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Acknowledgments

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

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

TRM Technical Support

Technical support and questions can be emailed to the EM&V project manager (Lark.Lee@tetratech.com) and the PUCT staff (Ramya.Ramaswamy@puc.texas.gov).

1. INTRODUCTION

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

M&V protocols are included for the following measures:

- HVAC: Variable Speed Heat Pumps
- HVAC: Air Conditioning Tune-up
- HVAC: Ground Source Heat Pump
- HVAC: Variable Refrigerant Flow Systems
- HVAC: Dedicated Outdoor Air Systems
- Whole House: Residential New Construction
- Whole House: Smart Home Energy Management System (SHEMS)
- Building Energy Codes: Residential Energy Code Compliance Enhancement
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Renewables: Solar Attic Fans
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors Less than 75 hp
- Miscellaneous: Nonresidential Custom
- Miscellaneous: Nonresidential Measurement and Verification
- Miscellaneous: ~~Thermal~~ Energy Storage
- Miscellaneous: ENERGY STAR® Uninterruptible Power Supply
- Miscellaneous: Low Pressure Irrigation
- Miscellaneous: Irrigation Pump Variable Frequency Drives
- Load Management: Residential Load Curtailment
- Load Management: Nonresidential Load Curtailment

Additional M&V protocols will be included in future versions of TRM Volume 4 as they are submitted, reviewed, and approved by the EM&V team and Commission staff. TRM Volume 1: Overview and User Guide, Section 4: Structure and Content details the organization of the measure templates presented in this volume.

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

Sector	Measure category	Measure description	12.0 update
Residential	HVAC	Variable speed heat pumps	TRM v12.0 origin.
Residential/ nonresidential	HVAC	Air conditioning tune-ups	Updated measure based on Section 3.2.1 of Volume 1 of the PY2023 IOU Energy Efficiency Report.
Nonresidential	HVAC	Ground source heat pumps	No revision.
Nonresidential	HVAC	Variable refrigerant flow systems (VRF)	Clarified language about current VRF federal standard effective date.
Nonresidential	HVAC	Dedicated outdoor air systems (DOAS)	TRM v12.0 origin.
Residential	Whole house	Residential new construction	Added pilot option for HERS index compliance path. Updated baseline to IECC 2018 or 2021.
Residential	Whole house	Smart home energy management system (SHEMS)	Added in-service rates (ISRs) from TRM Volume 2 residential lighting measures.
Residential	Building energy codes	Residential energy code compliance enhancement	No revision.
Residential and nonresidential	Renewables	Residential and nonresidential solar photovoltaics	No revision.
Residential and nonresidential	Renewables	Solar shingles	No revision.
Residential	Renewables	Solar attic fans	No revision.
Nonresidential	Miscellaneous	Behavioral	No revision.
Nonresidential	Miscellaneous	Air compressors less than 75 hp	No revision.
Nonresidential	Miscellaneous	Nonresidential custom	Added EUL for VFDs in non-HVAC applications.
Nonresidential	Miscellaneous	Nonresidential measurement and verification	Minor text edits and clarifications.
Nonresidential	Miscellaneous	Energy storage	No revision.
Nonresidential	Miscellaneous	ENERGY STAR® Uninterruptible power supply	No revision.

Sector	Measure category	Measure description	12.0 update
Nonresidential	Miscellaneous	Low pressure irrigation	TRM v12.0 origin.
Nonresidential	Miscellaneous	Irrigation pump variable speed drive (VFD)	TRM v12.0 origin.
Residential	Load management	Residential load curtailment	Clarified eligible end uses. Added guidance on tracking and reporting of load management programs separate from energy efficiency programs.
Nonresidential	Load management	Nonresidential load curtailment	Added guidance on tracking and reporting of load management programs separate from energy efficiency programs.

2. M&V MEASURES

2.1 M&V: HVAC

2.1.1 Variable Speed Heat Pumps Measure Overview

TRM Measure ID: R-HV-VS

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-burnout, early retirement, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new variable speed heat pump (VSHP) in an existing building, or the installation of a new central VSHP in a new residential construction. Each heat pump system consists of a heat pump system that includes an indoor unit with a matching remote condensing unit.

Eligibility Criteria

The measure applies to VSHP which can operate the compressor at various speeds as needed for the cooling or heating load necessary. The following criteria must be met to use this measure:

- Cooling capacity of ≤ 65,000 Btu/hour (5.4 tons).
- The compressor in the outdoor unit must have a minimum of 4 speeds or be inverter driven.
- The VSHP system consists of matched components of an outdoor unit, indoor unit, and temperature control device[1].

Equipment shall be properly sized for both heating and cooling to the dwelling based on ASHRAE or ACCA standards. Manufacturer datasheets for installed equipment or documentation of AHRI certification must be provided.[2]

[1] Temperature control device may be documented as acceptable from the manufacturer of the outdoor and indoor units, and does not need to be manufactured by the same company.

[2] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

The controls shall be set to limit the amount of electric resistance heat used. Contractors installing the heat pump equipment shall advise customers of the proper thermostat usage. Customers should be advised against using the emergency heat setting.

Baseline Condition

The baseline equipment efficiency is governed by Measure 2.~~1~~12.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2. This includes determining the proper baseline efficiencies for early retirement, replace on burnout, or new construction determination. The additional requirements of the documentation for the electric resistance furnace are also required in this measure.

The baseline capacity for this measure will be determined based on the algorithm below.

High-Efficiency Condition

There are two components of the high efficiency that are required for the variable speed heat pump measure, the equipment capacity and the equipment efficiency. The capacity varies between cooling and heating and the rated capacity needs to be documented for cooling at 95 degrees, heating at 47 degrees, and heating at 17 degrees. Rated system efficiency at cooling (EER2/EER2023 and SEER2/SEER2023) and heating (HSPF2/HSPF2023) efficiencies must meet or exceed the standard identified in Measure 2.~~1~~12.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2.

Energy and Demand Savings Methodology

~~Savings Algorithms and Input Variables~~

Energy and demand savings algorithms and associated input variables are listed below.

Energy Savings Algorithms

$$Total\ Energy\ Savings\ [\Delta kWh] = kWh_C + kWh_H$$

Equation 1

$$Cooling\ Energy\ Savings\ [kWh_C] = Load_C\left(\frac{1}{\eta_{baseline,C}} - \frac{1}{\eta_{installed,C}}\right) \times EFLH_C \times FLA_{vs} \times \frac{1\ kW}{1{,}000\ W}$$

Equation 2

$$Heating\ Energy\ Savings\ [kWh_H] = Load_H\left(\frac{1}{\eta_{baseline,\mathrm{H}}} - \frac{1}{\eta_{installed,\mathrm{H}}}\right) \times EFLH_H \times FLA_{vs} \times \frac{1\ kW}{1{,}000\ W}$$

Equation 3

Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Load_C \left(\frac{1}{\eta_{baseline,PC}} - \frac{1}{\eta_{installed,PC}}\right) \times CF_S \times \frac{1\ kW}{1{,}000\ W}$$

Equation 4

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = Load_H \left[\left(\frac{P_{H,base}}{\eta_{baseline,H}} - \frac{P_{H,installed}}{\eta_{installed,H}}\right) + \left(\frac{P_{H,installed} - P_{H,base}}{\eta_{Aux,H}}\right)\right] \times CF_W \times \frac{1\ kW}{1{,}000\ W}$$

Equation 5

Where:

Cap_C = *Minimum of rated cooling capacity of existing equipment or new equipment at 95 degrees from AHRI certificate [Btuh]*

$Load_C$ = *Calculated Cooling Design Load at Manual J temperature OR the Cap_C times 0.85 [Btuh]*

$Load_H$ = *Calculated Heating Design Load at Manual J temperature OR the $Load_C$ times Winter Load Adjustment from Table 2. [Btuh]*

Table 2. VSHPs—Winter Load Adjustment by Climate Zone[3]

Climate zone	Winter Load Adjustment
Zone 1: Amarillo	153%
Zone 2: Dallas	103%
Zone 3: Houston	90%
Zone 4: Corpus Christi	79%
Zone 5: El Paso	103%

$P_{H,base}$ = *Percent of peak hours where baseline heat pump meets load, Table 3* **Error! Reference source not found.**. *Value is 0% if baseline is electric resistance as determined by Measure 2.2.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2.*

[3] Estimated from the difference between CDH65 and HDH60 for the regional design temperatures from Manual J.

Table 3. VSHPs—$P_{H,Base}$ by CClimate ZZone[4]

Climate zone	$P_{H,base}$
Zone 1: Amarillo	6%
Zone 2: Dallas	48%
Zone 3: Houston	58%
Zone 4: Corpus Christi	100%
Zone 5: El Paso	100%

$P_{H,installed}$ = *Percent of peak hours where installed heat pump meets load (See* ***Error! Reference source not found.****)*

Cap_{17} = *Rated heating capacity of existing new equipment at 17 degrees from AHRI certificate [Btuh]*

Cap_{17} / Cap_C = *Capacity ratio of heating capacity at 17 degrees to the cooling capacity at 95 degrees*

Table 4. VSHPs—$P_{H,Installed}$ by climate Climate zone Zone and capacity Capacity RRatio[5]

Climate zone	Cap_{17} / Cap_C		
	< 0.60[6]	0.60 – 0.90	> 0.90
Zone 1: Amarillo	6%	57%	76%
Zone 2: Dallas	48%	90%	100%
Zone 3: Houston	58%	100%	100%
Zone 4: Corpus Christi	100%	100%	100%
Zone 5: El Paso	100%	100%	100%

$\eta_{baseline,C}$ = *Baseline cooling SEER2 efficiency of existing equipment (ER) or standard equipment (ROB/NC), see Measure 2.12.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2. [Btuh/W]*

$\eta_{baseline,PC}$ = *Baseline cooling EER2 efficiency of existing equipment (ER) or standard equipment (ROB/NC), see Measure 2.12.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2. [Btuh/W]*

$\eta_{installed,C}$ = *Rated cooling SEER2 efficiency of the newly installed equipment [Btuh/W]*

[4] Estimated from PDPF Top 50 hours temperatures and a baseline heat pump with Cap_{17} / Cap_C ratio equal to below 0.60.
[5] Estimated from PDPF Top 50 hours temperatures and engineering estimate of heat pump performance with various Cap_{17} / Cap_C ratio within winter temperature bins.
[6] Matches baseline ($P_{H,base}$)

$\eta_{installed,PC}$ = Rated cooling efficiency of the newly installed equipment [Btuh/W] = 0.85 x EER2 + 0.15 x SEER2[7]

$\eta_{baseline,H}$ = Baseline heating HSPF2 efficiency of existing equipment (ER) or standard equipment (ROB/NC), see Measure 2.2~~1~~.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2. [Btuh/W]

$\eta_{installed,H}$ = Rated heating HSPF2 efficiency of the newly installed equipment [Btuh/W]

$\eta_{aux,H}$ = 3.412, Rated heating efficiency of the auxiliary heat source deemed as electric resistance [Btuh/W]

FLA_{VS} = 1.15 default[8]~~.~~

1.25 if load is determined by sizing calculation, such as Manual J

$EFLH_{C/H}$ = Cooling/heating equivalent full-load hours, see Measure 2.~~1~~2.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2.

$CF_{S/W}$ = Summer/winter seasonal peak coincidence factor, see Measure 2.2~~1~~.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2.

Early Retirement

See Measure 2.2~~1~~.2 Central and Mini-Split Air Conditioners and Heat Pumps in Volume 2.

Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Winter Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

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7 Cooling efficiency is adjusted from EER2 for variable speed units because units will vary the speed during peak time, instead of 100 percent operation.

8 Accounts for the adjustment from capacity to load to match with the EFLH calculations in the Texas TRM.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 20 years for VSHP.[9,10]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of newly installed unit
    - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number including the following values:
        - Cooling Capacity at 95 degrees F
        - Heating Capacity at 47 degrees F
        - Heating Capacity at 17 degrees F
        - EER2, SEER2, and HSPF2 (Region IV)
- Manufacturer and model of controller or thermostat
- Heating capacity (kW) of auxiliary electric resistance heat
- Manual J load calculation, if applicable.
- Type of unit variable speed unit installed (Central HP, mini-split HP)
- Unit type subcategory (split, packaged)

[9] "Residential HVAC and DHW Measure Effective Useful Life Study Final Report". Group A, CALMAC ID: CPU0368.02. Prepared by DNV for the California Public Utilities Commission. p. 8, Table 1-3. April 9, 2024. https://www.calmac.org/publications/CPUC_Group_A_2023_Res_HVAC_and_DHW_EUL_Study_Final_ReportES.pdf.

[10] "Final Evaluation Report for X2001B: Connecticut Measure Life/EUL Update Study-Residential & Commercial". Prepared by Michaels Energy in partnership with Evergreen Economics for the Connecticut Energy Efficiency Board. p. 12-13, Table 3. May 11, 2023. https://energizect.com/sites/default/files/documents/X2001BFINALReport_051523.pdf.

- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air-source HP)
    - Baseline equipment used for savings (if different from unit replaced)
- Nominal cooling tonnage of retired unit (tons) (early retirement or replace-on-burnout)[11]
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, recording nameplate information, or other evaluator-approved approach. Sampling is allowed for multifamily complexes
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (early retirement unless default EUL is applied consistently across the program)
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment

Proof of purchase with date of purchase and quantity

-
    - Alternative: photo of unit installed or other pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 5. VSHPs—Revision History

TRM version	Date	Description of change
v12.0	10/2023	TRM v12.0 origin.

[11] Assume nominal baseline heating tonnage is equal to nominal baseline cooling tonnage.

2.1.2 Air Conditioning and Heat Pump Tune-Ups Measure Overview

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

Market Sector: Residential and commercial

Measure Category: HVAC

Applicable Building Types: Residential; commercial

Fuels Affected: Electricity

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

Program Delivery Type(s): Custom

Deemed Savings Type: Deemed efficiency loss factors are applied to measured operating performance indicators to estimate energy saving impacts; the deemed efficiency loss factors estimate equipment improvements based on each unit's specific operating conditions Not applicable

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

AC Ttune-ups promote a holistic approach to improve the operational efficiency of existing air conditioners and heat pumps (AC/HP) by completing six tune-up service measures. This protocol is used to estimateimproving the operational efficiency of existing air conditioners and heat pumps (AC/HP). This protocol estimates savings for tune-up measures through an M&V approach that relies on test-in and test-out measurements of key AC performance indicators following the completion of all tune-upthekey service and maintenance activitiesmeasures.

Applicable equipment types include:

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

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

Measure Description

ACAC/HP tune-ups must be professionally completed by a licensed qualified air conditioning contractor on packagesd or split air conditioners (DX or air-cooled) or air-cooled heat pumps. service technicians using measurement tools and equipment. All projects must have a post-install measurement of performance that the Efficiency Loss (EL) factor is applied to estimate savings. This protocol covers assumptions made for baseline equipment efficiencies based on previous M&V tune-ups in Texas from a three-year rolling average. The energy savings estimationspost-tune-up performance measurement, to which an Efficiency Loss (EL) factor is applied to estimate savings. The energy savings estimation process is designed to efficiently estimate the electric energy and demand savings attributable to each participating ACAC/HP tune-up unit. Following the completion of the service measures, the M&V methodology for tune-ups requires in-field measurement and recording of AC performance parameters under protocol conditions to record *in situ*, post-tune-up performance to calculate estimated energy impacts.

The ACAC/HP tune-up requires the completion of several maintenance activitiessix tune-up service measure. PotentialTypical tune-up service tasks are listed below. and must be consistently applied across program participants to determine the EL factors:

- Check thermostat setting
- Tighten electrical connections
- Lubricate motor and fan bearings
- Inspect and clean condensate drain
- 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

The scope of a tune-up program's activities must be approved by the program evaluator and be consistently applied across program participants.Applicable equipment types include:

Packaged and split air conditioners (DX or air-cooled)

Packaged and split heat pumps (air-cooled)

Eligibility Criteria

This measure only applies to existing air conditioning equipment (split and packaged air conditioner and heat pump systems) that receive the tune-up services and have not been serviced through a utility program in the last five years. 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 tune-up service measures., and the following conditions must be met by program implementers:

- The M&V Plan for AC/HP tune-up implementation must be provided and approved by the program evaluator.
- ~~Tune-up services have not been delivered through a utility program in the last five years.~~
- Tune-up services must be completed by a licensed contractor.[12]
- ~~Use of program-specified m~~Measurement equipment ~~and accuracies~~~~that meets~~must meet the resolution and accuracy criteria outlined in ~~.~~
- Verification is required to confirm that tune-up services have not been provided through a utility program in the last five years.
-
- ~~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)~~
- Outdoor air temperature at the time of service must ~~be~~meet one of the following criteria:
  - Greater than 75°F dry bulb or
  - Greater than 70°F wet bulb and greater than 56°F dry bulb

Baseline Condition

The baseline efficiency ~~conditions~~ condition for an individual unit can be ~~determine~~established in one of two ways.

1. Field Measurements: Using calibrated equipment, ~~Calculate the efficiency based on~~ test-in (TI) measurements are taken in the field before the tune-up services have been performed. These measurements are ~~bu~~taken~~t~~ after the equipment has reached steady state conditions. The TI measurements are for cooling only. Heat pump~~s high efficiency condition for~~ heating performance is based on Equation 12.
~~1.~~2. EL Factor Application: Based on applying ~~Calculate the efficiency using~~ the EL factor in ~~are calculated (see~~ Equation 11 and Equation 13~~) based on the efficiency loss values determined by this protocol (see Table 2)~~.

High-Efficiency Condition

The high-efficiency condition~~s~~ ~~are~~ is calculated ~~based~~ using ~~on~~ test-out (TO) measurements taken in the field with calibrated equipment after the tune-up services ha~~ve~~s been performed and the equipment has reached steady state conditions. The TO measurements are for cooling only. Heat pump ~~s high efficiency condition for~~ heating performance is based on Equation 12. ~~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.~~

[12] Air Conditioning/Refrigeration Contractor from the Texas Department of Licensing and Regulation.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 6

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

Equation 7

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

Equation 8

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

Equation 9

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

Equation 10

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

Equation 11

$$\eta^{(13)}_{\cancel{post,}H} = 0.3342 \times \eta^{(14)}{}_{\cancel{post,}C} + 3.9871$$

Equation 12

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

Equation 13

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

Equation 14

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

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

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

Equation 15

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

Equation 16

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

Equation 17

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

Equation 18

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

Equation 19

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

Equation 20

The Saturation Over Liquid Water equation is:

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

Equation 21

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

Equation 22

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

Equation 18

$$Specific\ Volume\ (Return\ Air), [v_{Return\ Air}] = \frac{0.3704867 \times (t_{db} + 459.67) \times (1 + 1.6078 \times W)}{P}$$

Equation 19

Note that if the CFM (airflow) in Equation 18 is determined using Method 1 (measured airspeed and duct grill dimensions), the above CFM value is calculated using Equation 20.

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

Equation 20

$$Total\ Input\ Power\ [Power_{TO}] = Power_{Blower}^{(15)} + Power_{Condenser}$$

Equation 21

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

Equation 22

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

Equation 23

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

Equation 24

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

Equation 25

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

Equation 26

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

Equation 27

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

Equation 28

[15] 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.

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

Equation 29

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 31; Nonresidential Volume 3, Tables 36 through 40)*

CF = *Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2, Table 32; Nonresidential Volume 3, Tables 36 through 40)*

Volts = *Measured voltage (volts) on single-phase electric power leads to ~~AC~~AC/HP components*

Amps = *Measured current flow (amps) on single-phase electric power leads to ~~AC~~AC/HP components*

PF = *Power factor ~~stipulated~~ based on motor type (see Table 9)*

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~~AC/HP components for three-phase loads*

A_1, A_2, A_3	=	Measured current flow (Amps) on each line (A_1, A_2, A_3) of the three power leads to ~~AC~~AC/HP components for three-phase loads
~~Efficiency loss~~EL	=	Efficiency loss factor~~; derived from a significant sample of field measurement data for units with versus without a refrigerant charge and commercial versus residential unit types~~ (see)
P	=	Atmospheric air pressure, from Table 8
P_{ws}	=	Saturation pressure over liquid water [psia]
v	=	Specific volume of air [cu.ft./lb]
Ln.	=	Natural Logarithm
e	=	Natural log constant (2.7182818284590452353602874713527)
T	=	Absolute temperature, Rankine scale $[°R = °\mathrm{F} + 459.67]$
t_{db}	=	Measured dry-bulb temperature [°F]
t_{wb}	=	Measured wet-bulb temperature [°F]
Wet $Bulb_{Return\ Air}$	=	Wet-bulb temperature of return air (load) to ~~AC~~AC/HP 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~~AC/HP evaporator [Btu/lb]
$h_{Suppy\ Air}$	=	Measured enthalpy of cooled supply air to indoor space [Btu/lb]
Mass Flow Rate	=	Calculated mass flow rate of moist return air [lb/hr]
CFM	=	~~AC~~AC/HP supply/return airflow [cu.ft./min.] (see Table 10)
Length	=	Measured length of duct grill long side [inches] (Method 1)
Width	=	Measured width of duct grill short side [inches] (Method 1)
Air Speed	=	Measured air velocity at duct grille [feet per second] (Method 1)

95°F	=	*95°F is the outdoor dry-bulb temperature at AHRI test conditions*
10°F	=	*10°F is the typical wet-bulb temperature change across an evaporator coil at AHRI conditions*

M&V Plan

An M&V Plan for data collection, EL factor determination, calculation assumptions, methodology, metering equipment, and quality assurance is required to guide the completion of the tune-up services. This plan can be completed by the utility, program implementer, or individual contractor. The plan must be approved by the evaluator prior to the commencement of using this measure.

Data Collection

Data collection of project parameters, equipment specifications, and in-field measurements are critical for ~~implementation of~~implementing the M&V methodology. The project parameters and equipment specification minimum requirements are the following:

- Project site address
- Project customer type (residential, school, retail, etc.)
- Cooling equipment type (AC/HP and split/packaged)
- Equipment specifications (make, model, etc.)
- Electric power phase type (single or three)
- Blower type (PSC, ECM, VS, etc.)
- Refrigerant type (R-22, R-410, etc.)

The M&V methodology for tune-ups requires consistent in-field measurements across ~~project~~projects. Field measurements should be taken when the cooling system is operating under stable full-load operating conditions obtained by adjusting the unit control to overcool the space. The unit shall not be in the start-up phase or experiencing transient conditions. The M&V plan should detail the program guidance to achieve this operation before measurement.

Once the conditions have been met, the TI and TO measurements should be completed in-situ, during operation for airflow, electrical, temperature, and refrigerant requirements. The M&V plan shall detail the required locations for these measurements. The outdoor ambient temperature measurements should be completed away from direct sunlight, exhaust vents, or other heat sources. The TI and TO measurements minimum requirements are:

- Outdoor dry bulb temperature (°F)
- Refrigerant charge adjustment (%)
- Airflow measurement (CFM) and the measurement location
- Supply air dry and wet bulb temperatures (°F)
- Return air dry and wet bulb temperatures (°F)
- Ambient outdoor temperature (°F)
- Blower and condenser power (W)

Energy and Demand Savings Tables

Efficiency Loss (EL) Factors

The EL factor for use shall be developed from previously implemented tune-up services and must be submitted to the evaluator for approval prior to implementing tune-up services for the program year.

The EL factors are calculated annually based on a rolling three-year average of the previous three years of tune-up data in Texas. In the event that three years of tune-up services data is not available in Texas, an interim EL factor can be generated at the end of the first year with data collected through November of the current year. The interim EL can be applied retroactively to the current year to replace the deemed amount. The second year will follow a similar protocol and create an average of the first two years to apply retroactively to the second year and prospectively to the third year.

The EL factors are developed from a sample of tune-up projects that will collect the TI and TO measurements. The sample of projects should be random and represent the the various technicians/measurement equipment, customer types, and equipment types in the program. The M&V plan should detail the sampling methodology to select at least 10 percent of the tune-up projects to havewith TOI and TO measurements. The TI and TO measurements for airflow for the development of the EL facorfactor can only use Airflow Method 1 from Table 10. The TI and TO measurements in the sample that require alternate airflow methods are not acceptable tofor determininge the EL Factor.

Full M&V data (where units are tested both before and after the tune-up) are collected for a random sample of 10 percent of all tune-ups. Implementers are required to work with the evaluation team to determine an appropriate methodology to select which 10 percent of tune-up projects require full M&V data and analysis.

The EL factor for each project shall be determined from the TI and TO measurements using the savings algoithmsalgorithms to determine efficiency.

$$EL = 1 - \left(\frac{\eta_{pre,C}}{\eta_{post,C}}\right)$$

Equation 30

Prior to implementation for each year, an efficiency loss analysis submitted for approval must include all parameters collected according to the M&V Plan. The EL factor is required tomust vary based on the market sector (Commercial/Residential) and the level of refrigerant charge adjustment completed (including none). It is expected that there will be multiple refrigerant charge adjustment bins for each market sector. The program may proposalpropose additional factors that may adjust EL factors for projects.

The baseline efficiency conditions (η_{pre}) are calculated using the measured post-service test-out (η_{TO}) and AHRI-adjusted (η_{post}) value in combination with the appropriate *efficiency loss* value for that tune-up. The efficiency loss factors, as described in Table 1 below, are calculated annually based on a rolling three-year average of the previous three years of tune-up data. Full M&V data (where units are tested both before and after the tune-up) are collected for a random sample of 10 percent of all tune-ups. Implementers are required to work with the evaluation team to determine an appropriate methodology to select which 10 percent of tune-up projects require full M&V data and analysis.

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

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

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

Table 2. AC Tune-Up Efficiency Loss Factors

Market sector	Refrigerant charge adjustmented
Residential	No
	Yes
Commercial	No
	Yes

Metering Equipment

The M&V plan requires the identification of the metering equipment and operational practices for calibration to ensure consistent data acquisition. Table 6 shows a sample toolkit list for reference.

Table 6. AC/HPTU Sample Tune-Up ToolkitACTUs— Components

Device	Use area	Quantity
Approved digital refrigerant analyzer: • Testo 556 • Testo 560 • Testo 550 • iManifold 913-M and 914-M	Refrigerant charge adjustment Refrigerant pressure Refrigerant temperature Superheat Subcooling	1-2
Testo 318-V Inspection Scope	Visual coil inspection	1
Spring clamp probes	Refrigerant line temperatures	2
Extech 407123 Anemometer	Airflow	1
Testo 605-H2 Humidity Stick	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
iManifold 912-M or wired outdoor air temperature probe	Ambient air temperature	1
Testo 510 Compact Digital Manometer	Static pressure	1
Magnetic static pressure tips	Static pressure	2
Set of barbed hose tees	Static pressure	1
1/8 mpt x barbed fitting	Static pressure	1
10' silicone tubing	Static pressure	1
Digital volt/amp Meter	Voltage and current	1
Ruler/tape measure	Duct and grill dimensions	1
Tablet computer or smartphone	AC/HP tune-up application	1

Each item in the toolkit list is required to meet the accuracy as detailed in Table 7.

A complete metering schedule identifying the AC/HP tune-up process and measurements performed for AC/HP tune-ups is presented in the M&V Metering Schedule. The technician follows the metering schedule during the tune-up process.

Equipment Accuracy

The accuracy for each required piece of metering equipment is shown in .

Table 7. AC/HPTU ACTUs—Measurement Resolution and Accuracy

Device	Measurement	Resolution	Accuracy[16]
Anemometer	Airflow velocity	0.01m/s	3.5% of reading
Manometer	Differential pressure	0.01 inches water	±0.02 for reading below 0.40 inH2O, 3% for reading above 0.40 inH2O

[16] It is acceptable to exceed the percent accuracy at low readings when the resolution does not have the ability to remain within the percent limits.

Device	Measurement	Resolution	Accuracy[16]
Refrigerant system analyzer	Refrigerant temperature	0.1°F	±0.9°F
	Refrigerant pressure	0.1 psi	±1.0%
Thermometer	Dry-/wet-bulb temperature	0.1°F	±0.9°F
	Ambient air temperature	1.0°F	±2.0°F
Volt/amp meter	Voltage	0.1 V	±1.0%
	Current	0.01 A	±2.0%
Ruler/tape measure	Air grill dimensions	1/8 in	±1/16 in

Airflow velocity measurements in ducts shall be collected as the average of a traverse across the duct. The minimum number of reading for each traverse is four. The traverse plane shall be placed 2-1/2 times of the diameter[17] downstream and upstream of any elbows or discharge points. If this condition can not be met, the traverse plane should be placed in the center of the longest straight length and the number of diameters to the elbows or discharge points should be collected.

Calculation Assumptions

Atmospheric Air Pressure

The ~~average~~ atmospheric air pressure is deemed for each climate ~~zone is listed in~~ inzone in Table 8 ~~below, which was derived from the average pressure from TMY3 weather data during tune-up season (defined in *Eligibility Criteria* above)~~.

Table 8. AC/HPTU ~~ACTUs—~~Deemed Atmospheric Pressure

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

Power Factors

The power factors for each motor type ~~is~~are deemed based on the motor type identified ~~Capturing power factors from units in the field can be difficult. Stipulating these factors is acceptable, and suggested power factor values are presented by motor type for packaged and split system AC and heat pump units~~ in Table 9.

[17] The estimated diameter of the rectangular duct is the average of the length and width.

Table 9. AC/HPTU ~~ACTUs—~~Recommended Power Factors for AC/HP Components

Power factors for AC/HP components	
Motor type	**Power factor**
Blower: Electrically commutated motor (ECM)	0.68
Blower: Permanent-split capacitor motor (PSC)	0.98
Blower: Three-phase	0.98
Outdoor condensing unit	0.85
Variable frequency drive (single-phase)	0.87
Variable frequency drive (three-phase)	0.65

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

Residential: The ~~reader is referred to~~ TRM Volume 2 ~~identifes~~identifies the ~~for~~ deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values for residential building types by climate zone for central ~~AC~~AC/HP units ~~or heat pump units~~.

Nonresidential: The ~~reader is referred to~~ TRM Volume 3 identifies the ~~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~~AC/HP units. ~~and heat pump units~~.

Cooling Load Calculation

The cooling capacity ($Cap_{TO,C}$) of the ~~AC~~AC/HP unit is calculated ~~automatically~~ from TO ~~technician~~ measurements ~~at test-out by the data collection and tracking system software~~ using supply and return air enthalpy measurements and the volumetric airflow (CFM) according to Equation 18. There are ~~three~~ two methods for estimating the airflow rate.

- Method 1 - Direct air measurement[18]~~: Direct air~~: Airflow is determined by measuring it directly ~~with~~in the ~~duct itself or at grilles~~airflow using vane anemometers, hot-wire anemometers, pitot tubes, flow hoods, etc. ~~velocity measurements combined with air-grille dimensions times velocity (in feet per second) times 60 minutes per hour [CFM = (grill area ft²)x (airspeed in feet per minute)].~~
- Method 2 ~~:~~ Manufacturer fan charts: Airflow is determined using the manufacturer's specific ~~The technician may select an estimate of airflow using the manufacturer's~~ ~~estimated~~ fan charts ~~identified in the M&V plan.~~
- ~~Method 3: The technician uses a the manufacturer~~ fan charts for the tuned-up unit ~~to select an estimate of airflow~~. The fan chart ~~used~~ must be specific to the unit and provided in the documentation. ~~Generic fan charts or correlations are not allowed.~~

The ~~three~~ two methods for determining ~~AC~~AC/HP system airflow values following completion of the ~~AC~~AC/HP tune-up at test out are summarized in Table 10 below.

[18] Method 1 is required for projects used to determine the EL factor.

Table 10. AC/HPTU ~~ACTUs—AC~~ Air~~-~~flow Determination Methods ~~for Estimating Cooling Capacity~~ at Test-Out

Method for estimating ~~AC~~AC/HP airflow	Data source
Method 1: Direct air measurement ~~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)~~Direct air measurement device (e.g., vane anemometer, hot-wire anemometer, pitot tube)
Method 2~~ & 3~~: ~~Generic F~~fan charts	Use a generic or actual fan chart to select airflow (CFM) value based on the closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower Must be provided in documentation
~~**Method 3**: Manufacturer fan charts~~	~~Use the manufacturer fan chart to select airflow (CFM) value based on the closest match to:~~ • ~~External static pressure~~ • ~~Nominal tons~~ • ~~Blower speed~~ • ~~Belt horsepower~~

Table 11. AC/HPTU ~~ACTUs—~~EER Adjustment Factor and Capacity Adjustment Factor Constants

EER adjustment factor and capacity adjustment factor constants[19]	
$C_1 = 1.013421588$	$D_1 = 1.003933337$
$C_2 = 0.017697661$	$D_2 = 0.016648337$
$C_3 = -0.006686796$	$D_3 = -0.017096426$
$C_4 = -0.000931159$	$D_4 = -0.000933205$
$C_5 = 8.04838 \times 10^{-5}$	$D_5 = 0.000222327$
$C_6 = -3.59283 \times 10^{-5}$	$D_6 = -0.000169511$

Table 12. ~~ACTUs—~~Tune-Up Constants for Saturation Pressure Over Liquid Water Calculation

Saturation pressure over liquid water constants[20]	
$C_8 = -1.0440397 \text{ E} + 04$	$C_{11} = 1.2890360 \text{ E} - 05$
$C_9 = -1.1294650 \text{ E} + 01$	$C_{12} = -2.4780681 \text{ E} - 09$
$C_{10} = -2.7022355 \text{ E} - 02$	$C_{13} = 6.5459673 \text{ E} + 00$

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

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

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein require the use of equipment in accordance with the toolkit (with specified manufacturer and model numbers) to measure key AC performance parameters in the field. The use of these tools or equivalent ensures consistent data acquisition conformance by all parties. The equipment required in the toolkit is shown in Table 8 for reference.

Table 8. AC Tune-Up Toolkit Components

Device	Use area	Quantity
Approved digital refrigerant analyzer: • Testo 556 • Testo 560 • Testo 550 • iManifold 913-M and 914-M	Refrigerant charge adjustment Refrigerant pressure Refrigerant temperature Superheat Subcooling	1-2
Testo 318-V Inspection Scope	Visual coil inspection	Optional
Spring clamp probes matched to the Testo A/C Analyzer	Refrigerant line temperatures	2
Testo 417 Large Vane Anemometer	Airflow	1
Testo 605-H2 Humidity Stick Or iManifold 911-M	Supply and return air wet-bulb temperature	2
Refrigeration hoses 5' NRP 45 Deg.	Refrigerant pressure	Set of 3
Charging calculator (R-22)	Refrigerant charge	1
Charging calculator (R-410A)	Refrigerant charge	1
Testo 905-T1 Temperature Stick or Testo 605H Humidity stick Or iManifold 912-M or wired outdoor air temperature probe	Ambient air temperature	1
Testo 510 Compact Digital Manometer (or other digital manometer of comparable accuracy)	Static pressure	1
Magnetic static pressure tips	Static pressure	2
Set of barbed hose tees	Static pressure	1
1/8 mpt x barbed fitting	Static pressure	1
10' silicone tubing	Static pressure	1
Digital volt/amp Meter	Voltage and current	1
Ruler/tape measure	Duct and grill dimensions	1
Tablet computer or smartphone if using iManifold; OR: laptop or desktop to use for data entry if using the Testo kit components	AC tune-up application	1

Metering Schedule

A complete metering schedule identifying the AC tune-up process and measurements performed for AC tune-ups is presented in the M&V Metering Schedule. The technician follows the metering schedule during the tune-up process.

Equipment Accuracy

The accuracy for each required piece of metering equipment is shown in Table 9.

Table 9. Measurement Resolution and Accuracy

Device	Model number	Measurement	Resolution	Accuracy
Inspection scope	Testo 318-V	Visual coil inspection	N/A	N/A
Anemometer	Testo 417[21]	Airflow velocity	0.01m/s	±0.1m/s+1.5% of reading
Manometer	Testo 510[6]	Differential pressure	0.01 inH2O	±0.01 inH2O (0-0.12 inH2O), ±0.02 inH2O (0.13-0.40 inH2O), ±(0.04 inH2O +1.5 % of reading) (rest of range)
Refrigerant system analyzer	Testo 556[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 560[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 550[6]	Refrigerant temperature	0.1°F	±1.8°F + 1 digit
		Refrigerant pressure	0.1 psi	±0.75% Full Scale + 1 Digit
	iManifold 913-M and 914-M[22]	Refrigerant temperature	0.1°F	±0.4°F
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
DB/WB thermometer	Testo 605-H2[6]	Dry-/wet-bulb temperature	0.1°F	±0.9°F
	iManifold 911-M[7]		0.1°F	±0.4°F
Surface thermometer	Testo 905-T2[6]	Condenser ambient air temperature	0.1°F	±1.8°F (-58 to +212°F)
	iManifold 912-M[7]		0.1°F	±0.4°F
Volt/amp meter	Fluke 27-II[23]	Voltage	0.1 V	±(0.5% +3)
		Current	0.01 A	±(1.5% +2)
Ruler/tape measure	N/a	Air grill dimensions[24]	1/8 in	±1/16 in

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

Claimed Peak Demand Savings

The summer peak demand for Air Conditioning equipment in Volume 2 and vVolume 3 of the TRM is acceptable methodology for this measure. Winter peak demand can not be claimed for this measure.A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.Additional calculators or third-party software is acceptable but must be identified and clearly documented in the M&V Plan.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of residential and commercial ACAC/HP tune-ups is 5 years.[25]

Program Tracking Data and Evaluation Requirements

The implementation of this measure requires several program level documents to be available to the evaluation team:

- M&V Plan
- Efficiency Loss Factor determination analysis

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

- Decision/Action Type: Operation and maintenance (O&M)
- Most recent tune-up service date or confirmation that the system has not been serviced within the previous five years
- Climate zone or county
- Building type
- Equipment type
- Equipment manufacturer, model number, and serial number
- Equipment manufacture year (eligible systems must be at least five years old)
- Equipment-rated cooling and heating capacities
- Equipment cooling and heating efficiency ratings
- Refrigerant type
- Refrigerant adjustment (added/removed, weight, percent)
- Note which five remaining ACAC/HP tune-up services measures were completed

[25] 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.

- Invoice or proof of service
- Test-out mMeasured cooling capacity
- Test-out mMeasured power inputs
- Test-out mMeasured mass flow rate
- Motor type for condenser and blower
- All other operating measurements and parameters listed in the M&V protocolplan
- Implementer inspection reports
- Before and after tune-up pictures of components illustrating condition change due to cleanings for all residential units, representative sample of commercial units not receiving a test-in
- If Method 2 is used for measuring airflow, a copy of the generic fan chart with an annotation or description of how it was read
- If Method 3 2 is used for measuring airflow, a copy of the manufacturer's fan chart including the variables that were used to identify the airflow., with an annotation or description of how it was read

References and Efficiency Standards

Not applicable.

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition and applicable to the tune-up measure include the following:
- Updated demand and energy coefficients for all commercial HVAC systems.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

Relevant Standards and Reference Sources

- ASHRAE Fundamentals 2021 – Chapter 1: Psychrometrics
- ASHRAE 90.1-1999 (Residential Buildings)
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.

Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 13. ~~ACTUs—M&V~~ AC/HP Tune-Up Revision History

TRM version	Date	Description of change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match the layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Revised efficiency loss factors based on 2015 results. Added VFD motor types.
v5.0	10/10/2017	Removed reference to deemed efficiency loss factors. Added clarity to separate units by refrigerant charge adjustments and unit size/type. Updated table references.
v6.0	10/2018	No revision.
v7.0	10/2019	No revision.
v8.0	10/2020	No revision.
v9.0	10/2021	No revision.
v10.0	10/2022	No revision.
v11.0	10/2023	Added age requirement to eligibility. Removed pressure correlation equation and replaced with deemed pressure by climate zone. Added language describing efficiency loss factor determination in more detail and implementer/evaluator responsibilities. Added an additional airflow rate determination method. Added additional tracking system and documentation requirements. Added reference to ASHRAE Fundamentals Chapter 1.
v12.0	10/2024	Updated measure based on Section 3.2.1 of Volume 1 of the PY2023 IOU Energy Efficiency Report.

2.1.3 Ground Source Heat Pumps Measure Overview

TRM Measure ID: NR-HV-GH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V and whole facility measurement

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

Measure Description

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

Applicable GSHP efficient measure types include:

- Single-stage GSHP
- Multi-stage GSHP
- Closed loop GSHP
- Direct geoexchange (DGX)
- Open loop WSHP
- Water-to-air
- Water-to-water

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

High-efficiency conditions for GSHP equipment must meet applicable standards. AHRI ratings for EER and COP must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 14.

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

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

Table 14. GSHPs—Minimum Efficiency Levels for Commercial Single-Stage GSHPs[26]

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

[26] Values from ASHRAE 90.1-2013.

Energy and Demand Savings Methodology

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

A whole facility EM&V methodology presents a plan to determine energy savings from replacing an existing HVAC system with a new GSHP system to provide heating and cooling for a commercial facility. This methodology measures and verifies initial energy savings estimates. The plan follows procedures guided by whole facility Option C in the International Performance Measurement and Verification Protocol (IPMVP). The development of the whole facility measurement methodology creates and implements a framework to provide high-quality verified savings while keeping within the standards currently used by similar commercial heating, ventilating, and air conditioning (HVAC) measures in TRM Volume 3. The Whole Facility guidance is found in the latest version of the IPMVP Core Concepts EVO 10000-1:2022.

M&V Plan and M&V Report

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

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

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

- Measure intent
- Selected IPMVP option and measurement boundary
- Baseline - period, energy, and conditions
- Reporting period
- Basis for adjustment
- Analysis procedure
- Energy prices (as applicable)
- Meter specifications
- Monitoring responsibilities
- Expected accuracy

- Budget (as applicable)
- Report format
- Quality assurance

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

$$\text{Peak } Demand\ Savings\ (kW)^{27} = kW_{Baseline} - kW_{New}$$

Equation 23

Where:

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

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

Equation 24

Where:

$kWh_{Baseline}$	=	*Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year*
kWh_{New}	=	*Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year*

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

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

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

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

Equation 25

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

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

Equation 26

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

Equation 27

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

Equation 28

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

Equation 29

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 30

Where:

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

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

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

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(must exceed baseline efficiency standards in Table 14) [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 14) [COP]*

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

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for GSHPs is 24 years.

This value is consistent with the minimum life expectancy reported in the Department of Energy GSHP guide.[28]

Program Tracking Data and Evaluation Requirements

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

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

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

- Baseline equipment rated cooling and heating capacities
- Baseline equipment cooling and heating efficiency ratings
- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- New equipment type (water-to-air, brine-to-air, water-to-water, brine-to-water)
- New equipment loop type (water, ground, groundwater)
- New equipment number of units
- New equipment rated cooling and heating capacities
- New equipment make and model
- ENERGY STAR or AHRI certificate matching new unit model number
- Installed cooling and heating efficiency ratings

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 15. GSHPs—~~M&V Ground Source Heat Pumps~~ Revision History

TRM version	Date	Description of change
v3.1	11/05/2015	TRM v3.1 origin.
v4.0	10/10/2016	No revision.
v5.0	10/10/2017	No revision.
v6.0	10/2018	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.
v7.0	10/2019	No revision.

TRM version	Date	Description of change
v8.0	10/2020	No revision.
v9.0	10/2021	Estimated useful life changed from 15 to 20 years for consistency with Volume 2.
v10.0	10/2022	No revision.
v11.0	10/2023	Updated program tracking and documentation requirements.
v12.0	10/2024	No revision.

2.1.4 Variable Refrigerant Flow Systems Measure Overview

TRM Measure ID: NR-HV-VR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Early retirement (ER), replace-on-burnout (ROB), and new construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V and whole facility measurement, calculator

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

Measure Description

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

Applicable VRF efficient measure types include:

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

Eligibility Criteria

- This measure applies to replacing an existing HVAC system with a new VRF system or a new construction VRF system.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[29,30]

Baseline Condition

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

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

High-Efficiency Condition

High-efficiency conditions for VRF equipment must meet applicable standards as specified in Table 16. Minimum efficiency requirements are established in ASHRAE 90.1-2013.[31] The minimum part-load efficiency requirements for units > 65,000 btuh ~~have been increased to~~ reflect the current federal standard, effective ~~May 30, 2023, with a manufacturing compliance date of~~ January 1, 2024.[32] Units < 65,000 Btuh are expected to comply with current federal standards for consumer products.

AHRI energy ratings for EER and COP, by manufacturer model numbers, follow required test protocols and parameters and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements from Table 16. Both air-cooled and water-cooled systems are rated per AHRI Standard 1230.

[29] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[30] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
[31] ASHRAE Standard 90.1-2013. Table 6.8.1-9.
[32] US Department of Energy (DOE) federal minimum efficiency standard for 65,000-759,000 Btuh systems. 10 CFR 431.97. https://www.regulations.gov/document/EERE-2018-BT-STD-0003-0080.
[33] US Department of Energy (DOE) federal minimum efficiency standard for < 65,000 Btuh systems, 10 CFR 430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

Table 16. VRF HVAC—Federal Standard Minimum Efficiency Requirements ~~for Electrically Operated VRF ACs and HPs~~

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[34]
VRF air conditioners, air-cooled	< 45,000	All	VRF multi-split system	11.7 EER2 14.3 SEER2	DOE Standards
	≥ 45,000 and < 65,000	All		11.2 EER2 13.8 SEER2	
	≥ 65,000 and < 135,000	None or electric resistance		11.2 EER 15.5 IEER	DOE Standards and ASHRAE 90.1-2013
	≥ 135,000 and < 240,000			11.0 EER 14.9 IEER	
	≥ 240,000 and < 760,000			10.0 EER 13.9 IEER	
	≥ 760,000			10.0 EER 11.6 IEER	ASHRAE 90.1-2013
VRF air-cooled (cooling mode)	< 65,000	All	VRF multi-split system	11.7 EER2 14.3 SEER2	DOE Standards
	≥ 65,000 and < 135,000	None or electric resistance	VRF multi-split system	11.0 EER 14.6 IEER	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system with heat recovery	10.8 EER 14.4 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system	10.6 EER 13.9 IEER	
			VRF multi-split system with heat recovery	10.4 EER 13.7 IEER	
	≥ 240,000 and < 760,000		VRF multi-split system	9.5 EER 12.7 IEER	
			VRF multi-split system with heat recovery	9.3 EER 12.5 IEER	
	≥ 760,000		VRF multi-split system	9.5 EER 10.6 IEER	ASHRAE 90.1-2013

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

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[34]
			VRF multi-split system with heat recovery	9.3 EER 10.4 IEER	
VRF water source (cooling mode)	< 65,000	All	VRF multi-split system 86⁰F entering water	12.0 EER 16.0 IEER	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system with heat recovery 86⁰F entering water	11.8 EER 15.8 IEER	
	≥ 65,000 and < 135,000		VRF multi-split system 86⁰F entering water	12.0 EER 16.0 IEER	
			VRF multi-split system with heat recovery 86⁰F entering water	11.8 EER 15.8 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system 86⁰F entering water	10.0 EER 14.0 IEER	
			VRF multi-split system with heat recovery 86⁰F entering water	9.8 EER 13.8 IEER	
	≥ 240,000 and < 760,000		VRF multi-split system 86⁰F entering water	10.0 EER 12.0 IEER	
			VRF multi-split system with heat recovery 86⁰F entering water	9.8 EER 11.8 IEER	

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Efficiency requirements	Source[34]
	≥ 760,000		VRF multi-split system 86°F entering water	10.0 EER	ASHRAE 90.1-2013
			VRF multi-split system with heat recovery 86°F entering water	9.8 EER	
VRF air-cooled (heating mode)	< 65,000 (cooling capacity)		VRF multi-split system	7.5 HSPF2	DOE Standards
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multi-split system 47°F db/43°F wb outdoor air	3.3 COP_H	DOE Standards and ASHRAE 90.1-2013
			VRF multi-split system 17°F db/15°F wb outdoor air	2.25 COP_H	
	≥ 135,000 (cooling capacity)		VRF multi-split system 47°F db/43°F wb outdoor air	3.2 COP_H	
			VRF multi-split system 17°F db/15°F wb outdoor air	2.05 COP_H	
VRF water source (heating mode)	< 135,000 (cooling)	None	VRF multi-split system 68°F entering water with and without heat recovery	4.3 COP_H	DOE Standards and ASHRAE 90.1-2013
	≥ 135,000 and < 240,000 (cooling)			4.4 COP_H	
	≥ 240,000 and < 760,000 (cooling)			3.9 COP_H	
	≥ 760,000 (cooling)			3.9 COP_H	ASHRAE 90.1-2013

Energy and Demand Savings Methodology

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

A whole facility EM&V methodology presents a plan to determine energy savings from replacing an existing HVAC system with a new VRF system to provide heating and cooling for a commercial facility. This methodology measures and verifies initial energy savings estimates. The plan follows procedures guided by whole facility Option C in the International Performance Measurement and Verification Protocol (IPMVP). The development of the whole facility measurement methodology is driven by the desire to create and implement a framework to provide high quality, verified savings while keeping within the standards currently used by similar commercial heating, ventilating, and air conditioning (HVAC) measures in TRM Volume 3. The Whole Facility guidance is found in the latest version of the IPMVP Core Concepts EVO 10000-1:2022.

M&V Plan and M&V Report

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

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

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

- Measure intent
- Selected IPMVP option and measurement boundary
- Baseline—period, energy, and conditions
- Reporting period
- Basis for adjustment
- Analysis procedure
- Energy prices (as applicable)
- Meter specifications
- Monitoring responsibilities
- Expected accuracy

- Budget (as applicable)
- Report format
- Quality assurance

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

$$Peak\ Demand\ Savings\ (kW)^{35} = kW_{Baseline} - kW_{New}$$

Equation 31

Where:

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

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

Equation 32

Where:

$kWh_{Baseline}$	=	*Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year*
kWh_{New}	=	*Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year*

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

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

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

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

Equation 33

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

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

Equation 34

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

Equation 35

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

Equation 36

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

Equation 37

Note: Use EER as efficiency value for kW savings calculations and SEER/IEER and COP as efficiency value for kWh savings calculations. The COP expressed for units > 65,000 Btu/h is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

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

Equation 38

Where:

$Cap_{pre,C/H}$	=	*Rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions [Btuh]*
$Cap_{post,C/H}$	=	*Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions [Btuh]*
$\eta_{pre,C}$	=	*Cooling efficiency of existing equipment [Btu/W] (i.e., EER_{pre})*
$\eta_{post,C}$	=	*Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(must exceed baseline efficiency standards in* Table 16*) [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 16*) [COP]*

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

Deemed Energy and Demand Savings

For new construction, renovation, or existing system replacements (as an alternative compliance path), the use of a deemed savings procedure is available for claiming VRF system efficiency above code minimum efficiencies. The methodology is identical to TRM Volume 3 split system/single packaged air conditioners and heat pumps by substituting the efficiencies from Table 16Table 16 as the baseline efficiencies for the new construction and replace on burnout energy and demand savings methodology.

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for commercial split and packaged air conditioners and heat pumps is 15 years.[36]

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

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: ER, ROB, NC, system type conversion
- Building type
- System type (VRF AC, VRF HP air-cooled, VRF HP water-source)
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed number of units
- Installed equipment type
- Installed rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For other building types only**: Description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-9 through Table 6.8.1-10.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

ANSI/AHRI Standard 1230, 2010 Standard for Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment, http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/ANSI/ANSI_AHRI_Standard_1230_2010_with_Add_2.pdf.

Document Revision History

Table 17. VRF HVAC—~~M&V Variable Refrigerant Systems~~ Revision History

TRM version	Date	Description of change
v5.0	10/10/2017	TRM v5.0 origin.
v6.0	10/2018	Minor formula corrections.
v7.0	10/2019	No revision.
v8.0	10/2020	Added DOE CCMS certification to eligibility list
v9.0	10/2021	No revision.
v10.0	10/2022	Clarify no M&V plan requirement for deemed path. Add system type to tracking requirements.
v11.0	10/2023	Updated baseline conditions to match federal regulations.
v12.0	10/2024	Clarified language about current VRF federal standard effective date.

2.1.5 Dedicated Outdoor Air Systems Measure Overview

TRM Measure ID: NR-HV-DO

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

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

Program Delivery Type: ~~Custom~~Prescriptive

Deemed Savings Type: ~~Not applicable~~Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

This protocol is used to stipulate savings for dedicated outdoor air systems (DOAS) measures. The development of the DOAS methodology is driven by the desire to create and implement a framework to provide high-quality verified savings while not restricting the ability of program implementers to use the tools and systems they developed.

Measure Description

This measure stipulates a savings methodology for the installation of a direct-expansion dedicated outdoor air system (DX-DOAS), either as a new construction or replacing an existing heating, ventilating, and air conditioning (HVAC) system.

Applicable DOAS efficient measure types include:

- Air-cooled systems with or without ventilation energy recovery
- Air-source heat pumps with or without ventilation energy recovery
- Water-cooled systems with or without ventilation energy recovery
- Water-source heat pumps with or without ventilation energy recovery

Eligibility Criteria

- This measure applies to replacing an existing HVAC fresh air intake ~~system~~ with ~~a~~ new DOAS ~~system~~ equipment or a new construction/~~or~~ major retrofit HVAC system that includes DOAS ~~system~~.
- Equipment must comply with the current DOE federal rule on minimum efficiency requirements for DOAS units.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[37,38]

[37] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[38] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

Baseline Condition

For both retrofit and new construction applications, the baseline condition for dehumidification applications is the current federal standard for integrated seasonal moisture removal efficiency 2 (ISMRE2). For heat pumps in heating mode, the baseline condition is the current federal standard for integrated seasonal coefficient of performance 2 (ISCOP2).

High-Efficiency Condition

Compliance with the minimum efficiency requirements specified in the federal rule is required as of May 1, 2024. High-efficiency conditions for DOAS equipment must exceed the standards as specified in Table 18Table 16.

DOAS systems are rated in ISMRE2 as per AHRI Standard 290. The federal rules also provide a minimum ISCOP2 for heating mode, but AHRI does not provide heating efficiency ratings for DOAS equipment so only dehumidification savings will be considered under this measure. ISMRE2 is a rating of moisture removal efficiency, in units of lbs of water removed per kilowatt-hour input.

Table 18. DOAS—Federal Standard for Direct Expansion DOAS ACs and HPs

System type	Subcategory	Efficiency requirements	Source[39]
DOAS air-cooled (dehumidification mode)	Without ventilation energy recovery	3.8 ISMRE2	DOE Standards
	With ventilation energy recovery	5.0 ISMRE2	
DOAS air-source heat pump (dehumidification mode)	Without ventilation energy recovery	3.8 ISMRE2	DOE Standards
	With ventilation energy recovery	5.0 ISMRE2	
DOAS water-cooled (dehumidification mode)	Without ventilation energy recovery	4.7 ISMRE2	DOE Standards
	With ventilation energy recovery	5.1 ISMRE2	
DOAS water-source heat pump (dehumidification mode)	Without ventilation energy recovery	3.8 ISMRE2	DOE Standards
	With ventilation energy recovery	4.6 ISMRE2	

[39] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR parts 429 and 431.

System type	Subcategory	Efficiency requirements	Source[39]
DOAS air-source heat pump (heating mode)	Without ventilation energy recovery	2.05 ISCOP2	DOE Standards
	With ventilation energy recovery	3.20 ISCOP2	
DOAS water-source heat pump (heating mode)	Without ventilation energy recovery	2.13 ISCOP2	DOE Standards
	With ventilation energy recovery	4.04 ISCOP2	

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

$$Summer\ Peak\ Demand\ Savings\ [kW_{Savings,C}] = \left(\frac{1}{ISMRE2_{Base}} - \frac{1}{ISMRE2_{Eff}}\right) \times MRC_A \times CF_S$$

Equation 39

$$Energy\ Savings\ [kWh_{Savings}] = \left(\frac{1}{ISMRE2_{Base}} - \frac{1}{ISMRE2_{Eff}}\right) \times MRC_A \times EFLH_C$$

Equation 40

Where:

$ISMRE2_{Base}$ = *Baseline integrated seasonal moisture removal efficiency, from federal standard [lbs/kWh] (see* Table 18Table 16)

$ISMRE2_{Eff}$ = *Rated equipment integrated seasonal moisture removal efficiency, from AHRI database [lbs/kWh]*

MRC_A = *Moisture removal capacity at point A[40], from AHRI database [lbs/hr]*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

[40] AHRI standard 290 outlines the test procedure to determine ISMRE2 ratings, which are a weighted average of MRE2 ratings at 4 operating points. Point A corresponds to an entering air dry bulb temperature of 95.0 °F and wet bulb temperature of 78.0 °F.

CF_C = *Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

Deemed Energy and Demand Savings

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for DOAS matches the commercial split and packaged air conditioners and heat pumps ~~is~~ of 15 years.[41]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: RTR, NC, system type conversion
- Building type
- Cooling s~~S~~ystem type (AC, ~~VRF~~ HP air-cooled, ~~VRF~~ HP water-~~source~~cooled, chiller)
- Installed number of units
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- ~~Installed equipment type and subtype~~
- Installed rated moisture removal capacity at point A (MRC_A)
- Installed rated integrated seasonal moisture removal efficiency (ISMRE2)
- **For other building types only**: Description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

[41] 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.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- Code of Federal Regulations. Title 10. Parts 429 & 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.regulations.gov/document/EERE-2017-BT-STD-0017-0018
- AHRI Standard 290-2020 Performance Rating of Direct Expansion-Dedicated Outdoor Air System Units. https://www.ahrinet.org/system/files/2023-06/AHRI_Standard_920_I-P_2020_add1.pdf

Document Revision History

Table 19. DOAS—Revision History

TRM version	Date	Description of change
v12.0	10/2024	TRM 12 origin.

2.2 M&V: WHOLE HOUSE

2.2.1 Residential New Construction Measure Overview

TRM Measure ID: R-HS-NH

Market Sector: Residential

Measure Category: Whole house

Applicable Building Types: Single-family; manufactured

Fuels Affected: Electricity and gas

Decision/Action Types: New construction (NC)

Program Delivery Type: Custom

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

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

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

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

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

- BeOpt[42]
- Ekotrope
- REM Rate

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

- Hourly analysis programs tested in accordance with ASHRAE 140 and meeting the requirements of ASHRAE 90.1 Appendix G (i.e., DOE-2, EnergyPlus, HAP, TRACE, IESVS, etc.)[43]

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

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

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

Measure Description

The Residential New Construction measure promotes a holistic approach to achieve energy-efficient new homes, including a combination of envelope and equipment-based improvements. The energy savings estimates are designed to efficiently estimate electric energy and demand savings attributable to each participating new home.

Eligibility Criteria

This measure does not apply to existing construction: only residential new construction projects completed in a given program year are eligible.[44]

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

Baseline Condition[45]

Broadly, baseline conditions for the building system (e.g., envelope materials, fenestration characteristics) are set according to relevant codes and standards. For single-family detached homes and residential multifamily buildings three stories or less, these standards are detailed in the Residential Provisions of the relevant version of the International Energy Conservation Code (IECC) based on project location, metro, outside of metro, and rural~~IECC 2015~~. New construction projects in metro areas should utilize IECC 2021 while outside of metro areas should utilize IECC 2018 based on local code adoption and standard building practices

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

demonstrating IECC 2018 or higher. Utilities may utililize IECC 2015 in rural areas if proper documentation of code compliance is available. Utilities should work with the EM&V team to determine appropriate documentation required.

-As this protocol requires simulation modeling, the provisions of Section R405—Simulated Performance Alternative—are of particular importance. Accordingly, baseline parameters and key model input values for new single-family detached homes and residential multifamily buildings three stories or less are detailed in Table 20. Baseline parameters and key model input values for new residential multifamily buildings of more than three stories (and portions thereof/units within) are detailed in Table 21. Additionally, utilities should work with the EM&V team if interested in piloting a New Homes program using the the alternate code compliance path, Section R406 Energy Rating Index.

For larger multifamily buildings, the baseline conditions established herein reference the relevant sections of ASHRAE 90.1-2013 and the Commercial Provisions of IECC 2015. Federal manufacturing standards are reflected in the equipment efficiency requirements for space conditioning and water heating equipment. Additionally, the program requirements of reference programs for this market, such as the ENERGY STAR® New Homes, inform some baseline requirements.

Exception:[46] Multifamily buildings with 4 or 5 stories above-grade[47] where dwelling units occupy 80 percent or more of the occupiable square footage of the building may select the most appropriate baseline condition. When evaluating mixed-use buildings for eligibility, exclude commercial/retail space when assessing whether the 80 percent threshold has been met.

Table 20 and Table 21: When a new statewide energy code is adopted by the State Energy Conservation Office (SECO) or building standard practices or local code adoption are demonstrated as higher than statewide code, the baseline parameters for residential whole-house measures must be updated to reflect this change. When a new statewide code is adopted, Rrecognizing that it takes time for new energy codes to be locally adopted and enforced, this M&V methodology requires the new statewide code as a baseline for the next program year cycle, but not less than twelve months from the energy code effective date. Based on current market research, standard building practices demonstrate the effective code is at least IECC 2018. In addition, many local jurstictions have adopted IECC 2018 or IECC 2021. ~~Effective September 1, 2016, Texas adopted IECC 2015.[13] From a TRM perspective, the new construction baseline condition change is effective January 1, 2018.~~

If a baseline study has been conducted since the adoption of the current statewide code that demonstrates standard practice different than the statewide energy code, the researched baseline may be used as the baseline from which to claim savings for the researched jurisdiction(s) subject to the review and approval of the EM&V team. Baseline studies will be reviewed periodically to ensure they remain relevant to the current Texas market and new data may be required for continued use.

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

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

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

Ideally, the relevant energy code will be tracked in the program tracking system. Alternatively, it may be tracked as part of the project documentation made available to evaluators upon request. Changes to baseline conditions from Table 20 and Table 21 or changes to the implementation of baseline conditions within an approved modeling package are allowable and subject to EM&V team approval.

Table 20. RES NC—~~New~~ SF/~~ and~~ MF Construction up to Three Stories—Reference Home Characteristics

Baseline and dwelling parameters and characteristics	Reference home specification/value
Architecture	
Number of stories above grade 1	Same as as-built
Foundation type	Same as as-built
Number of bedrooms	Same as as-built
Total conditioned floor area	Same as as-built
Total conditioned volume	Same as as-built
Wall height per floor	Same as as-built
Window distribution (N, S, E, W)	Same as as-built
Percentage of window to floor area	Same as as-built
Front door orientation	Same as as-built
Aspect ratio (length/width)	Same as as-built
Envelope	
Slab R-value and depth	See IECC 2018~~5~~ Table R402.1.2 or IECC 2021 Table R402.1.3 Insulation and Fenestration Requirements by Component
Floor assembly U-Factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration Requirements
Frame wall assembly U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration Requirements~~See IECC 2015 Table R402.1.4 Equivalent U-factors~~
Mass wall assembly U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration Requirements~~See IECC 2015 Table R402.1.4 Equivalent U-factors~~
Basement wall assembly U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration Requirements~~See IECC 2015 Table R402.1.4 Equivalent U-factors~~

Baseline and dwelling parameters and characteristics	Reference home specification/value
Crawl space wall assembly U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration RequirementsSee IECC 2015 Table R402.1.4 Equivalent U-factors
Rim joist assembly U-factor	Same as wall U-Factor
Fenestration U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration RequirementsSee IECC 2015 Table R402.1.4 Equivalent U-factors
Skylight U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration RequirementsSee IECC 2015 Table R402.1.4 Equivalent U-factors
Glazed fenestration SHGC	See IECC 2018 Table R402.1.2 or IECC 2021 Table R402.1.3 Insulation and Fenestration Requirements by ComponentSee IECC 2015 Table R402.1.2 Insulation and Fenestration Requirements by Component
Window overhang	None
interior shading fraction	Same as as-built
Door U-factor	Same as fenestration U-factor
Ceiling assembly U-factor	See IECC 2018 Table R402.1.4 Equivalent U-factors or IECC 2021 Table R402.1.2 Maximum Assembly U-Factors and Fenestration RequirementsTable R402.1.4 equivalent U-factors
Ceiling type	Same as as-built, except when as-built is a sealed attic assembly, then vented attic
Roof radiant barrier	None
Roof solar absorptivity	0.75
Envelope testing	
Air infiltration	5 ACH_{50} in IECC 2015 2018 CZ 2, 3 ACH_{50} in IECC 2015 2018 CZ 3-4[48]

[48] Note: The climate zones in IECC 20182015 do not align with the climate zones assigned in the Texas TRM. IECC climate zones referenced in this section can be found here: https://codes.iccsafe.org/content/IECC2018/chapter-3-ce-general-requirementshttps://codes.iccsafe.org/content/IECC2018P5/chapter-3-ce-general-requirements.

Baseline and dwelling parameters and characteristics	Reference home specification/value
HVAC equipment	
HVAC equipment type	Same as as-built, except where as-built home has electric resistance heat, in which case the reference home shall have an air source heat pump[49]
HVAC equipment location	Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic
Cooling capacity	Same as as-built
Heating capacity	Same as as-built
Cooling efficiency (SEER2)	14.3 (15 SEER)
Heating efficiency (AFUE)	80% AFUE
Heating efficiency (HSPF2)—heat pump	7.5~~8.2~~ (8.8 HSPF)
Duct location	Exposed in a vented attic
Duct R-value	R-8[50]
Total duct leakage	4 CFM_{25} per 100 ft^2 of conditioned floor
Thermostat type	Programmable thermostat
Heating setpoint	72°F
Cooling setpoint	75°F
Mechanical ventilation type	Same as as-built or as specified in IECC 2018 Table R405.5.2 or IECC 2021 Table R405.4.2~~Same as as-built or as specified in IECC 2015 Table 405.5.2~~
Mechanical ventilation rate	Same as as-built
Mechanical ventilation hours/day	Same as as-built or as specified in IECC ~~2015~~ 2018 Table R405.5.2 or IECC 2021 Table R405.4.2
Mechanical ventilation fan watts	Same as as-built or as specified in IECC 2018 Table R405.5.2 or IECC 2021 Table R405.4.2~~Same as as-built or as specified in IECC 2015 Table 405.5.2~~

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

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

Baseline and dwelling parameters and characteristics	Reference home specification/value
HVAC commissioning	
Grade III (untested/commissioned by rater)[51]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[52] Type: Stand-alone dehumidifier of same type (portable or whole-home) as the Rated Home Capacity: Same as rated home Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows: 25.00 or less: 0.79 liters/kWh 25.01-35.00: 0.95 liters/kWh 35.01-54.00: 1.04 liters/kWh 54.01-74.99: 1.20 liters/kWh 75.00 or more: 1.82 liters/kWh Dehumidistat setpoint: 60 percent RH	Same as as-built
Water heating system	
DHW fuel type	Same as as-built
DHW water heater location	Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic
DHW capacity (gallons)	Same as as-built for storage-type units; assume a 40-gallon storage water heater when as-built water heater is instantaneous
DHW energy factor (UEF)	Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[53]) as of April 16, 2015

[51] ANSI/RESNET/ACCA 310-2020. Standard for Grading the Installation of HVAC Systems. June 23, 2020. https://www.resnet.us/wp-content/uploads/ANSIRESNETACCA_310-2020_v7.1.pdf.
[52] ANSI/RESNET/ICC 301-2019 Addendum B-2020, Clarifications, HVAC Quality Installation Grading, and Dehumidification – Mandatory January 1, 2022
[53] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. https://www.ecfr.gov/cgi-

Baseline and dwelling parameters and characteristics	Reference home specification/value
DHW pipe insulation	R-3
All bath faucets and showers ≤ 2gpm	No
Hot water recirculation system	No
Drain water heat recovery	No
Lighting	
Lighting	75 IECC 2018 - 90 percent high efficacy permanently-installed fixtures IECC 2021 – 100 percent high efficacy permanently-installed fixtures
LED lighting	None
Appliances	
Refrigerator	Reference home should be modeled with ANSI/RESNET/ICC 30 (most recent published version and ANSI addenda) reference default values, equivalent to federal standard efficiency appliances. As-built for homes without high-efficiency appliances should also use the ANSI/RESNET/ICC 301 (most recent published version and ANSI addenda) reference defaults. For modeled appliance savings, as-built should reflect high-efficiency appliances. Programs claiming prescriptive appliance savings using Volume 2 of the TRM should use standard-efficiency appliances for both reference and as-built.
Dishwasher	
Range/oven	
Clothes washer and dryer	
Ceiling fans	

Table 21. RES NC—New MultifamilyMF Buildings Greater than Three Stories—Baseline Characteristics

Baseline and dwelling parameter and characteristics	Baseline specification/value
Envelope	
Unit type	Multifamily building
Number of stories above grade 1	Same as as-built
Foundation type	Same as as-built
Number of bedrooms	Same as as-built
Total conditioned floor area	Same as as-built
Total conditioned volume	Same as as-built

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Baseline and dwelling parameter and characteristics	Baseline specification/value
Wall height per floor	Same as as-built
Window distribution (N, S, E, W)	Same as as-built
Percentage of window-to-floor area	Same as as-built
Front door orientation	Same as as-built
Aspect ratio (length/width)	Use the same estimated average aspect ratio for both baseline and as-built; however, it is recommended to use the actual aspect ratio when actual house footprint dimensions are available
Roof solar absorptivity	Same as as-built; when as-built data is not available, use 0.75
Attic insulation U-value	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Cathedral ceiling insulation U-value	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Percentage cathedral ceilings	Same as as-built
Wall construction	2x4 light gauge metal framing – 16 inch on center spacing
Wall framing fraction	23 percent
Wall insulation	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Door R-value	Same as as-built.
Floor insulation	ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Rim joist	Same as wall insulation
Window U-factor	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Window SHGC	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
Air infiltration	Same as proposed
Mechanical ventilation	See ASHRAE 90.1-2013, Appendix G
Slab edge insulation	See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone
HVAC equipment	
HVAC equipment type	See ASHRAE 90.1-2013, Table G3.1.1A/G3.1.1B
Cooling capacity	Same as as-built or simulated to reflect reference home load, not to exceed 20 percent difference
Heating capacity	Same as as-built or simulated to reflect reference home load, not to exceed 20 percent difference

Baseline and dwelling parameter and characteristics	Baseline specification/value
Cooling efficiency	See ASHRAE 90.1-2013, Section 6.8
Heating efficiency	See ASHRAE 90.1-2013, Section 6.8
Thermostat type	Same as as-built
Heating setpoint (occupied/unoccupied)	70°F/70°F
Cooling setpoint (occupied/unoccupied)	78°F/80°F
HVAC commissioning	
Grade III (untested/commissioned by rater)[54]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the rated home, in which case:[55] Type: Stand-alone dehumidifier of same type (portable or whole-home) as the rated home Capacity: Same as rated home Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows: 25.00 or less: 0.79 liters/kWh 25.01-35.00: 0.95 liters/kWh 35.01-54.00: 1.04 liters/kWh 54.01-74.99: 1.20 liters/kWh 75.00 or more: 1.82 liters/kWh Dehumidistat setpoint: 60 percent RH	Same as as-built
Water heating system	
DHW fuel type	Same as as-built

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

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

Baseline and dwelling parameter and characteristics	Baseline specification/value
DHW capacity (gallons)	Same as as-built for storage; assume a 50-gallon storage water heater when as-built water heater is instantaneous
Energy factor (EF)	See ASHRAE 90.1-2013, Table 7.8
DHW temperature	120°F
DHW pipe insulation	None
Low-flow showerheads	None
Lighting	
High-efficacy lamps	0.51 Watts per ft^2

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

House Simulation Modeling

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

Energy Savings Methodology

Energy savings are estimated using whole-building simulation modeling based on on-site specific data collection, such as those data collected by HERS raters or raters certified by other evaluated approved EPA-recognized Home Certification Organization.

Summer Demand Savings Methodology

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

Winter Demand Savings Methodology

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

Post-Processing for Calculating Demand and Energy Savings

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

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a new home measure is established at 23 years.

Program Tracking Data and Evaluation Requirements

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

- Date of issuance of building permit
- Statewide energy code under which the building was built
- Building envelope:
    - Dwelling unit type
    - House footprint dimensions
    - Number of stories above grade 1
    - Foundation type
    - Number of bedrooms
    - Total conditioned floor area
    - Total conditioned volume
    - Wall height per floor
    - Window distribution (N, S, E, W)
    - Front door orientation

- Aspect ratio (length/width)—when available
- Roof solar absorptivity—when available
- Attic insulation R-value
- Cathedral ceiling insulation R-value
- Percentage cathedral ceilings
- Ceiling insulation grade
- Wall construction
- Wall framing fraction
- Wall insulation (R-value)
- Wall insulation grade
- Door material (wood, metal, vinyl, and whether solid core or hollow)—when available
- Rim joist
- Window U-factor
- Window SHGC
- Air infiltration
- Mechanical ventilation
- Slab edge insulation—only for houses located in IECC Climate Zone 4

- HVAC equipment:
  - HVAC equipment type
  - AHRI number of installed HVAC equipment—in the absence of an AHRI number, manufacturers' cut sheets and/or make and model numbers should be provided instead.
  - Cooling capacity
  - Heating capacity
  - Cooling efficiency (SEER)
  - Heating efficiency (AFUE for gas, HSPF for heat pumps)
  - Duct location
  - Duct insulation R-value
  - Duct leakage to outside (CFA)
  - Heating set-point temperature(s) (°F)
  - Cooling set-point temperature(s) (°F)
  - Thermostat type (setback or no setback)
  - Supply fan power (W/CFM)

- Water heating system:
  - Water heating systems
  - AHRI number of installed water heating equipment—raters should verify the energy factor (EF) on-site during the final inspection; as part of the implementer QA/QC protocol, verify the AHRI information
  - DHW fuel type
  - DHW capacity (gallons)
  - Energy factor
  - DHW set-point temperature
  - DHW pipe insulation
  - Number of low-flow showerheads and flow rate
  - Number of low-flow faucets and flow rate
- Lighting:
  - Number of sockets with high efficacy lamps or lighting power density, as appropriate.
- Appliances:
  - Number of ceiling fans
  - Refrigerator model number
  - Dishwasher model number
  - Clothes washer presence
  - Clothes washer model number
- HVAC commissioning:
  - Grade
- Dehumidification system:
  - Type
  - Capacity
  - Efficacy
  - Dehumidistat setpoint

Files to Submit for EM&V Review

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

- Reports of QA/QC or M&V
- Documentation for how the as-built home compares to the base home including and building characteristics modeling and energy savings information
- Documentation showing relevant code compliance

- Relevant modeling files from the approved modeling package
- All input data used to support the modeled energy and peak demand savings, subject to EM&V team approval as part of modeling package approval
- Output results describing energy and peak demand savings, subject to EM&V team approval as part of modeling package approval
- Savings calculations and/or calculators that perform energy savings calculations outside the model

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- RESNET accredited software: http://www.resnet.us/professional/programs/energy_rating_software
- ASHRAE 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*
- ASHRAE 140, Standard Method of Test for the Evaluation of Building Energy Analysis Programs
- ENERGY STAR Multifamily High Rise Program Simulation Guidelines

International Code Council, ~~2015~~ *2018/2021 International Energy Conservation Code*.

Document Revision History

Table 22. RES NC—~~M&V Residential New Construction~~ Revision History

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

TRM version	Date	Description of change
v5.0	10/10/2017	Added provision for multifamily new construction.
v6.0	10/2018	No revision.
v7.0	10/2019	Added provision for multifamily new construction, updated baseline to reflect the adoption of IECC 2015.
v8.0	10/2020	For reference home specification, added IECC 2015 for mechanical ventilation and federal standard efficiency for appliances.
v9.0	10/2021	For reference home specification, added HVAC commissioning and dehumidification system.
v10.0	10/2022	Updated references to current relevant standards.
v11.0	10/2023	Added clarification on baseline study usage and clarified that RESNET accreditation is not required and utilities can request EM&V review and approval of new software.
v12.0	10/2024	Added pilot option for HERS index compliance path. Updated baseline to IECC 2018 or 2021.

2.2.2 Smart Home Energy Management Systems (SHEMS) Measure Overview

TRM Measure ID: R-HS-SH

Market Sector: Residential

Measure Category: Whole house

Applicable Building Types: Single-family; manufactured

Fuels Affected: Electricity and gas

Decision/Action Types: New construction and retrofit

Program Delivery Type: Custom

Deemed Savings Type: Look-up tables

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

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

Measure Description

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

Eligibility Criteria

The measure applies to all residential applications.

Baseline Condition

The baseline condition is assumed to be uncontrolled loads.

High-Efficiency Condition

The high-efficiency condition is loads controlled by SHEMS.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

Annual energy (kWh) savings are calculated as follows.

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

Equation 41

Where:

$kWh_{connected}$ = *Average annual energy consumption of lighting and plug loads connected to SHEMS (see Table 23)*

ERP = *Energy reduction percentage (see Table 23)*

IEF_E = *Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 24)*

ISR = *In-service rate, the percentage of incentivized units that are rebated, installed and in use (see Table 25); default = 0.97*

kWh_{SHEMS} = *Average annual standby energy consumption from hub and smart devices products. Default per hub = 7 kWh, and default per smart product = 2.2 kWh.*

Table 23. SHEMS: —Default Total Kilowatt–hour Connected and ERP Results[56]

Equipment	Average total kWh connected (kWh/yr)	Energy reduction percentage (ERP)
TV system	594	49.1%
Computer system	373	48.1%
Other plugs	168	48.8%
Lighting	506	48.7%
Whole home	1,641	48.7%
Upstream/midstream—smart switch	42	48.9%
Upstream/midstream—smart plug	189	48.9%

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

Table 24. SHEMS: —Interactive Effects for Cooling Energy Savings & Heating Energy Penalties[57]

IEF_E					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.06	1.13	1.17	1.15	1.12
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.91	1.00	1.05	1.11	0.97
Electric resistance heat with AC	0.65	0.80	0.90	1.00	0.75
Electric resistance heat with no AC	0.57	0.69	0.76	0.83	0.65
No heat with AC	1.06	1.13	1.17	1.15	1.12
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[58]	0.88	0.98	1.04	1.07	0.95

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

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

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

Table 25. SHEMS—In-Service Rates by Program Type

Program type	ISR
Low-income community kits[59]	0.88
All other kit programs[60]	0.60
Retail (time of sale)[61]	0.76
Midstream/upstream	
Direct install[62]	0.97

Demand Savings

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

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

Equation 42

Where:

$Hours$ = *Annual hours per year controlled by SHEMS[63]; (Ddefault = 4,380[64])*

CF = *Coincidence factor (see Table 26)*

[59] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[60] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[61] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[62] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

[63] Estimated based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hours/day, or 1,936 hours/year) and half during standby hours (8,760-1,936 = 6,824 hours/year). The resulting weighted average is 4,380 hours/year. Same as APS measure.

[64] Estimated based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hours/day, or 1,936 hours/year) and half during standby hours (8,760-1,936 = 6,824 hours/year). The resulting weighted average is 4,380 hours/year. Same as APS measure.

Table 26. SHEMS—Coincidence Factors[65]

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

Upstream/Midstream Program Assumptions

Upstream/midstream delivery of SHEMS should generally follow the same guidance to calculate savings using the Unknown (per Smart Switch) and Unknown (per Smart Plug) default assumptions for $kWh_{connected}$ and ERP, provided in Table 23.

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for SHEMS is 10 years.

Program Tracking Data and Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked to inform the evaluation and apply the savings properly:

- Climate zone or county
- Quantity of smart products installed
- Kilowatt-hours of connected or system group type
- Heating system type (gas, electric resistance, heat pump), if known
- Cooling system type (air conditioner, evaporative, none), if known

[65] See Volume 1, Section 4. Values taken from residential *advanced power strips* measure.

- Program delivery type
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 27. SHEMS: —Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM 10.0 origin.
v11.0	10/2023	No revision.
v12.0	10/2024	Added ISRs from Volume 2 residential lighting measures.

2.3 M&V: BUILDING ENERGY CODES

2.3.1 Residential Energy Code Compliance Enhancement Measure Overview

TRM Measure ID: R-EC-RC

Market Sector: Residential

Measure Category: Energy code compliance enhancement

Applicable Building Types: All residential

Fuels Affected: Electricity

Decision/Action Types: New construction

Program Delivery Type: Custom

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

Savings Methodology: Custom

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Market Baseline

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

The baseline is established through an in-field study or studies to examine the current state of newly constructed buildings and major renovations by conducting site visits to collect information that assesses building practices and energy-consuming equipment. The baseline study must target single-family and multifamily residential building types for that evaluation cycle, maintaining relative precision values below 20 percent (85 percent confidence interval) for relevant building types.[66]

Potential Energy Savings

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

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

Compliance Adjustment Factor (CAF)

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

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

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

Gross Code Energy Savings

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

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

Naturally Occurring Market Adoption (NOMA)

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

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

Net Code Energy Savings

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

Attribution Factor (AF)

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

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

Allocation

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

Delphi Panel Overview

A Delphi panel is an acceptable data collection method to inform the development of factors in the savings framework. The panel is expected to consist of 10–15 industry experts, including builders, raters, engineers, code officials, consultants, and academics, preferably from the relevant jurisdiction(s). The panel should access all relevant and necessary information in the implementation plan and supporting documentation; including baseline study results, new construction and major renovation data, survey responses, and all evidence collected by the utility to support its energy compliance enhancement efforts. For more information on the Delphi process, see the Illinois TRM v10, Vol. 4, Section 6.6.[67]

Energy Savings Methodology

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

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

Equation 43

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

Equation 2

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

Equation 3

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

Equation 4

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

Equation 5

Where:

CAF	=	*Compliance adjustment factor*
NOMA	=	*Naturally occurring market adoption*
AF	=	*Attribution factor*

[67] 2022 Illinois Statewide Technical Reference Manual, v10.0, Volume 4, Section 6.6: Structured Expert Judgment Approaches. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010122_v10.0_Vol_4_X-Cutting_Measures_and_Attach_09242021.pdf.

Summer Demand Savings Methodology

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

Winter Demand Savings Methodology

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

Building Population

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

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

Deemed Energy and Demand Savings Tables

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type

- Building population
- Building area
- Building code jurisdiction
- Compliance enhancement activity log

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

- Market baseline
- Relevant standards
- Potential energy savings
- Gross energy savings
- Net energy savings
- Compliance adjustment factor
- Naturally occurring market adoption
- Allocation factor
- Allocation
- Building population factors

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 28. RES Code Compliance—~~Residential Energy Code Compliance~~ Revision History

TRM version	Date	Description of change
v10.0	11/2022	TRM 10.0 origin
v11.0	10/2023	Adjusted calculation process to estimate building population.
v12.0	10/2024	No revision.

2.4 M&V: RENEWABLES

2.4.1 Residential Solar Photovoltaics (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

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

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

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

Savings Methodology: Model-calculator (PVWatts®)

Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. The primary objective of these programs is to achieve cost-effective energy savings and peak demand savings. Participation in the solar photovoltaic program involves the installation of a PV system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts Calculator[68], to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

Not applicable.

[68] PVWatts Calculator: http://pvwatts.nrel.gov/.

Energy and Demand Savings Methodology

All PV systems shall be modeled using the current version of the NREL PVWatts calculator. Energy savings are estimated using the default weather data source (currently TMY2) offered by PVWatts®.[69] Demand savings use lookup tables derived from PVWatts, which uses the NREL National Solar Radiation Database (NSRDB) weather data sources for the location of the project.

Savings Algorithms and Input Variables

All Installations

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

- Installation address: Use the complete site address, including the five-digit ZIP code.
- Weather data file: Default NSRDB data is a detailed grid of solar radiation throughout Texas (and North America), identified as a blue square in the map (see Figure 2).
- Direct current (DC) system size (kW): Enter the sum of the DC power rating of all photovoltaic modules in the array at standard test conditions (STC) in kilowatts DC.
    - 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 29. RES Solar PV—Module Type Options

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

- Array type: Fixed (open rack), fixed (roof mount), one-axis tracking, one-axis backtracking, two-axis tracking.
- Tilt (deg): Enter the angle from horizontal of the photovoltaic modules in the array.
- Azimuth (deg): Enter the angle clockwise from true north, describing the direction that the array faces.
- Shading: Accept the PVWatts default values as the minimum shading[70] or adjust the shading percentage only if the actual conditions exceed this value.

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

- DC to AC size ratio: Adjust to match the equipment or use the default.
- Bifacial: Adjust to match installed equipment.
- All other input variables: Accept the PVWatts default values.

Annual Energy Savings (kWh)

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

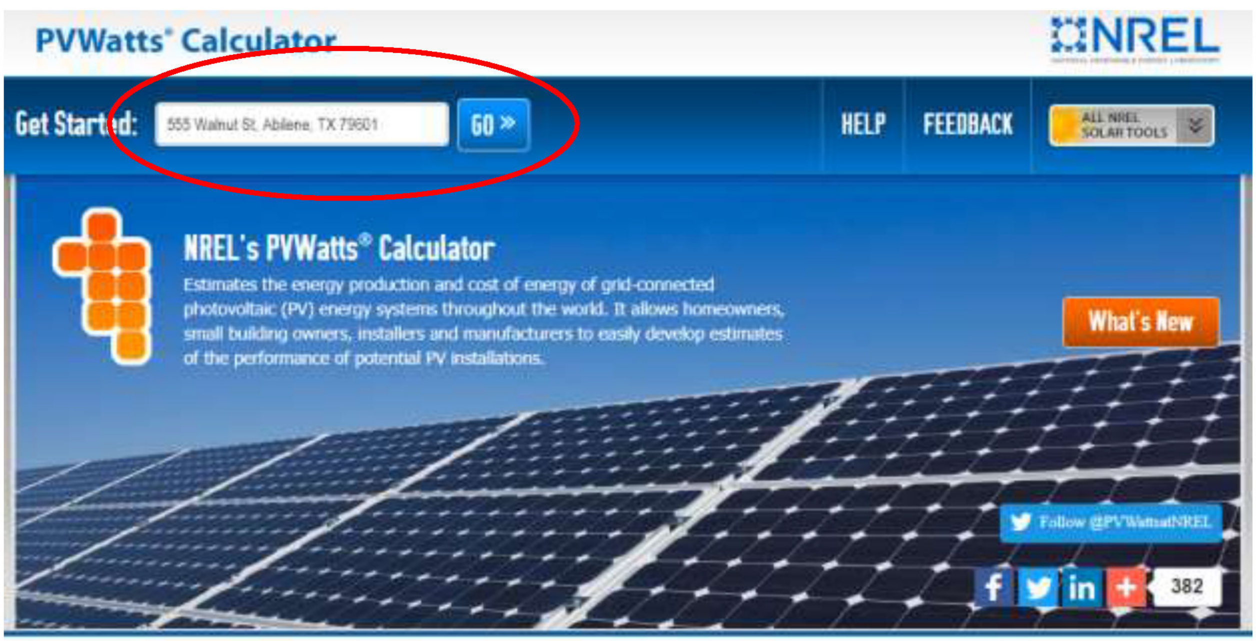
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain the total annual energy savings.

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

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

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

Figure 1. RES Solar PV—PVWatts Input Screen for Step 1



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

Figure 2. RES Solar PV—PVWatts Resource Data Map

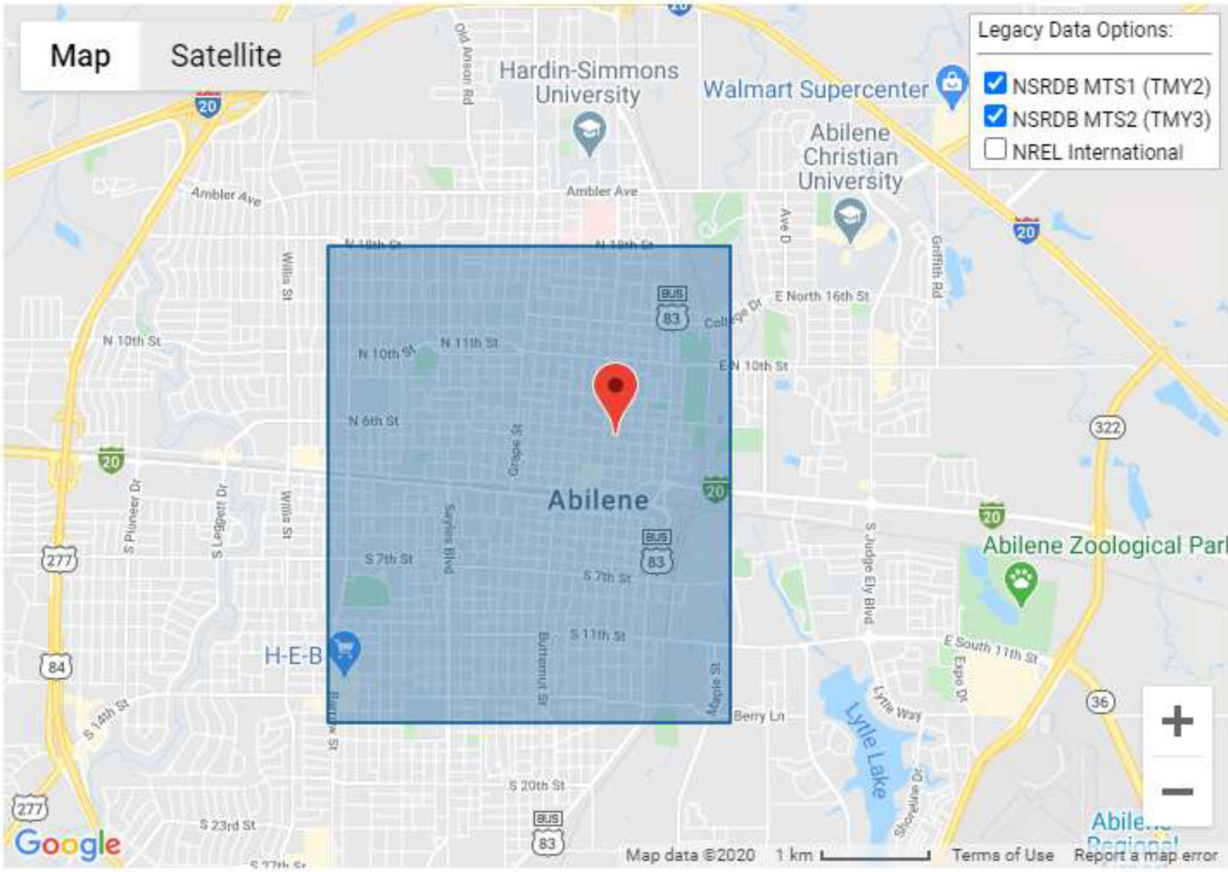
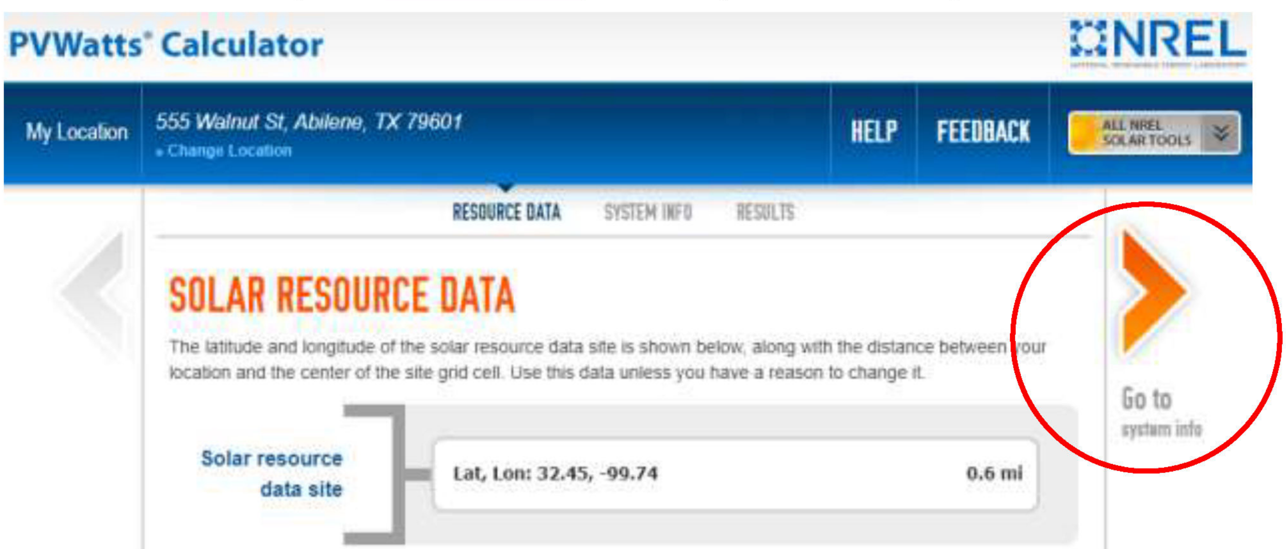


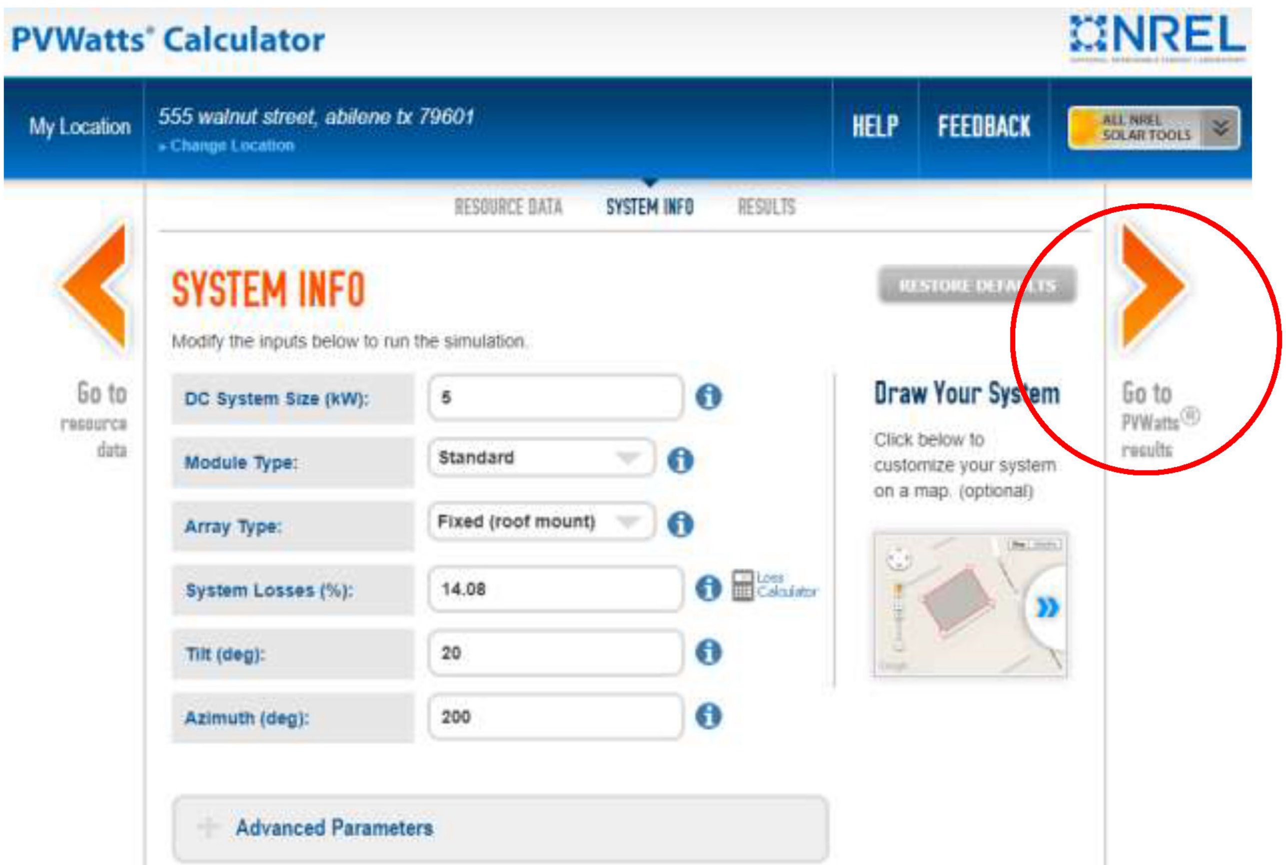
Figure 3. RES Solar PV—PVWatts Input Screen for Step 2



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

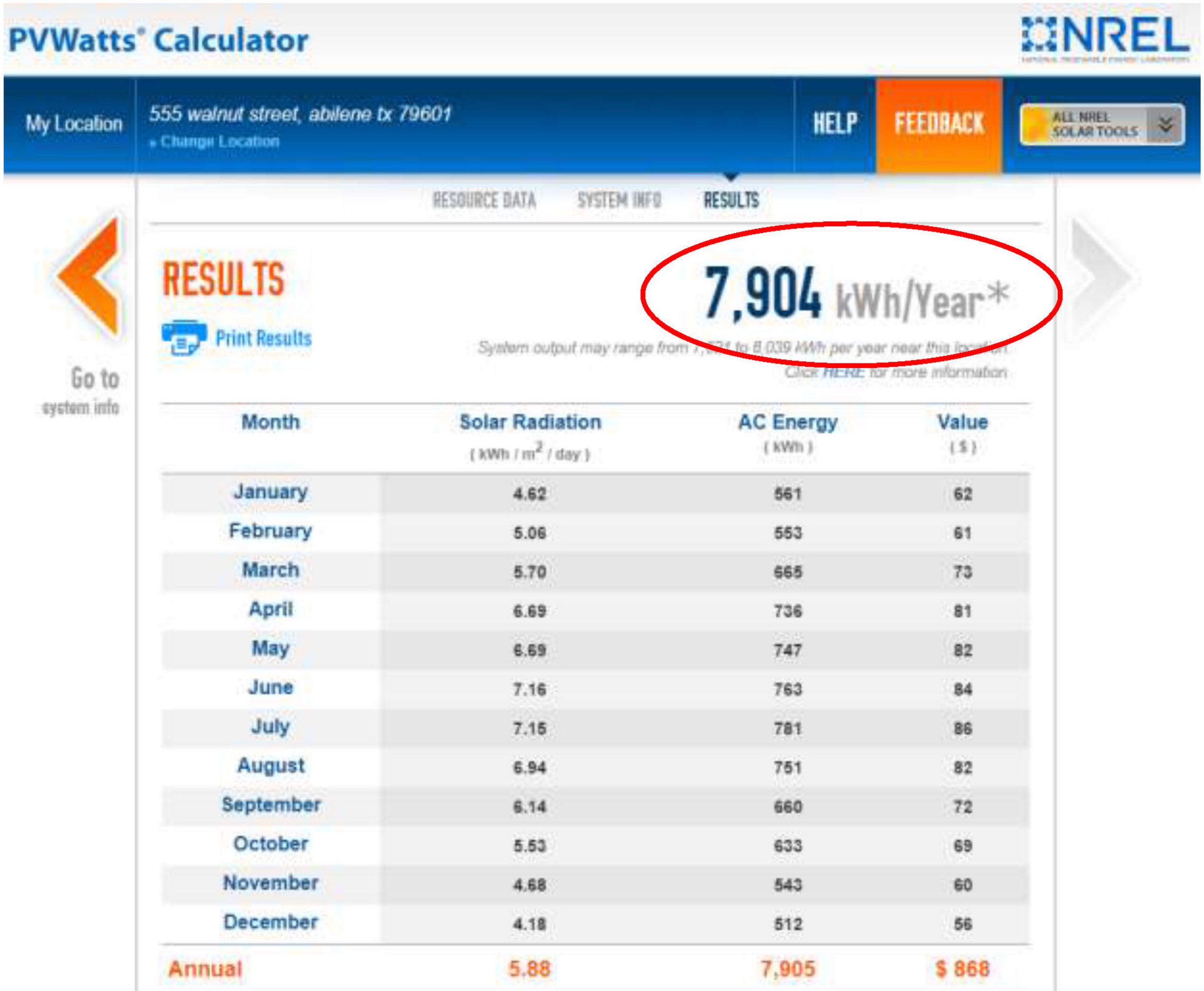
All other details (*System Losses*, *Advanced Parameters*, and *Initial Economics*) are left at default values. Once entered, the user presses "Go to PVWatts results." See Figure 4 below.

Figure 4. RES Solar PV—PVWatts Input Screen for Step 3



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

Figure 5. RES Solar PV—PVWatts Output Screen for Step 4



Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	4.62	561	62
February	5.06	553	61
March	5.70	665	73
April	6.69	736	81
May	6.69	747	82
June	7.16	763	84
July	7.15	781	86
August	6.94	751	82
September	6.14	660	72
October	5.53	633	69
November	4.68	543	60
December	4.18	512	56
Annual	5.88	7,905	$ 868

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

Figure 6. RES Solar PV—PVWatts Output Screen for Step 4 (continued)

Location and Station Identification	
Requested Location	555 walnut street, abilene tx 79601
Weather Data Source	Lat, Lon: 32.45, -99.74 0.6 mi
Latitude	32.45° N
Longitude	99.74° W
PV System Specifications *(Residential)*	
DC System Size	5 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	20°
Array Azimuth	200°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2
Economics	
Average Retail Electricity Rate	0.110 $/kWh
Performance Metrics	
Capacity Factor	18.0%

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

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

Summer Demand Savings Methodology

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

Deemed Summer Demand Savings

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

Equation 44

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

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

Winter Demand Savings Methodology

Deemed winter demand savings are determined using the weather zone map (Figure 7) and winter demand savings lookup values tables (Table 30 through Table 39) provided below. Deemed winter demand savings are the product of the system's DC system size and the appropriate lookup table value.

Deemed Winter Demand Savings

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

Equation 45

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

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

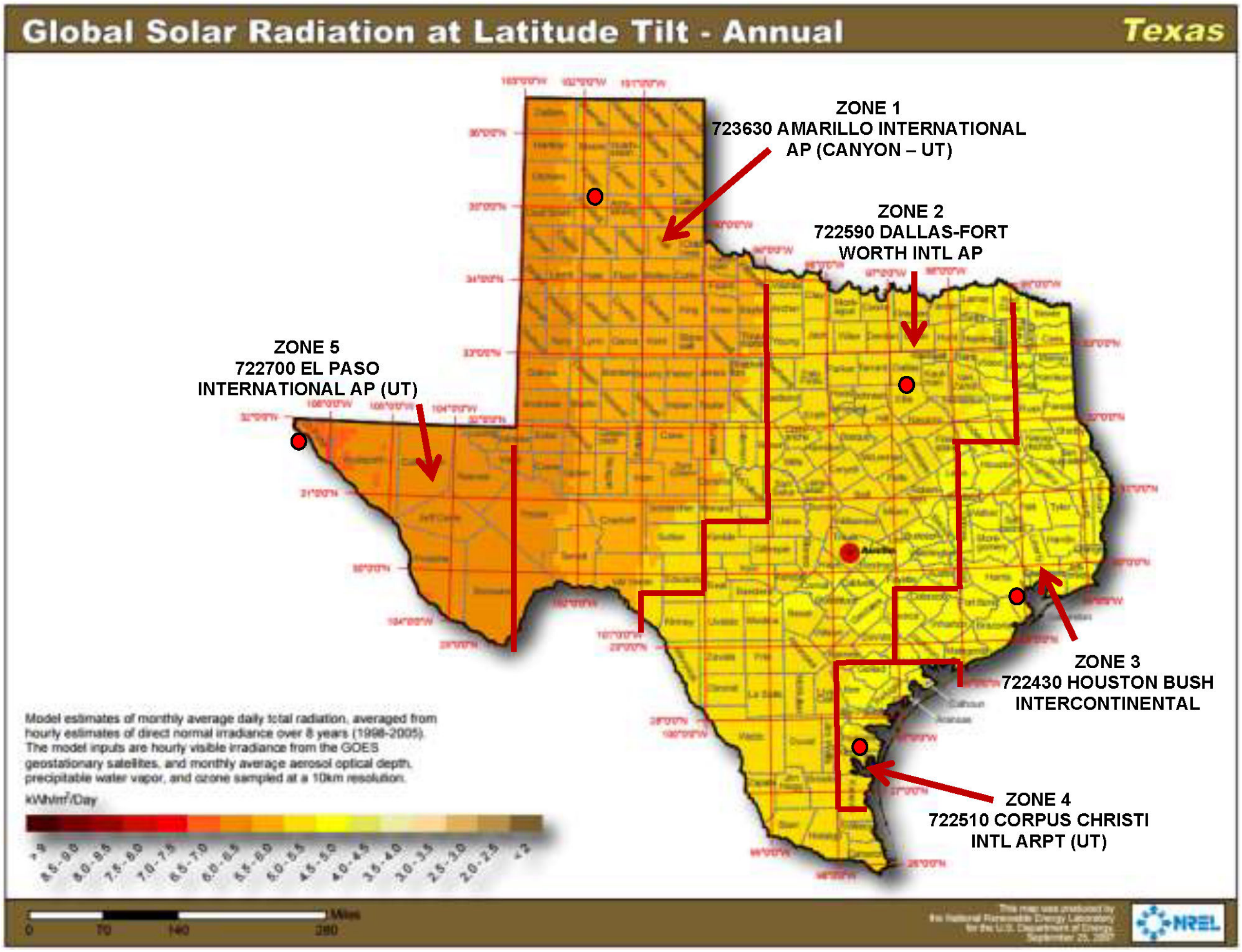
Deemed Energy Savings Tables

Not applicable.

Deemed Summer and Winter Demand Savings—Weather Zone Determination

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

Figure 7. RES Solar PV—Weather Zone Determination for Solar PV Systems[71]



Deemed Summer and Winter Demand Savings—Lookup Value Tables

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

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

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

Table 30. RES Solar PV—Climate Zone 1: Amarillo—Summer Demand kW Savings

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

Table 31. RES Solar PV—Climate Zone 1: Amarillo—Winter Demand kW Savings

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

Table 32. RES Solar PV—Climate Zone 2: Dallas—Summer Demand kW Savings

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

Table 33. RES Solar PV—Climate Zone 2: Dallas—Winter Demand kW Savings

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

Table 34. RES Solar PV—Climate Zone 3: Houston—Summer Demand kW Savings

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

Table 35. RES Solar PV—Climate Zone 3: Houston—Winter Demand kW Savings

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

Table 36. RES Solar PV—Climate Zone 4: Corpus Christi—Summer Demand kW Savings

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

Table 37. RES Solar PV—Climate Zone 4: Corpus Christi—Winter Demand kW Savings

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

Table 38. RES Solar PV—Climate Zone 5: El Paso—Summer Demand kW Savings

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

Table 39. RES Solar PV—Climate Zone 5: El Paso—Winter Demand kW Savings

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

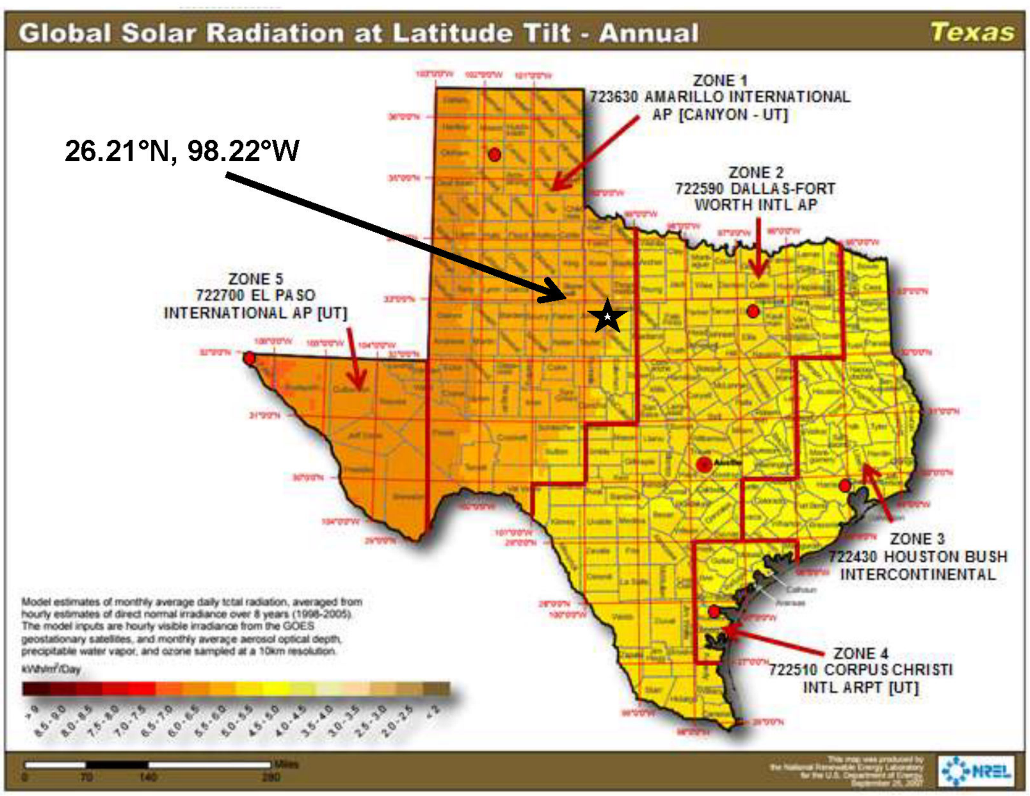
Deemed Summer and Winter Demand Savings—Example

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

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

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

Figure 8. RES Solar PV—Application of the Weather Zone Map



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

  Applying Equation 44,

  *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 45,

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

  *Deemed summer demand = 5.000 kW * 2%*

  *Deemed summer demand = 5.000 kW * 0.02*

  Deemed summer demand = 0.100 kW

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

The following information will be required to be collected.

- Project location (full address, including city, state, and zip code)
- Module type: Standard, premium, or thin film
- Array type: Fixed (open rack), fixed (roof mount), one-axis tracking, one-axis backtracking, two-axis tracking, etc.
- Tilt, azimuth, and DC system size rating for each array
- Shading study, if not using PVWatts default values