides perspectives, calculations, or metrics related to failure rates of load control receivers, thermostats or similar devices used to control participant loads during events.

The evaluation reserves the option to conduct participant level independent metering studies to inform the verification of load management program savings.

References and Efficiency Standards

Not applicable.

Petitions and Rulings

None

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 2-25: M&V Residential Load Management History

TRM Version	Date	Description of Change
v2.1 Addendum	3/31/2015 revised 6/2015	Memo to PUCT Staff initiating and establishing High 3 of 5 Baseline with Day-of Adjustment
v3.1	11/05/2015	TRM v3.1 Volume 4 origin
v4.0	10/10/2016	TRM v4.0 clarified language related to applying the adjustment factor to the High 3 of 5 Baseline and additional data provision details

2.5.2 Nonresidential Load Curtailment Measure Overview

TRM Measure ID: NR-LM-LM

Market Sector: Nonresidential

Measure Category: Demand Response

Applicable Building Types: Any building that meets minimum facility demand requirements (see Table 2-18)

Fuels Affected: Electricity

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

Program Delivery Type: Custom

Deemed Savings Type: Not Applicable

Savings Methodology: EM&V

Utilities operate nonresidential load management programs to obtain demand savings: to the extent energy savings are also estimated, they are estimated as a function of the estimated demand savings.[22] Demand savings calculations are performed using utility customer interval energy demand data from IDRs or Advanced Meters. The process by which measured and verified demand savings are estimated is outlined here.

Measure Description

This document presents the deemed savings methodology for participation in a load management program that involves the curtailment of an interruptible load during the summer peak period. Project sponsors, who have agreed to deliver demand savings to the utility from the utility's customer, must commit to an availability of curtailed load throughout the Summer Peak Demand Period. These project sponsors may include national or local energy efficiency service providers (EESPs), retail electricity providers (REPs) or individual customers.

Eligibility Criteria

While the program offerings of individual utilities may differ slightly from each other, the criteria presented herein are universally applied. A project will be eligible for rebates under the Load Management SOP program if the following criteria are met:

- Each metered load included in a project must be capable of providing a demand savings of a specified minimum kW (varies by utility, as seen in Table 2-26) during the summer peak period.

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

Table 2-26: Minimum Facility Demand Savings by Utility

Utility	Minimum Demand Savings [kW]
Oncor	100
TNMP	50[23]
AEP (TNC, TCC & SWEPCO)	50
Xcel	100[24]
CenterPoint	100
Sharyland	100
Entergy	250
El Paso Electric	100

Table 2-27: Peak Demand Period by Utility

Utility	Hours	Months	Exceptions
Oncor, AEP, TNMP, CenterPoint, Sharyland, Entergy, El Paso Electric	1PM – 7PM	June, July, August, September	Weekends, Federal Holidays
Xcel	12PM – 8PM[25]	June, July, August, September	Weekends, Federal Holidays

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

[23] TNMP prefers that project sponsors be capable of providing at least 50 kW of peak demand reduction at each site for which load reduction is offered; however, TNMP may accept applications including sites providing less than 50kW of peak demand reduction in the interest of meeting its peak load reduction targets.
[24] The utility prefers that project sponsors be capable of providing at least 100kW of peak demand reduction at each site for which load reduction is offered; however, the utility may accept applications including sites providing less than 100kW of peak demand reduction in the interest of meeting its peak load reduction targets.
[25] Note that although Xcel starts and ends events outside the 1 pm to 7 pm period, Xcel only claims savings for deliveries during the rule-defined 1-7 pm peak period.

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

The following loads are excluded from consideration:

- A customer who has load contracted with a REP where that contract prevents the load from participating in a curtailment.
- Loads where curtailment would result in negative environmental or health effects.
- Curtailable load that receives an incentive through any other energy efficiency program.
- Curtailable load that takes electric service at transmission voltage and that serves a for-profit end-use customer.

Baseline Condition

Standard facility operation.

High-Efficiency Condition

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

Additional Utility Program Details

Each utility in Texas provides slightly different guidelines for its load management program. These details differ in the length of the unscheduled interruptions (also called curtailments), the maximum number of unscheduled interruptions and/or maximum number of total hours interrupted, and the length of notification provided to the project sponsor. Table 2-28 highlights these differences.

Each utility requires that participants will be willing to participate in a maximum number of unscheduled interruptions, or a maximum number of scheduled (test) interruption hours. In addition to these, all utilities require that a scheduled interruption be performed. The purpose of this is to ensure that the project sponsor will be able to curtail the requested kW within the required notification time and to provide an estimate of the load reduction in the event that no unscheduled interruptions occur during the season. Additionally, some of the utilities offer different baseline methods or options for their customers to choose from. These options are shown in Table 2-29 through Table 2-31.

Table 2-28: Utility Program Details Overview

Utility	Options Available	Scheduled Interruption Length	Maximum Length	Notification Required	Maximum Unscheduled Interruptions
Oncor	No	3 hours	4 hours	1 hour	25 hours
AEP (TCC & TNC)	See Table 2-29	1 hour	2 hours or 4 hours	1 hour	4, 8, or 12 interruptions
AEP SWPECO	See Table 2-30	1 hour	2 hours or 4 hours	1 hour	4 or 12 interruptions
TNMP	No	1-2 hours	4 hours	30 minutes	4 interruptions; 18 hours
CenterPoint	No	1-3 hours	4 hours	30 minutes	4 interruptions
Xcel	See Table 2-23	--	4 hours	1 hour	6 or 12 interruptions; 24 or 48 hours
Sharyland Utilities	No	1-2 hours	4 hours	1 hour	4 interruptions; 18 hours
Entergy	No	1 hour	4 hours	--	4 interruptions
El Paso Electric	No	1-5 hours	5 hours	1 hour	4 interruptions; 20 hours

Table 2-29: AEP (TNC & TCC) Interruption Options

Option	Maximum of Unscheduled Interruptions	Minimum Length (hours)	Maximum Length (hours)
A	4	1	4
B	12	1	4
C	12	1	2
D	8	1	4
E	8	1	2

Table 2-30: AEP (SWEPCO) Interruption Options

Option	Maximum of Unscheduled Interruptions	Minimum Length (hours)	Maximum Length (hours)
A	4	1	4
B	12	1	4
C	12	1	2

Table 2-31: Xcel Interruption Options

Option	Maximum of Unscheduled Interruptions	Maximum Length (hours)
A	6	4
B	12	4

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Utilities operate load management programs to obtain demand savings: to the extent energy savings are also estimated, they are estimated as a function of the estimated demand savings.[26]. Demand savings calculations are performed using utility customer interval energy usage data from IDRs or Advanced Meters. The Verified Demand Savings for the curtailment period uses the following algorithm:

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

Equation 43

Where:

Baseline Period kW = *Baseline average demand calculated according to the High 5 of 10 baseline method, detailed below*

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

High 5 of 10 Baseline (High X of Y Method) with Day-of Adjustment:

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

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

The day-of baseline adjustment is estimated by comparing participants' average demand for electricity on the day of the event during the two hours prior to notification of the pending event (the "adjustment period") to participants' average demand for electricity on the "high five" days

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

during those same two hours. The difference (positive or negative) between day-of demand and high five demand in the adjustment period is the "uncapped additive adjustment". [27] The average load during the adjustment period on the event day is compared to the average load during the adjustment period hours from the baseline days. The difference (positive or negative) between day-of demand and high five baseline day demand in the adjustment period is the uncapped additive adjustment. To apply the adjustment period to the unadjusted baseline, the following steps are used:

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

The curtailment event demand savings are then calculated by subtracting the average demand during the event from the high 5 of 10 baseline demand.

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

Example Calculation

Table 2-32 serves to illustrate the steps of the High 5 of 10 baseline calculation method. Specific participants' results may vary. Numbers from the table in bold font represent data selected for the calculation.

[27] In the situation where notification may not be given or notification information is unavailable, the two hours preceding one hour before the event begins on the event day and baseline days will be used as the adjustment period.

Table 2-32. High 5 of 10 Example Load Management Event Data

Event Day and Potential Baseline Days	Load Management Event Date	Potential Baseline Day 1	Potential Baseline Day 2	Potential Baseline Day 3	Potential Baseline Day 4	Potential Baseline Day 5
Event Hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600
Average kW During Event Hours	1078.89	**990.57**	919.45	**926.36**	892.42	880.13
Notification Hour	1400					
Adjustment Period Hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400
Adjustment Period Avg. kW	959.39	**752.26**	672.08	**637.98**	695.12	698.88

Event Day and Potential Baseline Days	Potential Baseline Day 6	Potential Baseline Day 7	Potential Baseline Day 8	Potential Baseline Day 9	Potential Baseline Day 10
Event Hours	1500-1600	1500-1600	1500-1600	1500-1600	1500-1600
Average kW During Event Hours	**950.63**	842.19	**1008.69**	795.80	**1049.24**
Notification Hour					
Adjustment Period Hours	1200-1400	1200-1400	1200-1400	1200-1400	1200-1400
Adjustment Period Avg. kW	**657.64**	539.75	**801.02**	647.12	**850.18**

Calculation Steps:

1)

Unadjusted High Five Baseline = Average kW during event times in five highest days of ten prior to event day (kW)

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

2)

Uncapped Additive Adjustment = Average kW during adjustment time on event day (kW) - Average kW during adjustment time in the same five highest days of ten prior to event day

Uncapped Additive Adjustment = 959.39 - (752.26+637.98+657.64+801.02+850.18)/5 = 219.57 kW

3)

Adjustment Cap = 50% of Unadjusted High Five Baseline (kW)

Adjustment Cap = 0.5 * 985.10 = 492.55 kW

4)

Choose Additive Adjustment = Minimum {Absolute value of Uncapped Additive Adjustment, Adjustment Cap} (kW)

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

5)

Final Baseline = Additive Adjustment + Unadjusted High Five Baseline (kW)

Final Baseline = 219.57 + 985.10 = 1204.67 kW

6)

kW Savings = Final Baseline – Curtailment kW (kW)

kW Savings = 1204.67 – 1078.89 = 125.78 kW

Additional Calculation Considerations

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

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

Savings for individual sponsors will be calculated by averaging the performance across all events for each sponsor.

Total program year kW load management event savings will be calculated as the sum of each sponsor's average event savings for which the sponsor was called upon to curtail load. Rounding of savings should occur only at the sponsor level or program year average event savings level. Total program year kWh load management event savings will be calculated as the sum of each sponsor's hourly kW savings for the program year.

Measure Life and Lifetime Savings

Not applicable.

Program Tracking Data & Evaluation Requirements

- IDR or Advanced Meter data associated with the project will be provided by the project sponsor or retrieved by the utility following an event. Depending on the utility, the data will be provided at 30-minute increments (or smaller) to evaluate both baseline demand usage and demand usage during curtailment.

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

References and Efficiency Standards

Petitions and Rulings

None.

Relevant Standards and Reference Sources

- El Paso Electric: EOE 2010 Load Management Program Manual. http://www.epelectricefficiency.com/files/EPE_LM_10_ProgramManual.pdf. Accessed 09/06/2013.
- AEP: Texas North Company Load Management SOP 2013 Program Manual. http://www.aepefficiency.com/loadmanagement/TNC/2013_TNC_LM%20Manual_Agreement.pdf. Accessed 02/28/14.
- AEP: Texas Central Company Load Management SOP 2013 Program Manual. http://www.aepefficiency.com/loadmanagement/TCC/2013_TCC_LM_Manual_Agreement.pdf. Accessed 09/06/2013; manual no longer available online.
- AEP: Southwestern Electric Power Company Load Management 2013 Program Manual. http://www.swepcogridsmart.com/texas/downloads/Load%20Management_Program_Manual.pdf. Accessed 09/06/2013.
- Entergy: 2013 Load Management Handbook. http://www.entergy-texas.com/content/energy_efficiency/documents/Load_Management_Handbook.pdf. Accessed 09/06/2013.
- CenterPoint: EnergyShare 2013 Program Manual. http://www.centerpointelectric.com/staticfiles/CNP/Common/SiteAssets/doc/2013_Load_Management_Program_Manual.pdf. Accessed 09/06/2013.

- Texas-New Mexico: Load Management 2013 SOP. http://tnmpefficiency.com/downloads/Load_Management_Program_Manual.pdf. Accessed 09/06/2013.
- Xcel Energy: 2013 Load Management Pilot Standard Offer Program. http://www.xcelefficiency.com/TX/Xcel_LM_Manual_2013.pdf. Accessed 09/06/2013; pilot program has been replaced.
- Sharyland Utilities: 2013 Load Management SOP. http://www.sharylandefficiency.com/load-management/Sharyland_2013_Peak_Load_Mgmt_Program_Manual.pdf Accessed 09/06/2013; 2013 Manual no longer available online.
- Oncor: Commercial Load Management Standard Offer Program. https://www.oncoreepm.com/load-management-program.aspx. Accessed 09/06/2013.

Document Revision History

Table 2-33: M&V Nonresidential Load Management History

TRM Version	Date	Description of Change
v3.0	4/10/2015	The baseline calculation methodology was modified to be the highest 5 of 10 prior days for all the programs. In addition, a new day-of adjustment factor was added with an adjustment cap.
v3.1	11/05/2015	TRM v3.1 Volume 4 origin
v4.0	10/10/2016	TRM v4.0 clarified language related to applying the adjustment factor to the High 5 of 10 Baseline and additional data provision details

APPENDIX E: M&V METERING SCHEDULE

1.0 Arrive on site and meet customer

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

1.2 Record customer information:

a. Address
b. City
c. Zip
d. County
e. Email
f. Utility Account Number (From utility bill)
g. Altitude [Ft]
h. Residential Program or Commercial Program
i. Building Type
j. Phone Number

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

2.1 Record Unit Information

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

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

2.3 Air Flow Power Consumption

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

2.4 Condenser and Compressor Measurements

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

2.5 Enter Information from Refrigerant Analyzer:

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

2.6 Measure and Record Supply and Return Air Conditions:

a. Return Air Dry Bulb Temperature[°F]
b. Return Air Wet Bulb Temperature[°F]
c. Supply Air Dry Bulb Temperature [°F]
d. Supply Air Wet Bulb Temperature [°F]

2.7 Review System Performance