Table 265. Steam Trap – Peak Demand Savings, With Audit

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Commercial dry cleaners	Mercantile	Stand-alone retail	5.05E-03	2.80E-03	2.19E-03	1.12E-03	1.33E-03
Low pressure ≤ 15 psig	All	Industrial or process	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03
Medium pressure > 15 and < 30 psig	All	Industrial or process	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03
Medium pressure ≥ 30 and < 75 psig	All	Industrial or process	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03
High pressure ≥ 75 and < 125 psig	All	Industrial or process	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02
High pressure ≥ 125 and < 175 psig	All	Industrial or process	1.68E-02	1.68E-02	1.68E-02	1.68E-02	1.68E-02
High pressure ≥ 175 and < 250 psig	All	Industrial or process	2.27E-02	2.27E-02	2.27E-02	2.27E-02	2.27E-02
High pressure ≥ 250 and < 300 psig	All	Industrial or process	2.90E-02	2.90E-02	2.90E-02	2.90E-02	2.90E-02
Commercial heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/ university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	8.19E-04	1.26E-03	9.53E-04	5.72E-04	7.05E-04
		Secondary school	8.19E-04	1.12E-03	1.03E-03	6.67E-04	8.19E-04
	Food sales	Convenience	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	8.19E-04	9.53E-04	8.38E-04	6.67E-04	5.33E-04
		24-hour full-service	8.19E-04	9.34E-04	8.38E-04	6.86E-04	5.14E-04
		Quick-service restaurant	9.14E-04	1.16E-03	9.72E-04	6.48E-04	4.95E-04
		24-hour quick-service	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	Hospital	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
		Outpatient healthcare	5.14E-04	5.33E-04	5.52E-04	1.52E-04	7.62E-05
	Large multifamily	Midrise apartment	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lodging	Large hotel	1.64E-03	1.56E-03	6.29E-04	4.00E-04	4.00E-04
		Nursing home	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Small hotel/motel	6.86E-04	8.00E-04	3.62E-04	1.91E-04	1.14E-04
	Retail	Stand-alone retail	1.89E-03	1.05E-03	8.19E-04	4.19E-04	4.95E-04
		24-hour stand-alone retail	8.19E-04	1.09E-03	7.81E-04	4.76E-04	5.33E-04
		Strip mall	7.43E-04	1.05E-03	8.00E-04	4.00E-04	5.14E-04
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	1.37E-03	1.26E-03	8.00E-04	4.57E-04	5.14E-04
		Small office	5.52E-04	7.62E-04	5.33E-04	2.67E-04	2.86E-04
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Service	Service	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	5.14E-04	5.33E-04	3.62E-04	1.52E-04	7.62E-05

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 6 years for standard steam traps and 20 years for venturi steam traps.[566]

Program Tracking Data and Evaluation Requirements

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

- Application type of steam system
- Climate zone if application is commercial heating
- Steam trap quantity
- Type of measure undertaken for each trap: repaired, replaced, or maintained
- Audit documentation, if conducted, including count of leaking or faulty steam traps
- Maintenance documentation, if conducted, indicating strainer maintenance activities undertaken

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

Document Revision History

Table 266. Nonresidential Steam Trap Repair and Replacement Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

[566] EULs for the steam trap measure are sourced from the Illinois TRM version 9.0, measure 4.4.16 Steam Trap Replacement or Repair. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf.

2.7.10 Hydraulic Gear Lubricants Measure Overview

TRM Measure ID: NR-MS-HL

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithm

Savings Methodology: Engineering algorithms and estimates

Measure Description

Hydraulic gear lubricants are used in manufacturing. Energy efficient hydraulic gear lubricants offer reduced energy consumption over standard lubricants because they have a lower coefficient of friction which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which in turn reduces the energy requirements. Additionally, efficient lubricants have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures which optimizes volumetric and mechanical efficiency.

Eligibility Criteria

The measure is applicable to manufacturing and industrial sites using hydraulic gear lubricants for gearboxes.

Baseline Condition

The baseline condition is a gearbox using standard hydraulic lubricants.

High-Efficiency Condition

The high-efficiency condition is a gearbox using energy-efficiency hydraulic lubricants which have a higher viscosity index than standard lubricants.

Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

Savings Algorithms and Input Variables

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 243

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[567]
n	=	*Motor efficiency, actual or default to value in Table 267~~Table 267~~*
hours	=	*Operating hours per year, actual*
EI	=	*Efficiency increase, 1.0% per gear mesh*[568]

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Table 267. Motor Efficiencies[569]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936
30	0.941
40	0.941
50	0.945

567 Assume motor is designed to operate at maximum efficiency, neat 75% of rated load. See DOE Motor Challenge Fact Sheet available at https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf. Accessed August 2021.

568 Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf. Accessed August 2021.

569 Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

Motor horsepower	Full load efficiency
60	0.950
75	0.950
100	0.954

Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

Claimed Peak Demand Savings

There are no demand savings for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the equipment that the lubricant is used with.[570]

Program Tracking Data and Evaluation Requirements

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

- Quantity
- Motor horsepower
- Motor operating hours

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

[570] U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors", Median of "Table 8.2.23 Average Application Lifetime". Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

Document Revision History

Table 268. Nonresidential Hydraulic Gear Lubricants Revision History

v9.0	10/2021	TRM v9.0 origin.

2.7.11 Hydraulic Oils Measure Overview

TRM Measure ID: NR-MS-HO

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Algorithm

Savings Methodology: Engineering algorithms and estimates

Measure Description

Hydraulic oils are lubricants used in manufacturing. Energy efficient hydraulic oil lubricants offer reduced energy consumption over standard oils because they have a lower coefficient of friction which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which in turn reduces the energy requirements. Additionally, efficient oils have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures which optimizes volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient hydraulic oils reduce the operating temperature of the hydraulic system.

Eligibility Criteria

The measure is applicable to manufacturing and industrial sites using hydraulic oil lubricants for hydraulic equipment performance.

Baseline Condition

The baseline condition is hydraulic equipment using standard hydraulic oils.

High-Efficiency Condition

The high-efficiency condition is hydraulic equipment using energy-efficient hydraulic oils which have a higher viscosity index than standard oils.

Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

Savings Algorithms and Input Variables

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 244

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[571]
n	=	*Motor efficiency, actual or default to value in Table 269~~Table 269~~*
hours	=	*Operating hours per year, actual*
EI	=	Efficiency increase, 3.2%[572]

Table 269. Motor Efficiencies[573]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936

571 Assume motor is designed to operate at maximum efficiency, neat 75% of rated load. See DOE Motor Challenge Fact Sheet available at https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf. Accessed August 2021.

572 Focus on Energy Lubricant Study, https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study.

573 Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nomincal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125.

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Motor horsepower	Full load efficiency
30	0.941
40	0.941
50	0.945
60	0.950
75	0.950
100	0.954

Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

Claimed Peak Demand Savings

There are no demand savings for this measure.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the motor that the oil is used with.[574]

Program Tracking Data and Evaluation Requirements

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

- Quantity
- Motor horsepower
- Motor operating hours

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

[574] U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors", Median of "Table 8.2.23 Average Application Lifetime". Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf

Document Revision History

Table 270. Nonresidential Hydraulic Oils Revision History

v9.0	10/2021	TRM v9.0 origin.

APPENDIX A: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

The following appendix describes the method to calculate savings for any dual baseline measure, including all early retirement measures. This supersedes the previous Measure Life Savings found in PUCT Dockets 40083 and 40885 and is revised to clarify the understanding of the measure life calculations and reduce any misrepresentation of net present value (NPV) of early retirement projects.

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

Option 1—Weighting Savings and Holding Measure Life Constant

Step 1: Determine the measure life for first-tier (FT) and second-tier (ST) components of the calculated savings:

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

Equation 245

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

Equation 246

Where:

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

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

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

Equation 247

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

Equation 248

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

Equation 249

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

Equation 250

Where:

ΔkW_{FT}	=	*First-tier demand savings*
ΔkW_{ST}	=	*Second-tier demand savings*
$kW_{retired}$	=	*Demand of the first-tier baseline system, usually the retired system*[575]
$kW_{baseline}$	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[576]
$kW_{installed}$	=	*Demand of the replacement system*[577]
ΔkWh_{FT}	=	*First-tier energy savings*
ΔkWh_{ST}	=	*Second-tier energy savings*
$kWh_{retired}$	=	*Energy usage of the first-tier baseline system, usually the retired system*[575][575]
$kWh_{baseline}$	=	*Energy usage of the second-tier baseline system, usually the baseline ROB system*[576][576]
$kWh_{installed}$	=	*Energy usage of the replacement system*[577][577]

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

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

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

Equation 251

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

Equation 252

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

Equation 253

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

Equation 254

---

575 Retired system refers to the existing equipment that was in use before the retrofit has occurred.

576 Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the Early Retirement project (as specified in the applicable measure).

577 Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

Where:

$NPV_{FT,\ kW}$	=	*Net Present Value (kW) of first-tier projects*
$NPV_{ST,\ kW}$	=	*Net Present Value (kW) of second-tier projects*
$NPV_{FT,\ kWh}$	=	*Net Present Value (kWh) of first-tier projects*
$NPV_{ST,\ kWh}$	=	*Net Present Value (kWh) of second-tier projects*
e	=	*Escalation Rate* [578]
d	=	*Discount rate weighted average cost of capital (per utility)* [578578]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [578578]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [578578]
ML_{FT}	=	*First-tier Measure Life (calculated in Equation 245~~Equation 245~~)*
ML_{ST}	=	*Second-tier measure life (calculated in Equation 246~~Equation 246~~)*

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

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

Equation 255

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

Equation 256

Where:

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

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

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

Equation 257

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

Equation 258

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

Formatted: Footnote Reference,o,fr,Footnote_Reference,Char Char Char Char,o1,o2,o3,o4,o5,o6,o11,o21,o7,TT - Footnote Reference,FC,Style 9

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

---

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

Where:

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

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

$$Weighted\ kW = \frac{NPV_{Total\ kW}}{NPV_{EUL,kW}} = \frac{\left[\left(1-\left(\frac{1+e}{1+d}\right)^{RUL}\right)\times\left(kW_{retired}-kW_{installed}\right)\right]+\left[\left(1-\left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right)\times\frac{(1+e)^{EUL}}{(1+d)^{EUL}}\times\left(kW_{baseline}-kW_{installed}\right)\right]}{\left[\left(1-\left(\frac{1+e}{1+d}\right)^{EUL}\right)\times\left(kW_{retired}-kW_{installed}\right)\right]}$$

Equation 259

$$Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPV_{EUL,kWh}} = \frac{\left[\left(1-\left(\frac{1+e}{1+d}\right)^{RUL}\right)\times\left(kWh_{retired}-kWh_{installed}\right)\right]+\left[\left(1-\left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right)\times\frac{(1+e)^{EUL}}{(1+d)^{EUL}}\times\left(kWh_{baseline}-kWh_{installed}\right)\right]}{\left[\left(1-\left(\frac{1+e}{1+d}\right)^{EUL}\right)\times\left(kWh_{retired}-kWh_{installed}\right)\right]}$$

Equation 260

Where:

Weighted kW	=	*Weighted lifetime demand savings*
Weighted kWh	=	*Weighted lifetime energy savings*
$NPV_{Total,\,kW}$	=	*Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 255~~Equation 255~~*
$NPV_{Total,\,kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 256~~Equation 256~~*
$NPV_{EUL,\,kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 257~~Equation 257~~*
$NPV_{EUL,\,kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 258~~Equation 258~~*

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

Formatted: Font: (Default) Arial, 11 pt, Font color: Auto

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

Repeat Step 1 through Step 4 from Option 1.

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

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

Equation 261

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

Equation 262

Where:

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

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

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

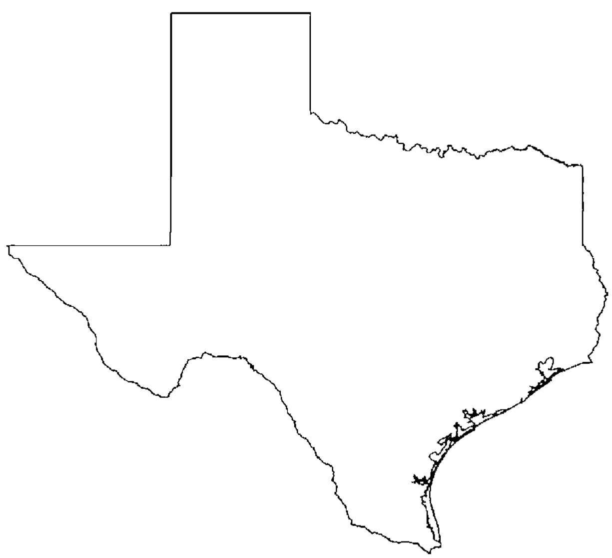
Public Utility Commission of Texas

Texas Technical Reference Manual

Version ~~8~~9.0

Volume 4: Measurement and Verification Protocols

Program Year 202~~1~~2



Last Revision Date:

November 202~~0~~1

Public Utility Commission of Texas

Texas Technical Reference Manual

Version ~~8~~9.0

Volume 4: Measurement and Verification Protocols

Program Year 202~~1~~2

Last Revision Date:

November 202~~0~~1

Table of Contents

List of Figures

List of Tables

Acknowledgments

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

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

TRM Technical Support

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

1. INTRODUCTION

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

M&V protocols are included for the following measures:

- HVAC: Air Conditioning Tune-up
- HVAC: Ground Source Heat Pump
- HVAC: Variable Refrigerant Flow Systems
- Whole House: Residential New Construction
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors less than 75 hp
- Miscellaneous: Commercial Retro-commissioning
- Miscellaneous: Thermal Energy Storage
- Load Management: Residential Load Curtailment
- Load Management: Nonresidential Load Curtailment

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

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

Sector	Measure category	Measure description	~~8~~9.0 update
Residential and Nonresidential	HVAC	Air conditioning tune-ups	No revisions.
Nonresidential	HVAC	Ground source heat pumps	No revisions.
Nonresidential	HVAC	Variable refrigerant flow systems	~~Added DOE CCMS certification to eligibility list~~No revisions.
Residential	Whole house	Residential new construction	~~For reference home specification, added IECC 2015 for mechanical ventilation and federal standard efficiency for appliances~~For reference home specification, added HVAC commissioning and dehumidification system.
Residential and Nonresidential	Renewables	Residential and nonresidential solar photovoltaics	~~Updated instructions for new version of PVWatts® and references to NREL National Solar Radiation Database (NSRD) (previously TMY3)~~Clarified PVWatts® kWh modeling instructions and documentation requirements. Provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges.
Residential and Nonresidential	Renewables	Solar shingles	No revisions.
Residential	Renewables	Solar Attic Fans	Reinstate measure requiring M&V data collection
Nonresidential	Miscellaneous	Behavioral	~~Added hourly interval data as a requirement, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period~~Updated model requirements to account for pandemic and other non-routine events.~~.~~
Nonresidential	Miscellaneous	Air compressors less than 75hp	No revisions.
Nonresidential	Miscellaneous	Commercial retro-commissioning	~~Updated model fitness requirements, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period~~Updated model requirements to account for pandemic and other non-routine events.~~.~~
Nonresidential	Miscellaneous	Thermal energy storage	~~Added 30-minute interval data as a requirement when using IPMVP option C~~No revisions.
Residential	Load management	Residential load curtailment	~~Added guidance on rounding, ensuring meters are functioning prior to an event, and changing the error threshold from one to two percent of total participants~~Added peak demand period by utility. Added links to program manuals.

Sector	Measure category	Measure description	.0 update
Nonresidential	Load management	Nonresidential load curtailment	~~Added guidance on rounding~~Added eligibility exclusion for critical load customers and removed tables detailing the utility programs. Updated links to program manuals.

2. M&V MEASURES

2.1 M&V: HVAC

2.1.1 Air Conditioning Tune-Ups Measure Overview

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

Market Sector: Residential and commercial

Measure Category: HVAC

Applicable Building Types: Residential; commercial

Fuels Affected: Electricity

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

Program Delivery Type(s): Custom

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

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

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

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

Measure Description

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

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

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

Applicable equipment types include:

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

Eligibility Criteria

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

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 1

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

Equation 2

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

Equation 3

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

Equation 4

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

Equation 5

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

Equation 6

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

Equation 7

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

Equation 8

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

Equation 9

---

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

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

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

Equation 10

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

Equation 11

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

Equation 12

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

Equation 13

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

Equation 14

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

Equation 15

The Saturation Over Liquid Water equation is:

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

Equation 16

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

Equation 17

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

Equation 18

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

Equation 19

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

Equation 20

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

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

Equation 21

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

Equation 22

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

Equation 23

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

Equation 24

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

Equation 25

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

Equation 26

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

Equation 27

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

Equation 28

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

Equation 29

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

Equation 30

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

Where:

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

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

$EFLH_{C/H}$	=	*Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Residential Volume 2 Table 2-37 and Table 2-38); Nonresidential Volume 3 Table 2-16 through Table 2-20)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Equations 49 and 50); Nonresidential Volume 3 Tables 2-16 through Table 2-20)*
Volts	=	*Measured voltage (Volts) on single-phase electric power leads to AC components*
Amps	=	*Measured current flow (Amps) on single-phase electric power leads to AC components*
PF	=	*Power factor stipulated based on motor type (see Table 3)*
V_1, V_2, V_3	=	*Measured voltage, line to line on each of the three electric power leads (V_1, V_2, V_3) to AC components for 3-phase loads*
A_1, A_2, A_3	=	*Measured current flow (Amps) on each line (A_1, A_2, A_3) of the three power leads to AC components for 3-phase loads*

efficiency loss	=	*Efficiency loss factor; derived from a significant sample of field measurement data for units with versus without a refrigerant charge and commercial versus residential unit types (see* Table 2*)*
P	=	*Measured total pressure of moist air [inches Mercury]*
P_{ws}	=	*Saturation pressure over liquid water [psia]*
P_{atm}	=	*Atmospheric pressure [psia]*
v	=	*Specific volume of air [cu.ft./lb]*
Ln.	=	*Natural Logarithm*
e	=	*Natural Log constant (2.7182818284590452353602874713527)*
Z	=	*Elevation-Altitude [feet]*
T	=	*Absolute temperature, Rankine scale* $[°R = °\mathrm{F} + 459.67]$
t_{db}	=	*Measured dry bulb temperature [ºF]*
t_{wb}	=	*Measured wet bulb temperature [ºF]*
Wet Bulb$_{Return\ Air}$	=	*Wet-bulb temperature of return air (load) to AC evaporator [ºF]*
Wet Bulb$_{Supply\ Air}$	=	*Wet-bulb temperature of cooled supply air to indoor space [ºF]*
Dry Bulb$_{Outdoor}$	=	*Dry-bulb temperature of outdoor air at time of tune-up [ºF]*
$h_{Return\ Air}$	=	*Measured enthalpy of return air (load) to AC evaporator [Btu/lb]*
$h_{Suppy\ Air}$	=	*Measured enthalpy of cooled supply air to indoor space [Btu/lb]*
Mass Flow Rate	=	*Measured heat carrying capacity of moist return air [lb/hr]*
CFM	=	*AC supply/return air flow [cu.ft./min.] (Method 1 see Table 4)*
Length	=	*Measured length of duct grill long side [inches] (Method 2)*
Width	=	*Measure width of duct grill short side [inches] (Method 2)*
Air Speed	=	*Measured air velocity at duct grille [feet per second] (Method 2)*
95ºF	=	*95 degrees Fahrenheit is the outdoor dry bulb temperature at AHRI test conditions*
10ºF	=	*10 degrees Fahrenheit is the typical wet bulb temperature change across an evaporator coil at AHRI conditions*

Energy and Demand Savings Tables

Efficiency Loss Factors

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

Table 2. AC Tune-Up Efficiency Loss Factors

Market sector	Refrigerant charge adjusted
Residential	No
	Yes
Commercial	No
	Yes

Power Factors

Capturing power factors from units in the field can be difficult. Stipulating these factors is acceptable, and suggested power factor values are presented by motor type for packaged and split system AC and heat pump units in Table 3.

Table 3. Recommended Power Factors for AC Components

Power factors for AC components	
Motor type	**Power factor**
Blower: Electrically Commutated Motor (ECM)	0.68
Blower: Permanent-Split Capacitor Motor (PSC)	0.98
Blower: Three Phase	0.98
Outdoor Condensing unit	0.85
Variable Frequency Drive (Single Phase)	0.87
Variable Frequency Drive (Three Phase)	0.65

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

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

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

Cooling Load Calculation

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

The two methods for determining AC system airflow values following completion of the AC tune-up at test out are summarized in Table 4 below.

Table 4. AC Air Flow Determination Methods for Estimating Cooling Capacity at Test-Out

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

Table 5. EER Adjustment Factor and Capacity Adjustment Factor Constants

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

Table 6. Constants for Saturation Pressure Over Liquid Water Calculation

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

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

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein require the use of equipment in accordance with the toolkit (with specified manufacturer and model numbers) to measure key AC performance parameters in the field. The use of these tools or equivalent ensures consistent data acquisition conformance by all parties. The equipment required in the toolkit is shown in Table 7 for reference.

Table 7. AC Tune-Up Toolkit Components

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

Metering Schedule

A complete metering schedule identifying the AC tune-up process and measurements performed for AC tune-ups is presented in M&V Metering Schedule~~2.5.2APPENDIX A:~~. The technician follows the metering schedule during the tune-up process.

Equipment Accuracy

The accuracy for each required piece of metering equipment is shown in Table 8.

Table 8. Measurement Resolution and Accuracy

Device	Model number	Measurement	Resolution	Accuracy
Inspection Scope	Testo 318-V	Visual Coil Inspection	N/A	N/A
Anemometer	Testo 417[6]	Air Flow Velocity	0.01m/s	±0.1m/s+1.5% of reading
Manometer	Testo 510[6]	Differential pressure	0.01 inH2O	±0.01 inH2O (0-0.12 inH2O), ±0.02 inH2O (0.13-0.40 inH2O), ±(0.04 inH2O +1.5 % of reading) (rest of range)
Refrigerant System Analyzer	Testo 556[6]	Refrigerant Temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant Pressure	0.1 psi	±0.5% Full Scale
	Testo 560[6]	Refrigerant Temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant Pressure	0.1 psi	±0.5% Full Scale
	Testo 550[6]	Refrigerant Temperature	0.1°F	±1.8°F + 1 digit
		Refrigerant Pressure	0.1 psi	±0.75% Full Scale + 1 Digit
	iManifold 913-M and 914-M[7]	Refrigerant Temperature	0.1°F	±0.4°F
		Refrigerant Pressure	0.1 psi	±0.5% Full Scale
DB/WB Thermometer	Testo 605-H2[6]	Dry/Wet Bulb Temperature	0.1°F	±0.9°F
	iManifold 911-M[7]		0.1°F	±0.4°F
Surface Thermometer	Testo 905-T2[6]	Condenser Ambient Air Temperature	0.1°F	±1.8°F (-58 to +212°F)
	iManifold 912-M[7]		0.1°F	±0.4°F
Volt/Amp Meter	Fluke 27-II[8]	Voltage	0.1 V	±(0.5% +3)
		Current	0.01 A	±(1.5% +2)
Ruler / Tape Measure	N/A	Air Grill Dimensions[9]	1/8 in	±1/16 in

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of residential and commercial AC tune-ups is 5 years.[10]

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: O&M
- Building type
- Climate/weather zone
- Equipment type
- Equipment rated cooling and heating capacities
- Equipment cooling and heating efficiency ratings
- Equipment make and model
- Refrigerant type
- Refrigerant adjustment (added/removed, weight)
- Note which five remaining AC tune-up service measures were completed
- Test-out measured cooling capacity
- Test-out measured power inputs
- Test-out measured mass flow rate
- All other operating measurements and parameters listed in M&V protocol

References and Efficiency Standards

Not applicable.

[10] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group. Page 1-3, Table 1.

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 90.1-1999 (Residential Buildings)
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 9. M&V AC Tune-Up Revision History

TRM version	Date	Description of change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match the layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Revised efficiency loss factors based on 2015 results. Added VFD motor types.
v5.0	10/10/2017	Removed reference to deemed efficiency loss factors. Added clarity to separate units by refrigerant charge adjustments and unit size/type. Updated table references.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	No revisions.

2.1.2 Ground Source Heat Pumps Measure Overview

TRM Measure ID: NR-HV-GH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V and whole facility measurement

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

Measure Description

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

Applicable GSHP efficient measure types include:

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

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

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

Table 10. Minimum Efficiency Levels for Commercial Single Stage GSHPs[11]

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

[11] Values from ASHRAE 90.1-2013.

Energy and Demand Savings Methodology

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

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

M&V Plan and M&V Report

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

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

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

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

- Report format
- Quality assurance

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

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

Equation 31

Where:

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

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

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

Equation 32

Where:

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

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

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

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

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

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

Equation 33

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

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

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

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

Equation 36

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

Equation 37

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

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

Equation 38

Where:

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

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

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

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in* Table 10*) [Btu/W]*

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

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(Must exceed baseline efficiency standards in* Table 10*) [COP]*

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

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for ~~commercial split and packaged air conditioners and heat pumps~~GSHPs is 20~~15~~ years.

This value is consistent with the minimum life expectancy reported in the Department of Energy GSHP guide.[13][~~14~~]

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ER system type conversion
- Building type
- Climate zone
- Baseline equipment type

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

~~[14] A 15-year EUL is cited in several places: PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.~~

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 11. M&V Ground Source Heat Pumps Revision History

TRM version	Date	Description of change
v3.1	11/05/2015	TRM v3.1 origin.
v4.0	10/10/2016	No revisions.
v5.0	10/10/2017	No revisions.
v6.0	10/2018	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	Estimated useful life changed from 15 to 20 years for consistency with Volume 2.

2.1.3 Variable Refrigerant Flow Systems Measure Overview

TRM Measure ID: NR-HV-VR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

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

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

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

This protocol is used to estimate savings for variable refrigerant flow systems (VRF) measures through an M&V approach. The development of the VRF M&V methodology is driven by the desire to create and implement a framework to provide ~~high~~ 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.[15,16]

Baseline Condition

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

Replace-on-Burnout (ROB) and New Construction (NC): The baseline for ROB or NC projects is a code-minimum VRF system as specified by ASHRAE 90.1-2013. VRF system minimum efficiencies are not currently covered by IECC 2015. Minimum efficiency conditions are shown in Table 12 below. See the Deemed Energy and Demand Savings section below for more details.

High-Efficiency Condition

High-efficiency conditions for VRF equipment must meet applicable standards. AHRI energy ratings for EER and COP, by manufacturer model numbers, follow required test protocols and parameters and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements from Table 12. Both air-cooled and water-cooled systems are rated per AHRI Standard 1230.

Table 12. Baseline Efficiency Levels for Electrically Operated VRF ACs and HPs

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Conditioners, Air Cooled	< 65,000	All	VRF multi-split system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-9
	≥ 65,000 and < 135,000	None or Electric Resistance		11.2 EER 13.1 IEER	
	≥ 135,000 and < 240,000			11.0 EER 12.9 IEER	
	≥ 240,000			10.0 EER 11.6 IEER	

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

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Cooled (cooling mode)	< 65,000	All	VRF multi-split system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000	None or Electric Resistance	VRF multi-split system	11.0 EER 12.3 IEER	
			VRF multi-split system with heat recovery	10.8 EER 12.1 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system	10.6 EER 11.8 IEER	
			VRF multi-split system with heat recovery	10.4 EER 11.6 IEER	
	≥ 240,000		VRF multi-split system	9.5 EER 10.6 IEER	
			VRF multi-split system with heat recovery	9.3 EER 10.4 IEER	
VRF Water Source (cooling mode)	< 65,000	All	VRF multi-split system 86^{0}F entering water	12.0 EER	ASHRAE 90.1-2013 Table 6.8.1-10
			VRF multi-split system with heat recovery 86^{0}F entering water	11.8 EER	
	≥ 65,000 and < 135,000		VRF multi-split system 86^{0}F entering water	12.0 EER	
			VRF multi-split system with heat recovery 86^{0}F entering water	11.8 EER	
	≥ 135,000		VRF multi-split system 86^{0}F entering water	10.0 EER	
			VRF multi-split system with heat recovery 86^{0}F entering water	9.8 EER	

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Cooled (heating mode)	< 65,000 (cooling capacity)	-	VRF multi-split system	7.7 HSPF	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multi-split system 47°F db/43°F wb outdoor air	3.3 COP_H	
			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 capacity)	-	VRF multi-split system 68°F entering water	4.2 COP_H	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 135,000 (cooling capacity)		VRF multi-split system 68°F entering water	3.9 COP_H	

Energy and Demand Savings Methodology

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

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

M&V Plan and M&V Report

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

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

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

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

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

$$Peak\ Demand\ Savings\ (kW)^{17} = kW_{Baseline} - kW_{New}$$

Equation 39

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

Where:

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

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

Equation 40

Where:

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

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

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

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

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

Equation 41

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

Equation 42

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

Equation 43

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

Equation 44

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

Equation 45

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

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

Equation 46

Where:

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

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

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

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in* Table 12*) [Btu/W]*

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

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(must exceed baseline efficiency standards in* Table 12*) [COP]*

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

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

$HSPF_{pre,H}$ = *Heating Season Performance Factor (HSPF) of existing equipment [BTU/W]*

$HSPF_{post,H}$ = *Heating Season Performance Factor (HSPF) of newly installed equipment [BTU/W]*

3.412 = *The amount of British Thermal Units (Btu) per hour in one watt (1 W = 3.412 Btuh)*

Deemed Energy and Demand Savings

For new construction, renovation, or existing system replacements (as an alternative compliance path), the use of a deemed savings procedure is available for claiming VRF system efficiency above code minimum efficiencies. The methodology is identical to TRM Volume 3 split system/single packaged air conditioners and heat pumps by substituting the efficiencies from Table 12 as the baseline efficiencies for the new construction and replace on burnout energy and demand savings methodology.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for commercial split and packaged air conditioners and heat pumps is 15 years.[18]

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ER, ROB, NC, system type conversion
- Building type
- Climate zone
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed number of units
- Installed equipment type
- Installed rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model

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

- Installed unit AHRI/DOE CCMS certificate or reference number
- **For other building types only**: Description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-9 through Table 6.8.1-10.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.
- ANSI/AHRI Standard 1230, 2010 Standard for Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment, http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/ANSI/ANSI_AHRI_Standard_1230_2010_with_Add_2.pdf.

Document Revision History

Table 13. M&V Variable Refrigerant Systems Revision History

TRM version	Date	Description of change
v5.0	10/10/2017	TRM v5.0 origin.
v6.0	10/2018	Minor formula corrections.
v7.0	10/2019	No revisions.
v8.0	10/2020	Added DOE CCMS certification to eligibility list
v9.0	10/2021	No revisions.

2.2 M&V: WHOLE HOUSE

2.2.1 Residential New Construction Measure Overview

TRM Measure ID: R-HS-NH

Market Sector: Residential

Measure Category: Whole house

Applicable Building Types: Single-family; manufactured

Fuels Affected: Electricity and gas

Decision/Action Types: New construction (NC)

Program Delivery Type: Custom

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

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

This M&V protocol details the savings estimate for residential new construction projects. The protocol may be applied to the construction of single-family detached homes, multifamily buildings, or individual units within new multifamily buildings. The residential new construction M&V methodology creates a framework to provide ~~high~~ 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[19]
- RESNET accredited software
- Hourly analysis programs tested in accordance with ASHRAE 140 and meeting the requirements of ASHRAE 90.1 Appendix G (i.e., DOE-2, EnergyPlus, HAP, TRACE, IESVS, etc.)[20]

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

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

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

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

Measure Description

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

Eligibility Criteria

This measure does not apply to existing construction: only residential new construction projects completed in a given program year are eligible.[21]

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[22]

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

Accordingly, baseline parameters and key model input values for new single-family detached homes and residential multifamily buildings three stories or less are detailed in Table 14.

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

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

Baseline parameters and key model input values for new residential multifamily buildings of more than three stories (and portions thereof/units within) are detailed in Table 15.

Exception:[23] Multifamily buildings with 4 or 5 stories above-grade[24] where dwelling units occupy 80% or more of the occupiable square footage of the building may select the most appropriate baseline condition. When evaluating mixed-‑use buildings for eligibility, exclude commercial/retail space when assessing whether the 80% threshold has been met.

Table 14 and Table 15: When a new statewide energy code is adopted by the State Energy Conservation Office (SECO), the baseline parameters for residential whole-house measures must be updated to reflect this change. Recognizing that it takes time for new energy codes to be locally adopted and enforced, this M&V methodology requires the new code as a baseline for the next program year cycle, but not less than twelve months from the energy code effective date. Effective September 1, 2016, Texas adopted 2015 IECC 2015.[13] From a TRM perspective, the new construction baseline condition change is effective January 1, 2018.

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

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

Ideally, the relevant energy code will be tracked in the program tracking system. Alternatively, it may be tracked as part of the project documentation made available to evaluators upon request. Changes to baseline conditions from Table 14 and Table 15 or changes to the implementation of baseline conditions within an approved modeling package is are allowable and subject to EM&V team approval.

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

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

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

Baseline and dwelling parameters and characteristics	Reference home specification/value
Architecture	
Number of stories above grade 1	Same as as-built
Foundation type	Same as as-built
Number of bedrooms	Same as as-built
Total conditioned floor area	Same as as-built
Total conditioned volume	Same as as-built
Wall height per floor	Same as as-built
Window distribution (N, S, E, W)	Same as as-built
Percentage of window to floor area	Same as as-built
Front door orientation	Same as as-built
Aspect ratio (length / width)	Same as as-built
Envelope	
Slab R-value and depth	See IECC 2015 Table R402.1.2 Insulation and Fenestration Requirements by Component
Floor assembly U-Factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Frame wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Mass wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Basement wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Crawl space wall assembly U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Rim joist assembly U-factor	Same as Wall U-Factor
Fenestration U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Skylight U-factor	See IECC 2015 Table R402.1.4 Equivalent U-factors
Glazed fenestration SHGC	See IECC 2015 Table R402.1.2 Insulation and Fenestration Requirements by Component
Window overhang	None
interior shading fraction	Same as as-built
Door U-factor	Same as fenestration U-factor
Ceiling Assembly U-factor	Table R402.1.4 equivalent U-factors
Ceiling type	Same as as-built, except when as-built is a sealed attic assembly, then vented attic
Roof radiant barrier	None
Roof solar absorptivity	0.75

Baseline and dwelling parameters and characteristics	Reference home specification/value
Envelope testing	
Air infiltration	5 ACH_{50} in IECC 2015 CZ 2, 3 ACH_{50} in IECC 2015 CZ 3-4[25]
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.[26]
HVAC equipment location	Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic
Cooling capacity	Same as as-built
Heating capacity	Same as as-built
Cooling efficiency (SEER)	14
Heating efficiency (AFUE)	80% AFUE
Heating efficiency (HSPF) - heat pump	8.2
Duct location	Exposed in a vented attic
Duct R-value	R-8[27]
Total duct leakage	4 CFM_{25} per 100 ft^2 of conditioned floor
Thermostat type	Programmable thermostat
Heating setpoint	72°F
Cooling setpoint	75°F
Mechanical ventilation type	Same as as-built or as specified in IECC 2015 Table 405.5.2
Mechanical ventilation rate	Same as as-built
Mechanical ventilation hours/day	Same as as-built or as specified in IECC 2015 Table 405.5.2
Mechanical ventilation fan watts	Same as as-built or as specified in IECC 2015 Table 405.5.2

[25] Note: The climate zones in IECC 2015 do not align with the climate zones assigned in the Texas TRM. IECC climate zones referenced in this section can be found here: https://codes.iccsafe.org/content/IECC2015/chapter-3-ce-general-requirements
[26] 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.
[27] 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)[28]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the Rated Home, in which case:[29] 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% 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 ~~A~~as-~~B~~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[30]) as of April 16, 2015
DHW pipe insulation	R-3

[28] 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.

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

[30] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. ~~Online. Available:~~ https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=cf13a6a9929a57e8a7ca3826966e322c&mc=true&n=sp10.3.430.c&r=SUBPART&ty=HTML#se10.3.430_132. ~~Accessed July 2019.~~

Baseline and dwelling parameters and characteristics	Reference home specification/value
All bath faucets and showers <~~<~~= 2gpm	No
Hot water recirculation system	No
Drain water heat recovery	No
Lighting	
~~Fluorescent L~~lighting	75% high efficacy ~~of~~ permanently installed fixtures
LED lighting	None
Appliances~~[31]~~	
Refrigerator	Reference home should be modeled with HERS reference default values, equivalent to federal standard efficiency appliances. As-built for homes without high-efficiency appliances should also use the HERS reference defaults. For modeled appliance savings, as-built should reflect high-efficiency appliances. Programs claiming prescriptive appliance savings using Volume 2 of the TRM should use standard efficiency appliances for both reference and as-built.~~Federal standard efficiency or same as as-built~~
Dishwasher	~~Federal standard efficiency or same as as-built~~
Range/oven	~~Federal standard efficiency or same as as-built~~
Clothes washer and dryer	~~Federal standard efficiency or same as as-built~~
Ceiling fans	~~Federal standard efficiency or same as as-built~~

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

Baseline and dwelling parameters and characteristics	Baseline specification/value
Envelope	
Unit type	Multifamily building
Number of stories above grade 1	Same as as-built
Foundation type	Same as as-built
Number of bedrooms	Same as as-built
Total conditioned floor area	Same as as-built
Total conditioned volume	Same as as-built
Wall height per floor	Same as as-built
Window distribution (N,S,E,W)	Same as as-built
Percentage of window to floor area	Same as as-built

~~[31] Programs that wish to claim deemed savings for appliances from Volume 2 of the TRM should use the "same as as-built" baseline specification.~~

Baseline and dwelling parameters and characteristics	Baseline specification/value
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%
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% difference
Heating capacity	Same as as-built or simulated to reflect reference home load, not to exceed 20% difference
Cooling efficiency	See ASHRAE 90.1-2013, Section 6.8
Heating efficiency	See ASHRAE 90.1-2013, Section 6.8
Thermostat type	Same as as-built
Heating setpoint (occupied/unoccupied)	70°F/70°F

Baseline and dwelling parameters and characteristics	Baseline specification/value
Cooling setpoint (occupied/unoccupied)	78°F/80°F
HVAC commissioning	
Grade III (untested/commissioned by Rater)[32]	Same as as-built
Dehumidification system	
None, except where a dehumidification system is specified by the Rated Home, in which case:[33] 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% RH	Same as as-built
Water heating system	
DHW fuel type	Same as as-built
DHW capacity (gallons)	Same as as-built for storage. Assume a 50-gallon storage water heater when as-built water heater is instantaneous.
Energy factor (EF)	See ASHRAE 90.1-2013, Table 7.8
DHW temperature	120°F
DHW pipe insulation	None
Low-flow showerheads	None
Lighting	
High efficacy lamps	0.51 Watts per ft^2

32 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.

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

House Simulation Modeling

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

Energy Savings Methodology

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

Summer Demand Savings Methodology

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

Winter Demand Savings Methodology

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

Post-Processing for Calculating Demand and Energy Savings

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

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

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a new home measure is established at 23~~.0~~ years.

Program Tracking Data and Evaluation Requirements

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

- Date of issuance of building permit
- Statewide energy code under which the building was built
- Building envelope
  - Dwelling unit type
  - House footprint dimensions
  - Number of stories above grade 1
  - Foundation type
  - Number of bedrooms
  - Total conditioned floor area
  - Total conditioned volume
  - Wall height per floor
  - Window distribution (N, S, E, W)
  - Front door orientation
  - Aspect ratio (length / width)—when available
  - Roof solar absorptivity—when available
  - Attic insulation R-value
  - Cathedral ceiling insulation R-value
  - Percentage cathedral ceilings
  - Ceiling insulation grade
  - Wall construction
  - Wall framing fraction

- Wall insulation (R-value)
- Wall insulation grade
- Door material (wood, metal, vinyl, and whether solid core or hollow)—when available
- Rim joist
- Window U-factor
- Window SHGC
- Air infiltration
- Mechanical ventilation
- Slab edge insulation—only for houses located in IECC climate zone 4

- HVAC equipment
  - HVAC equipment type
  - AHRI number of installed HVAC equipment—in the absence of an AHRI number, manufacturers' cut sheets and/or make and model numbers should be provided instead.
  - Cooling capacity
  - Heating capacity
  - Cooling efficiency (SEER)
  - Heating efficiency (AFUE for gas,), and HSPF for heat pumps)
  - duct location
  - Duct insulation R-value
  - Duct leakage to outside (CFA)
  - Heating set-point temperature(s) (°F)
  - Cooling set-point temperature(s) (°F)
  - Thermostat type (setback or no setback)
  - Supply fan power (W/CFM)
- Water heating system
  - Water heating systems
  - AHRI number of installed water heating equipment—raters should verify the energy factor (EF) on-site during the final inspection; as part of the implementer QA/QC protocol, verify the AHRI information
  - DHW fuel type
  - DHW capacity (gallons)
  - Energy factor
  - DHW set-point temperature
  - DHW pipe insulation

    - Number of low-flow showerheads and flow rate
    - Number of low-flow faucets and flow rate
- Lighting
    - Number of sockets with high efficacy lamps or lighting power density, as appropriate.
- Appliances
    - Number of ceiling fans
    - Refrigerator model number
    - Dishwasher model number
    - Clothes washer presence
    - Clothes washer model number
- HVAC commissioning
    - Grade
- Dehumidification System
    - Type
    - Capacity
    - Efficacy
    - Dehumidistat setpoint

Files to Submit for EM&V Review

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

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

References and Efficiency Standards

- ~~RESNET accredited software: http://www.resnet.us/professional/programs/energy_rating_software~~
- ~~ASHRAE 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*~~

- ~~ASHRAE 140, Standard Method of Test for the Evaluation of Building Energy Analysis Programs~~
- ~~ENERGY STAR Multifamily High Rise Program Simulation Guidelines~~
- ~~International Code Council, *2015 International Energy Conservation Code*.~~

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- ~~Not applicable.~~ RESNET accredited software: http://www.resnet.us/professional/programs/energy_rating_software
- ASHRAE 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*
- ASHRAE 140, Standard Method of Test for the Evaluation of Building Energy Analysis Programs
- ENERGY STAR Multifamily High Rise Program Simulation Guidelines
- International Code Council, *2015 International Energy Conservation Code*.

Document Revision History

Table 16. M&V Residential New Construction Revision History

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

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

2.3 M&V: RENEWABLES

2.3.1 Residential Solar Photovoltaics (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

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

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

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

Savings Methodology: Model-calculator (PVWatts®)

Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. The primary objective of these programs is to achieve cost-effective energy savings and peak demand savings. Participation in the solar photovoltaic program involves the installation of a PV system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator[34], to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

Eligibility Criteria

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

Baseline Condition

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

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

High-Efficiency Condition

Not applicable.

Energy and Demand Savings Methodology

All PV systems shall be modeled using the current version of the National Renewable Energy Laboratory's (NREL) PVWatts® calculator. Energy savings are estimated using the default weather data source (currently TMY2) offered by PVWatts®.[35] 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 5 degrees difference in tilt or azimuth):

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

Table 17. Module Type Options

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

- Array type: fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking
- Tilt (deg): enter the angle from horizontal of the photovoltaic modules in the array
- Azimuth (deg): enter the angle clockwise from true north describing the direction that the array faces
- All other input variables: accept the PVWatts® default values

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

Annual Energy Savings (kWh)

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

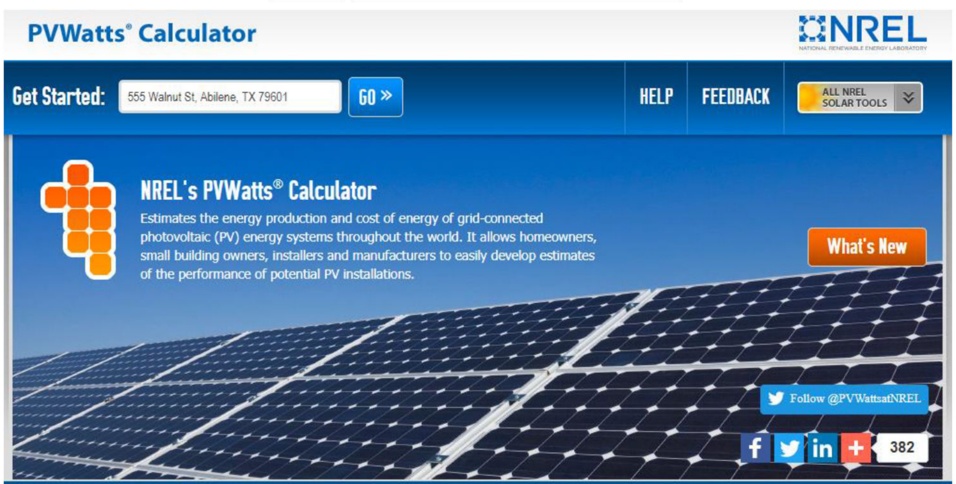
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain the total annual energy savings.

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

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

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

Figure 1. 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. Confirm the resulting location ~~by looking at the map shown in~~ and proceed to system info, as shown in Figure 3.

Figure 2. PVWatts® Resource Data Map

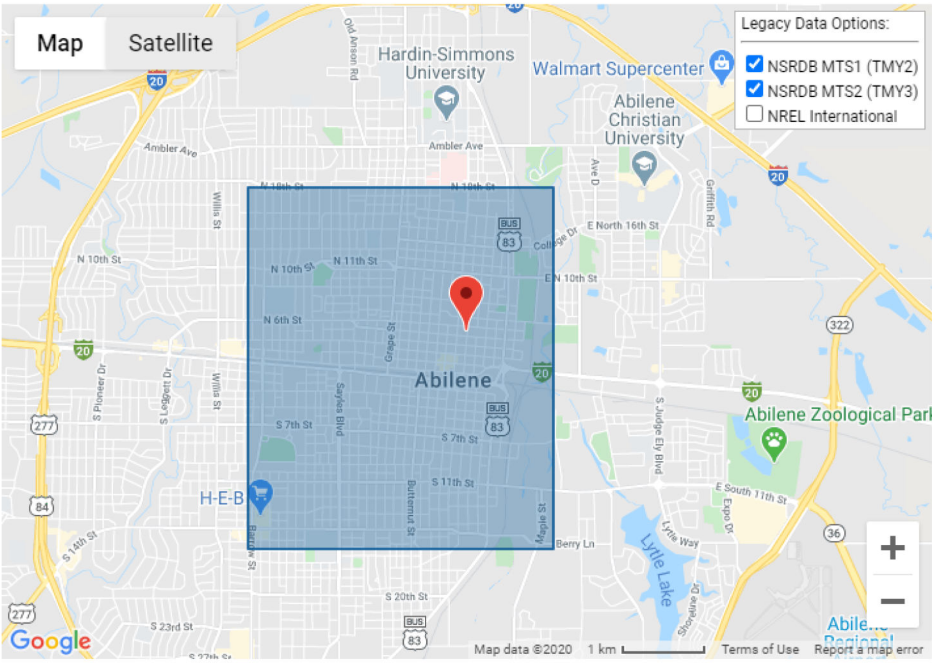
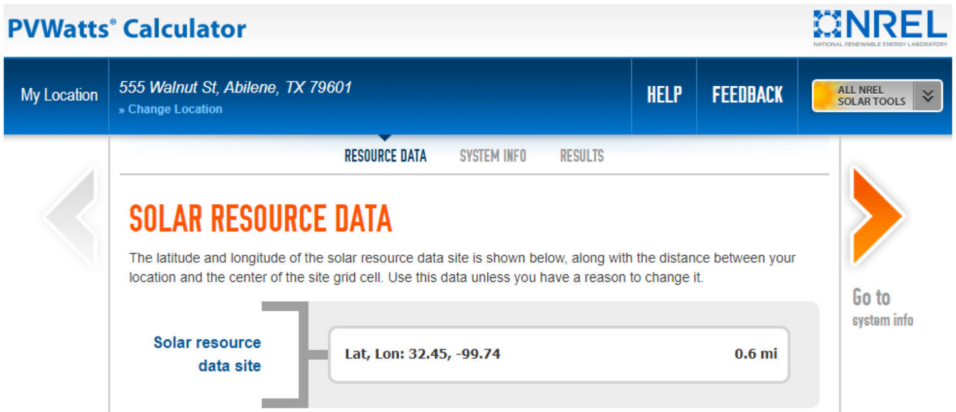


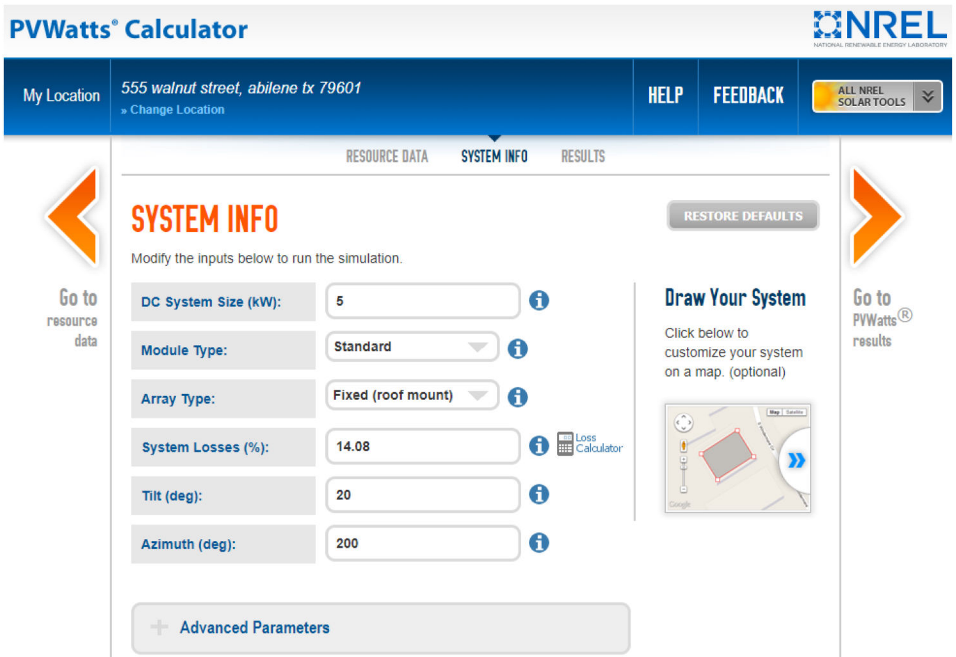
Figure 3. PVWatts® Input Screen for Step 2



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

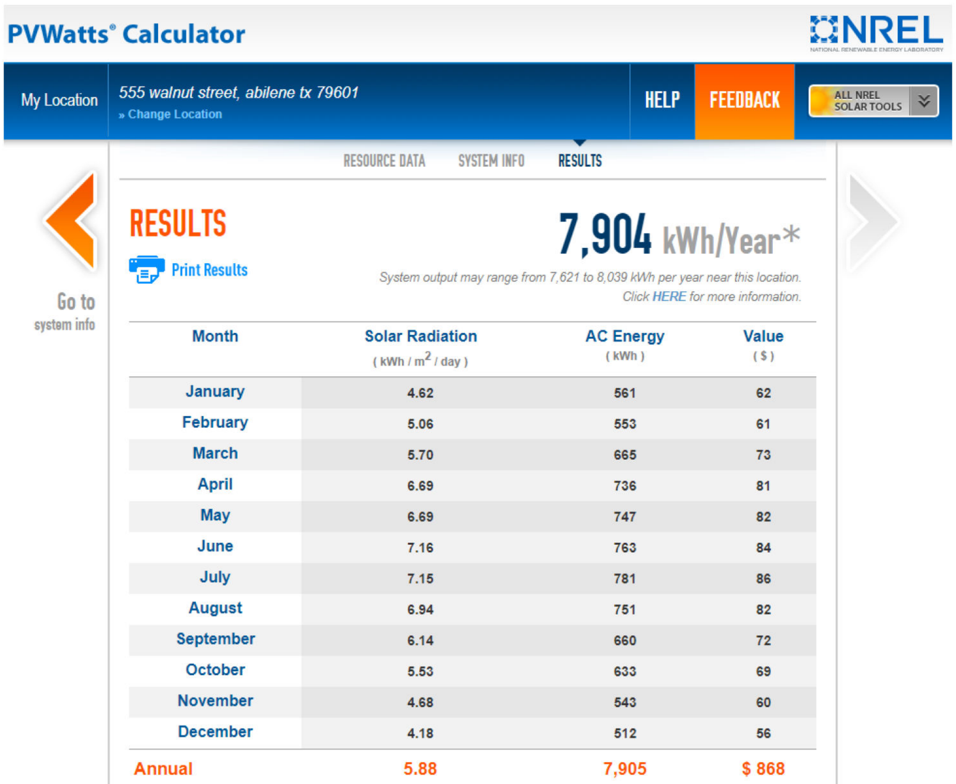
All other details (System Losses, Advanced Parameters, and Initial Economics) are left at default values. Once entered, the user presses "Go to PVWatts® results." See Figure 4 below.

Figure 4. PVWatts® Input Screen for Step 3



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

Figure 5. PVWatts® Output Screen for Step 4



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

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

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

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

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

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

Summer Demand Savings Methodology

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

Deemed Summer Demand Savings

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

Equation 47

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

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

Winter Demand Savings Methodology

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

Deemed Winter Demand Savings

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

Equation 48

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

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

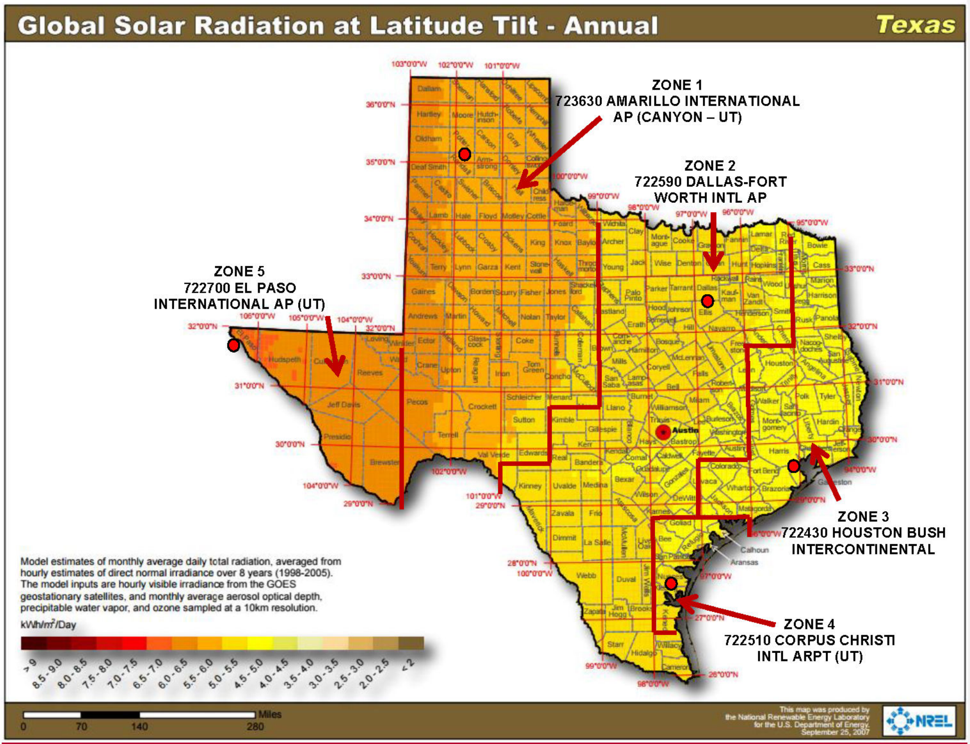
Deemed Energy Savings Tables

Not applicable.

Deemed Summer and Winter Demand Savings—Weather Zone Determination

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

Figure 7. Weather Zone Determination for Solar PV Systems[36]



Deemed Summer and Winter Demand Savings—Lookup Value Tables

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

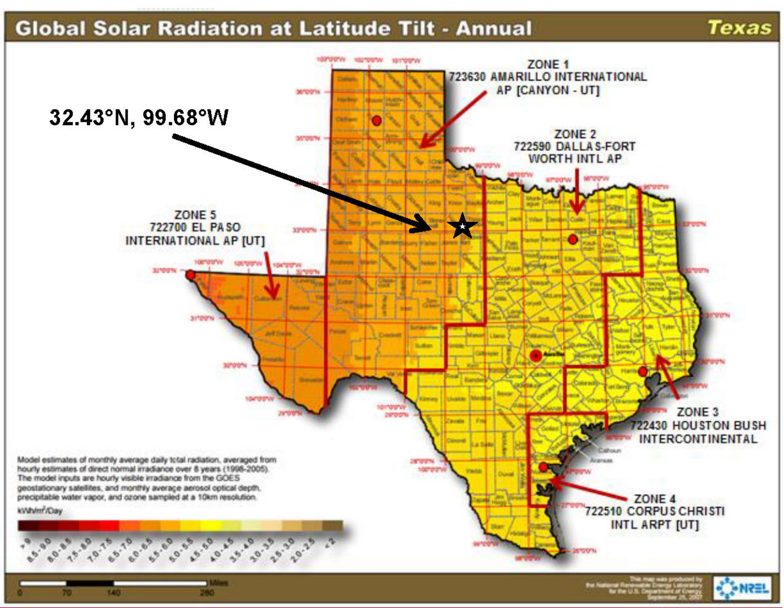
Deemed Summer and Winter Demand Savings—Example

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

- **Step 1.** Determine the appropriate weather zone. Geographic coordinates for this system (32.45°N, 99.74°W from) were derived when determining the annual energy savings (kWh).

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

Figure 8. Application of the Weather Zone Map



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

  Applying Equation 47~~Equation 47~~,

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

  *Deemed summer demand = 5.000 kW * 49%*

  *Deemed summer demand = 5.000 kW * 0.49*

  Deemed summer demand = 2.450 kW

  Applying Equation 48~~Equation 48~~,

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

  *Deemed summer demand = 5.000 kW * 2%*

  *Deemed summer demand = 5.000 kW * 0.02*

  Deemed summer demand = 0.100 kW

Summer and Winter Demand Savings—Alternative Method

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

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

The following information will be required to be collected.

- Project location (full address, including city, state, and zip code)
- Module type: standard, premium, or thin film
- Array Type: fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking, etc.
- Tilt, azimuth, and DC system size rating for each array
- The calculation of electricity production through PVWatts® can be completed by accessing the online calculator or utilizing an API, application programming interface. The required documentation varies between the two methods.
  - Online Calculator: Date of PVWatts® run, and PVWatts® printed results report (as a file retained with project documentation)
- API: Date of API access and response, documentation of API programming (including the access endpoint and request parameters), and the response results.
- Selected climate zone and demand method used
- For projects using the alternative method, retention of the TRM 4.0 PV tool workbook for each array evaluated

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides estimate for EUL.

Relevant Standards and Reference Sources

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

Document Revision History

Table 28. M&V Residential Solar PV Revision History

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

~~2.3.1~~2.3.2 Nonresidential Solar Photovoltaics (PV) Measure Overview

TRM Measure ID: NR-RN-PV

Market Sector: Commercial

Measure Category: Renewables

Applicable Building Types: All

Fuels Affected: Electricity

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

Program Delivery Type: Prescriptive

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

Savings Methodology: Model-calculator (PVWatts®)

Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. These programs are offered by Texas utilities, with the primary objective to achieve cost-effective energy and peak demand savings. Participation in the PV program involves the installation of a solar photovoltaic system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator,[37] to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

Not applicable.

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

Energy and Demand Savings Methodology

Solar PV systems shall be modeled using the current version of the National Renewable Energy Laboratory's (NREL) PVWatts® calculator. Energy savings are estimated using the default weather data source, offered by PVWatts®.[38] Demand savings use lookup tables derived from PVWatts®, based on NREL National Solar Radiation Database (NSRDB) weather data sources defined by location of the project.

Savings Algorithms and Input Variables

All Installations

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

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

Table 29. Module Type Options

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

- Array Type: fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking
- Tilt (deg): enter the angle from horizontal of the photovoltaic modules in the array
- Azimuth (deg): enter the angle clockwise from true north describing the direction that the array faces
- All other input variables: accept the PVWatts® default values

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

Annual Energy Savings (kWh)

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

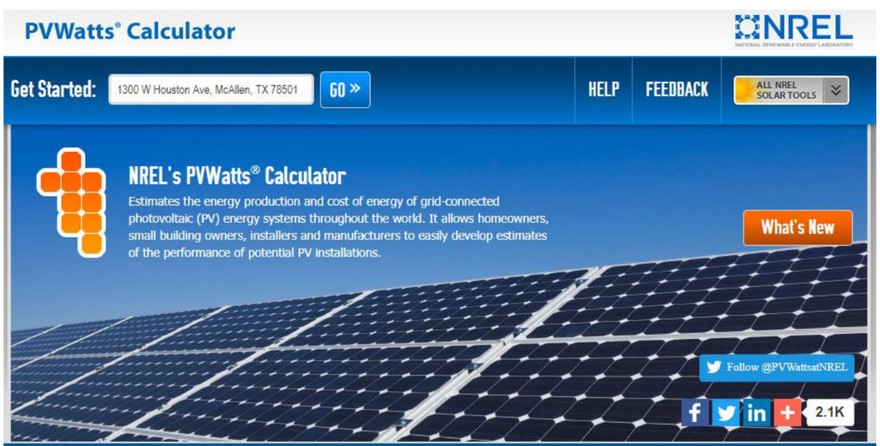
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain total annual energy savings.

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

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

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

Figure 9. PVWatts® Input Screen for Step 1



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

Figure 10. PVWatts® Resource Data Map

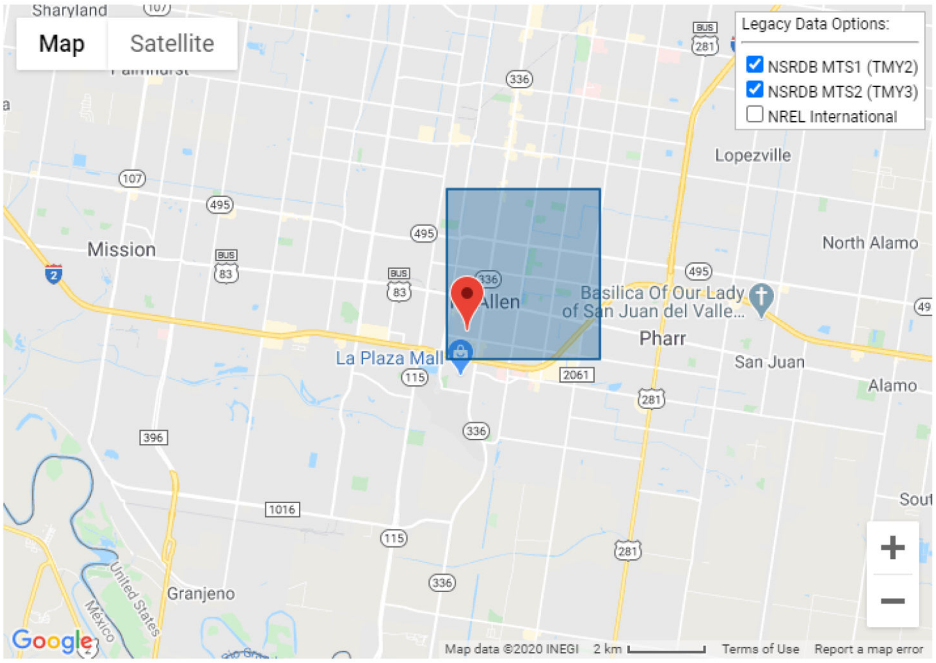
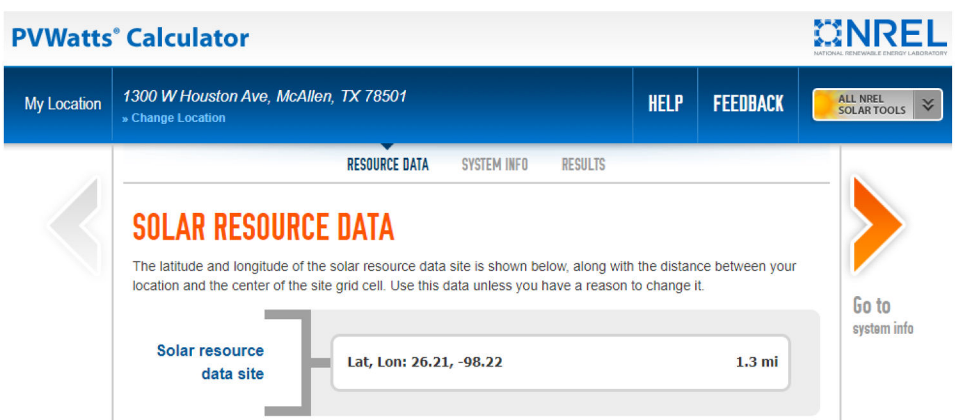


Figure 11. PVWatts® Input Screen for Step 2

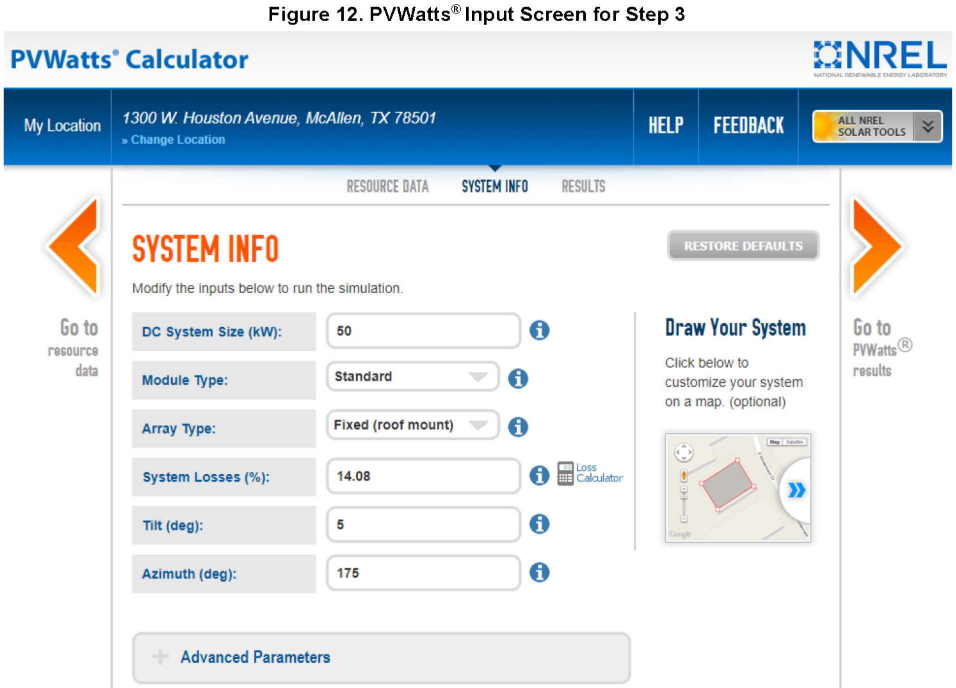


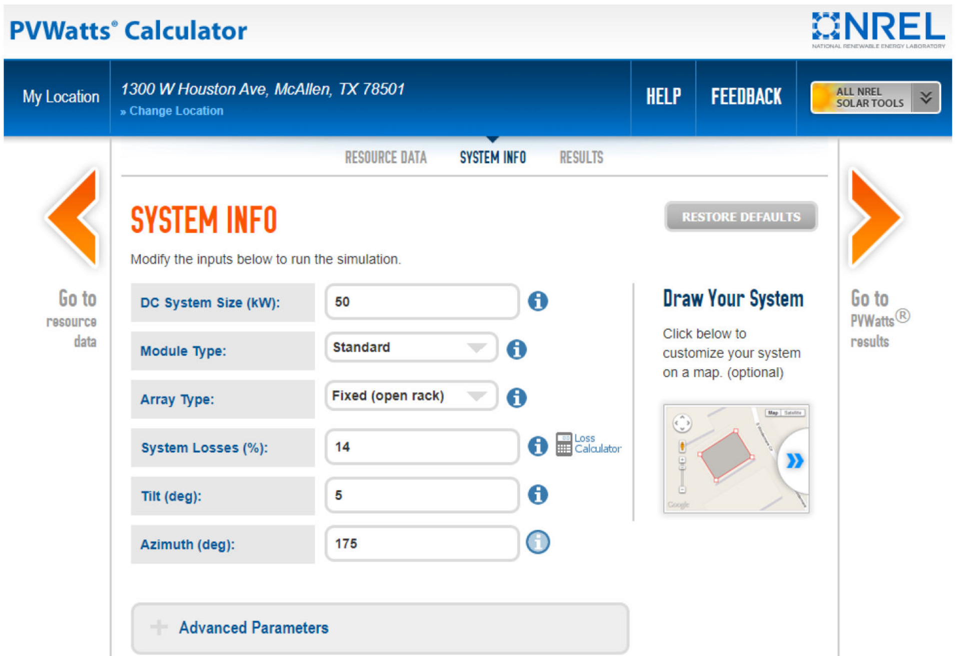
Step 3. The user enters system info as follows:

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

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

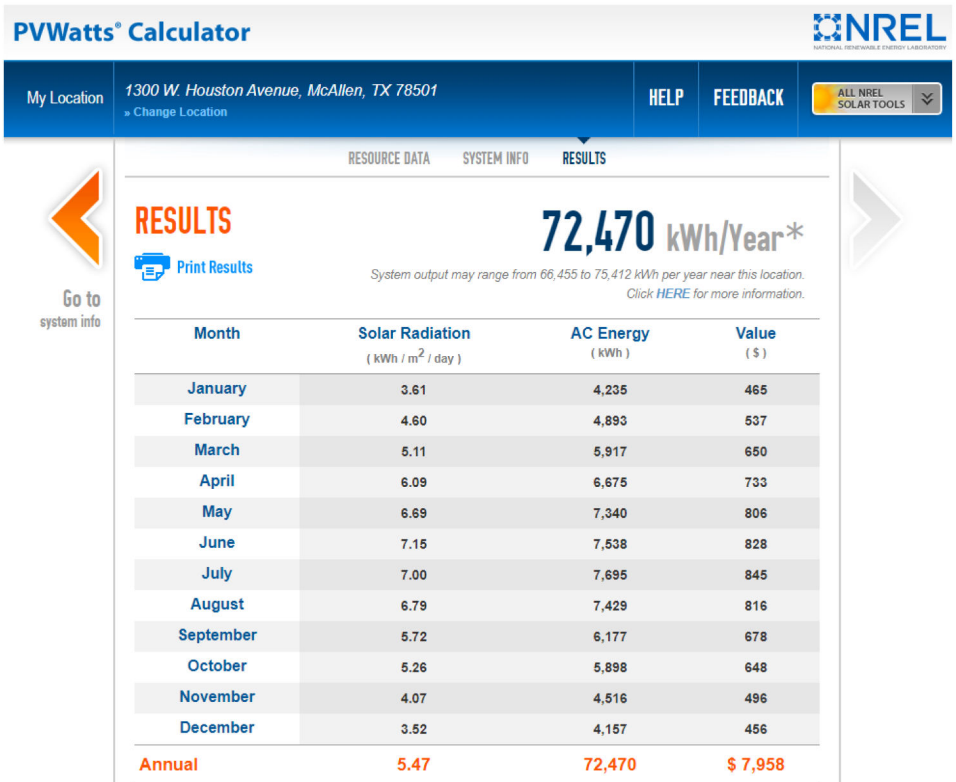
Figure 12. PVWatts® Input Screen for Step 3



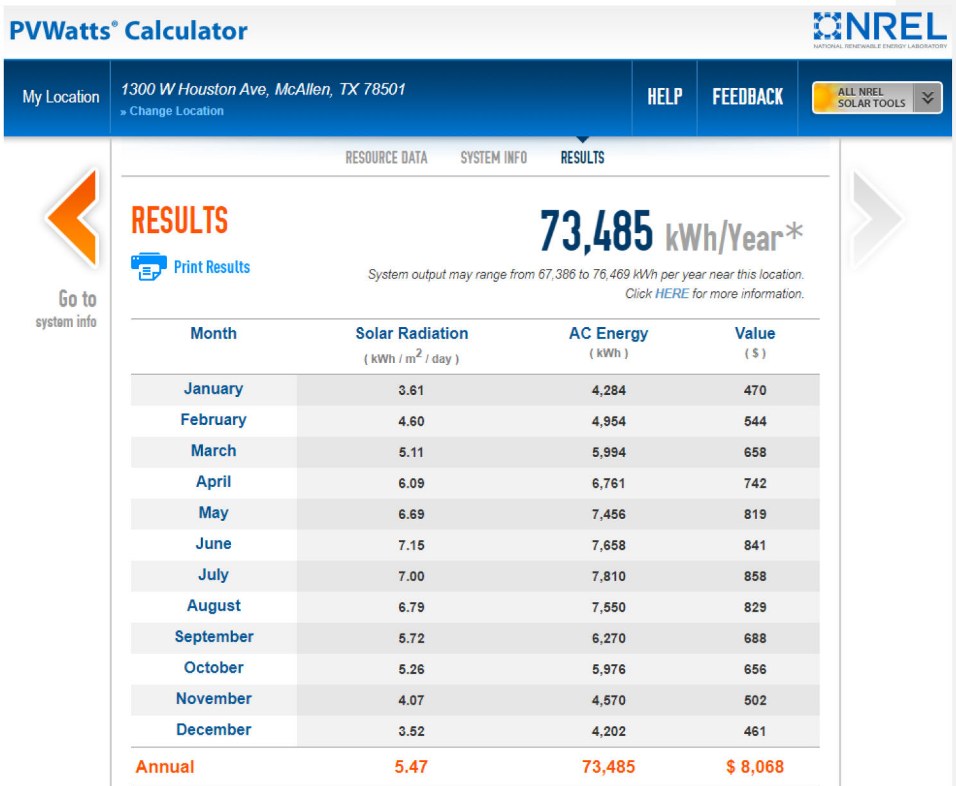


Step 4. PVWatts® returns an estimate of annual energy production (kWh), in this case ~~73,485~~ 72,470 kWh. See Figure 13.

Figure 13. PVWatts® Output Screen for Step 4



Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	3.61	4,235	465
February	4.60	4,893	537
March	5.11	5,917	650
April	6.09	6,675	733
May	6.69	7,340	806
June	7.15	7,538	828
July	7.00	7,695	845
August	6.79	7,429	816
September	5.72	6,177	678
October	5.26	5,898	648
November	4.07	4,516	496
December	3.52	4,157	456
Annual	5.47	72,470	$ 7,958



Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	3.61	4,284	470
February	4.60	4,954	544
March	5.11	5,994	658
April	6.09	6,761	742
May	6.69	7,456	819
June	7.15	7,658	841
July	7.00	7,810	858
August	6.79	7,550	829
September	5.72	6,270	688
October	5.26	5,976	656
November	4.07	4,570	502
December	3.52	4,202	461
Annual	5.47	73,485	$ 8,068

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

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

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

Location and Station Identification	
Requested Location	1300 W Houston Ave, McAllen, TX 78501
Weather Data Source	Lat, Lon: 26.21, -98.22 1.3 mi
Latitude	26.21° N
Longitude	98.22° W
PV System Specifications *(Residential)*	
DC System Size	50 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	5°
Array Azimuth	175°
System Losses	14%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2
Economics	
Average Retail Electricity Rate	0.110 $/kWh
Performance Metrics	
Capacity Factor	16.8%

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

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

Summer Demand Savings Methodology

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

Deemed Summer Demand Savings

$$\textit{Deemed summer demand savings} = \textit{DC system size (kW)} * \textit{Lookup Value}$$

Equation 49

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

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

Winter Demand Savings Methodology

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

Deemed Winter Demand Savings

$$\text{Deemed winter demand savings} = \text{DC system size (kW)} * \text{Lookup Value}$$

Equation 50

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

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

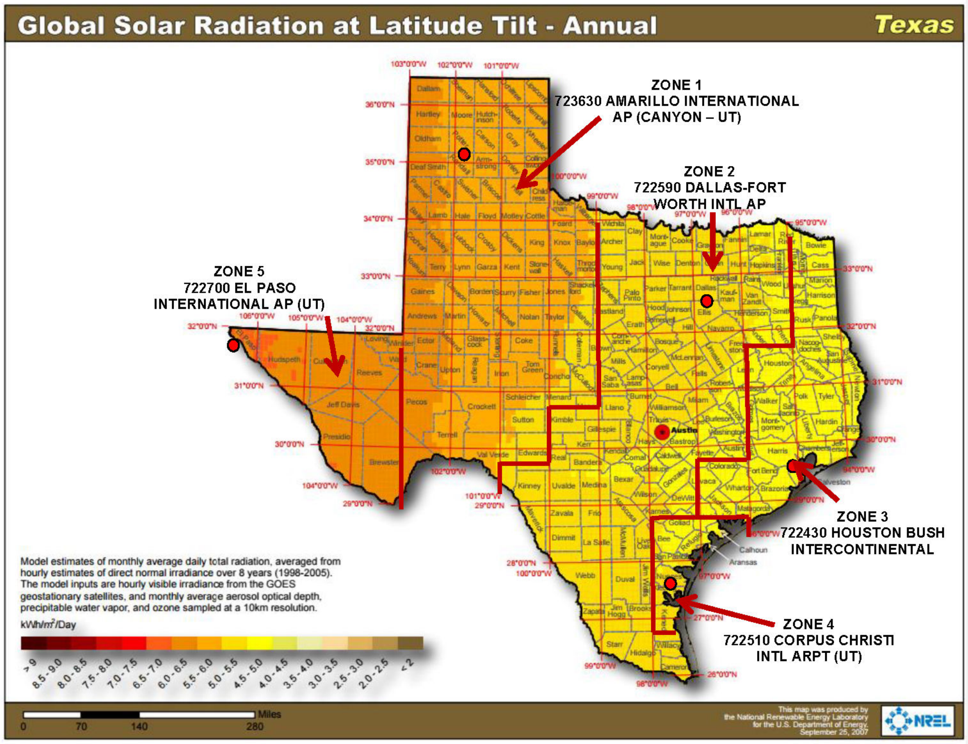
Deemed Energy Savings Tables

Not applicable.

Deemed Summer and Winter Demand Savings—Weather Zone Determination

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

Figure 15. Weather Zone Determination for Solar PV Systems[39]



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%, as shown in Table 30~~18~~.

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