| Steam type | Building type | Principal building activity | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
|---|---|---|---|---|---|---|---|
| | 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.[535]

## 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

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

### Document Revision History

**Table 269. Steam Traps—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v9.0 | 10/2021 | TRM 9.0 origin. |
| v10.0 | 10/2022 | TRM 10.0 update. No revision. |

535 EULs for the steam trap measure are sourced from the Illinois TRM 9.0, volume 2, measure 4.4.16 Steam Trap Replacement or Repair. https://www.ilsag.info/wp-content/uploads/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

$$Energy\ Savings\ [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times hours \times EI$$

**Equation 251**

*Where:*

| | | |
|---|---|---|
| $HP_{motor}$ | = | *Horsepower of the motor, actual nameplate* |
| *0.746* | = | *Constant to convert from hp to kW* |
| *LF* | = | *Motor load factor*[536] *= 75%* |
| $\eta$ | = | *Motor efficiency (use default from Table 270 if actual is not available)* |
| *hours* | = | *Operating hours per year, actual* |
| *EI* | = | *Efficiency increase = 1.0% per gear mesh*[537] |

**Table 270. Hydraulic Gear Lubricants—Motor Efficiencies**[538]

| 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 |

536 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.

537 Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf. Accessed September 2022.

538 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.[539]

## 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

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

[539] 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 271. Hydraulic Gear Lubricants—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v9.0 | 10/2021 | TRM v9.0 origin. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |

## 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, optimizing 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

$$Energy\ Savings\ [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times hours \times EI$$

**Equation 252**

*Where:*

| | | |
|---|---|---|
| $HP_{motor}$ | = | *Horsepower of the motor, actual nameplate* |
| *0.746* | = | *Constant to convert from hp to kW* |
| *LF* | = | *Motor load factor, 75%*[540] |
| $\eta$ | = | *Motor efficiency (use default from Table 272 if actual is not available)* |
| *hours* | = | *Operating hours per year, actual* |
| *EI* | = | *Efficiency increase*[541] *= 3.2%* |

**Table 272. Hydraulic Oils—Motor Efficiencies**[542]

| 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 |

540 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.

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

542 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.

| 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.[543]

## 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.

[543] 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

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 273. Hydraulic Oils—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v9.0 | 10/2021 | TRM v9.0 origin. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |

## 2.7.12 Hand Dryers Measure Overview

**TRM Measure ID:** NR-MS-HD

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** Retail, commercial, and industrial settings

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This document presents the methodology for calculating the savings realized from installing efficient hand dryers, which save energy by drying with air movement using motion sensors, thus reducing hand-drying time.

### Eligibility Criteria

To qualify for this measure, existing hand dryer equipment must currently utilize more than 5 watt-hour (Wh) or more per use and replacement hand dryers must consume no more than 5 Wh per use. This measure is applicable in retail, commercial and industrial settings.

### Baseline Condition

The baseline efficiency case is a hand dryer which utilizes more than 5 Wh or more per use. These hand dryers are often push-button activated.

### High-Efficiency Condition

Eligible high-efficiency equipment is a hand dryer equipped with motion sensors that uses 5 Wh or less per use.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

The energy savings from the installation of efficient hand dryers are a result of savings due to decrease in power and or runtime of the efficient hand dryers over the pre-retrofit equipment. The energy and demand savings are calculated using the following equations:

$$Energy\ Savings\ [\Delta kWh] = \frac{UPD \times DPY \times \Delta Wh}{1{,}000} \times IEF_E$$

**Equation 253**

$$\Delta Wh = Wh_{Baseline} - Wh_{Efficient}$$

**Equation 254**

*Where*:

$UPD$ = *Number of uses per day (see Table 274)*

$DPY$ = *Number of days the facility operates per year (if unknown, see Table 274)*

$IEF_E$ = *Interactive effects factor for energy (see Table 274* )

**Table 274. Hand Dryers—Deemed Energy and Demand Interactive Factors[544]**

| Space conditioning type | $IEF_E$ | $IEF_D$ |
|---|---|---|
| Refrigerated air | 1.05 | 1.10 |
| Evaporative cooling | 1.02 | 1.04 |
| None (unconditioned/uncooled) | 1.00 | 1.00 |

$Wh_{Baseline}$ = *Baseline energy consumption in watt-hours, 20.65*[545]

$Wh_{Efficient}$ = *Efficient energy consumption in watt-hours, 3.94*[546]

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF \times IEF_D$$

**Equation 255**

544 Texas Technical Reference Manual, Volume 2, Section 2.1, Table 11, Nonresidential Lighting.

545 Baseline and efficient Wh per use are averages of the energy consumption of 48 surveyed individual hand dryer units by CLEAResult in Arkansas which consume either greater than 5 Wh or less than 5 Wh per use, respectively. The difference between these equals the assumed Wh savings per use.

546 Ibid.

*Where*:

| | | |
|---|---|---|
| *AOH* | = | *Annual operating hours (see Table 275)* |
| *CF* | = | *Peak coincidence factor (see Table 275)* |
| $IEF_D$ | = | *Interactive effects factor for demand (see Table 274)* |

**Table 275. Hand Dryers—Savings Calculation Input Assumptions**

| Usage level | Building type | Coincidence factor[547] | | | | | AOH[548] | UPD[549] | DPY[550] |
|---|---|---|---|---|---|---|---|---|---|
| | | CZ 1 | CZ 2 | CZ 3 | CZ 4 | CZ 5 | | | |
| Low | Office | 0.87 | 0.88 | 0.86 | 0.90 | 0.90 | 36 | 50 | 250 |
| | Warehouse | 0.79 | 0.81 | 0.79 | 0.80 | 0.85 | | | |
| Medium/moderate | Grocery (small) | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 235 | 225 | 365 |
| | Restaurant | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | | | |
| | Retail | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | | | |
| High | Conference center | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 339 | 500 | 237 |
| | School[551] | 0.39 | 0.39 | 0.90 | 0.87 | 0.40 | | | |
| | Stadium | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | | | |
| | Theater | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | | | |
| | University | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | | | |
| High (grocery) | Grocery/retail (large) | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | | 500 | 365 |
| Heavy duty/extreme | Airport | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 2,614 | 2,500 | 365 |
| | Transportation center | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | | | |

547 Coincidence factors from the Texas TRM Volume 3, Section 2.1, Table 8, Nonresidential Lighting. It is assumed that building occupancy with respect to lighting is an appropriate proxy for occupants' utilization of hand dryers.

548 The assumed annual operating hours per building type are calculated as a simple average of 16 surveyed efficient hand dryers' cycle times multiplied by the assumed uses per day and days per year per usage level (as indicated in Table 275), then converted to hours by dividing this product by 3,600.

549 Industry Standard. Medium/Moderate Uses per day is supported by both Excel Dryer Data (Cost Savings with Hand Dryers vs Average Cost of Paper Towels https://www.exceldryer.com/calculator-dial/) and World Dryer Data (http://staging.worlddryer.com/savings-calculator)

550 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995. Table 2. https://eta-publications.lbl.gov/sites/default/files/lbnl-37398e.pdf.

551 Assuming K–12 without summer session

## Deemed Energy and Demand Savings Tables

The deemed energy and demand savings for hand dryers with unknown number of operating days per year, base/efficient cycles times, and base/efficient unit wattages are as follows:

**Table 276. Hand Dryers—Energy Savings**

| Usage level | Building type | Deemed energy savings |
|---|---|---|
| Low | Office | 223 |
| | Warehouse | 223 |
| Medium/moderate | Grocery (small) | 1,468 |
| | Restaurant | 1,468 |
| | Retail | 1,468 |
| High | Conference center | 2,118 |
| | School[552] | 2,118 |
| | Stadium | 2,118 |
| | Theater | 2,118 |
| | University | 2,118 |
| High (grocery) | Grocery/retail (large) | 3,262 |
| Heavy duty/extreme | Airport | 16,312 |
| | Transportation center | 16,312 |

552 Assuming K–12 without summer session.

**Table 277. Hand Dryers—Peak Demand Savings**

| Usage level | Building type | Deemed demand savings | | | | |
|---|---|---|---|---|---|---|
| | | CZ 1 | CZ 2 | CZ 3 | CZ 4 | CZ 5 |
| Low | Office | 5.43 | 5.49 | 5.37 | 5.62 | 5.62 |
| | Warehouse | 4.93 | 5.05 | 4.93 | 4.99 | 5.30 |
| Medium/moderate | Grocery (small) | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |
| | Restaurant | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |
| | Retail | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |
| High | Conference center | 4.06 | 4.06 | 4.06 | 4.06 | 4.06 |
| | School[553] | 2.43 | 2.43 | 5.62 | 5.43 | 2.50 |
| | Stadium | 4.06 | 4.06 | 4.06 | 4.06 | 4.06 |
| | Theater | 4.06 | 4.06 | 4.06 | 4.06 | 4.06 |
| | University | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |
| High (grocery) | Grocery/retail (large) | 8.65 | 8.65 | 8.65 | 8.65 | 8.65 |
| Heavy duty/extreme | Airport | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |
| | Transportation center | 5.62 | 5.62 | 5.62 | 5.62 | 5.62 |

### Claimed Peak Demand Savings

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

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years[554] for efficient hand dryers.

## Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Building type
- Cooling type

553 Assuming K–12 without summer session.

554 Based on studies conducted by two separate parties; Comparative Environmental Life Cycle Assessment of Hand Drying Systems by Quantis (pg. 2) and Guidelines to Reduce/Eliminate Paper Towel Use by Installing Electric Hand Dryers by Partners in Pollution Prevention P3 (pg. 17).

- Hand dryer quantity
- Hand dryer make and model

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 278. Hand Dryers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM v10.0 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].

**<u>Option 1—Weighting Savings and Holding Measure Life Constant</u>**

**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 256**

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

**Equation 257**

*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 258**

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

**Equation 259**

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

**Equation 260**

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

**Equation 261**

*Where:*

| | | |
|---|---|---|
| $\Delta kW_{FT}$ | = | *First-tier demand savings* |
| $\Delta kW_{ST}$ | = | *Second-tier demand savings* |
| $kW_{retired}$ | = | *Demand of the first-tier baseline system, usually the retired system*[555] |
| $kW_{baseline}$ | = | *Demand of the second-tier baseline system, usually the baseline ROB system*[556] |
| $kW_{installed}$ | = | *Demand of the replacement system*[557] |
| $\Delta kWh_{FT}$ | = | *First-tier energy savings* |
| $\Delta kWh_{ST}$ | = | *Second-tier energy savings* |
| $kWh_{retired}$ | = | *Energy usage of the first-tier baseline system, usually the retired system*[555] |
| $kWh_{baseline}$ | = | *Energy usage of the second-tier baseline system, usually the baseline ROB system*[556] |
| $kWh_{installed}$ | = | *Energy usage of the replacement system*[557] |

**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 262**

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

**Equation 263**

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

**Equation 264**

555 Retired system refers to the existing equipment that was in use before the retrofit has occurred.
556 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).
557 Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

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

**Equation 265**

*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* [558]

*d* = *Discount rate weighted average cost of capital (per utility)* [558]

$AC_{kW}$ = *Avoided cost per kW ($/kW)* [558]

$AC_{kWh}$ = *Avoided cost per kWh ($/kWh)* [558]

$ML_{FT}$ = *First-tier measure life (calculated in Equation 256)*

$ML_{ST}$ = *Second-tier measure life (calculated in Equation 257)*

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

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

**Equation 266**

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

**Equation 267**

*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*

[558] 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.

**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 268**

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

**Equation 269**

*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:

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

**Equation 270**

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

**Equation 271**

*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 266* |

| | | |
|---|---|---|
| $NPV_{Total, kWh}$ | = | *Total energy contributions to NPV of both ER and ROB component, calculated in Equation 267* |
| $NPV_{EUL, kW}$ | = | *Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 268* |
| $NPV_{EUL, kWh}$ | = | *Energy contributions to NPV without weighting, using original EUL, calculated in Equation 269* |

## 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 272**

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

**Equation 273**

*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**

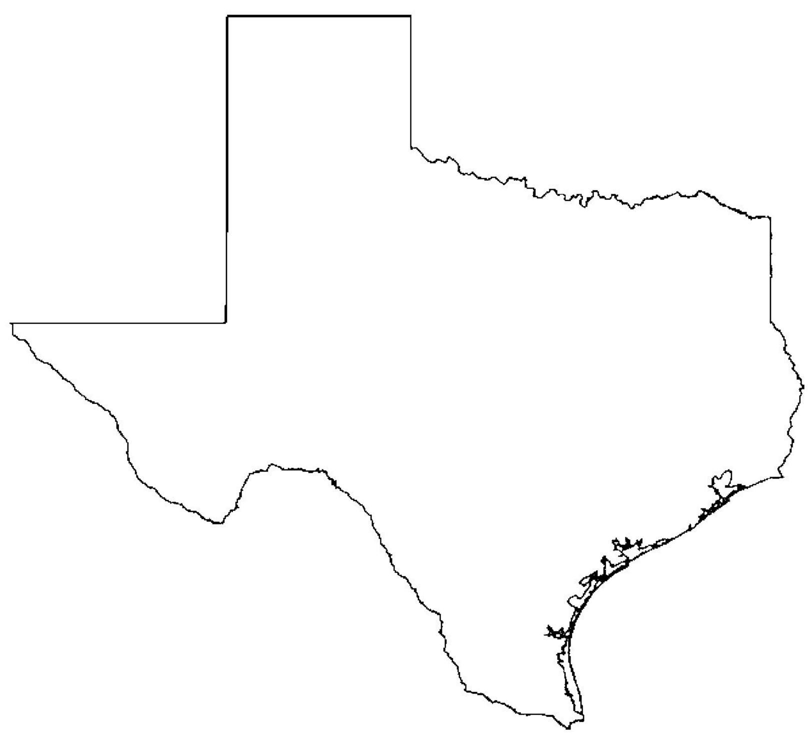
**Version 10.0**

**Volume 4: Measurement and Verification Protocols**

**Program Year 2023**

**Last Revision Date:**

**November 2022**



# Public Utility Commission of Texas

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## Acknowledgments

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

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

## TRM Technical Support

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

# 1. INTRODUCTION

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

M&V protocols are included for the following measures:

- HVAC: Air Conditioning Tune-up
- HVAC: Ground Source Heat Pump
- HVAC: Variable Refrigerant Flow Systems
- Whole House: Residential New Construction
- Whole House: Smart Home Energy Management System (SHEMS)
- Building Energy Codes: Residential Energy Code Compliance Enhancement
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Renewables: Solar Attic Fans
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors Less than 75 hp
- Miscellaneous: Nonresidential Measurement and Verification
- 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 | 10.0 update |
|---|---|---|---|
| Residential and nonresidential | HVAC | Air conditioning tune-ups | No revisions |
| Nonresidential | HVAC | Ground source heat pumps | Updated to comply with IPMVP Core Concepts 2022 |
| Nonresidential | HVAC | Variable refrigerant flow systems | Updated to comply with IPMVP Core Concepts 2022 |
| Residential | Whole house | Residential new construction | Updated to require reference home modeling be completed with ANSI/RESNET/ICC 301 (most recent published version and ANSI addenda) reference defaults; added language for additional rater certification options; updated all MINHERS references with ANSI/RESNET/ICC references |
| Residential | Whole house | Smart home energy management system (SHEMS) | TRM 10.0 origin |
| Residential | Building energy codes | Residential energy code compliance enhancement | TRM 10.0 origin |
| Residential and nonresidential | Renewables | Residential and nonresidential solar photovoltaics | No revisions |

| Sector | Measure category | Measure description | 10.0 update |
|---|---|---|---|
| Residential and nonresidential | Renewables | Solar shingles | No revisions |
| Residential | Renewables | Solar attic fans | No revisions |
| Nonresidential | Miscellaneous | Behavioral | Updated to comply with IPMVP Core Concepts 2022 |
| Nonresidential | Miscellaneous | Air compressors less than 75 hp | Updated to comply with IPMVP Core Concepts 2022 |
| Nonresidential | Miscellaneous | Nonresidential measurement and verification | Updated measure to apply to measurement and verification beyond Retro-commissioning; added reference to IPMVP Core Concepts 2022; added evaluator preapproval for projects without one-hour incremental data or less than one-year pre- and post-measurement data; added a 40 percent pre-analysis energy savings claim option. |
| Nonresidential | Miscellaneous | Thermal energy storage | Updated to comply with IPMVP Core Concepts 2022 |
| Residential | Load management | Residential load curtailment | Added footnote for Additional Calculation Considerations; updated Reference Sources. |
| Nonresidential | Load management | Nonresidential load curtailment | Updated Utility Program Details Overview; updated Reference Sources. |

# 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**

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

**Equation 7**

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

**Equation 8**

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

**Equation 9**

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

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

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

**Equation 10**

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

**Equation 11**

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

**Equation 12**

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

**Equation 13**

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

**Equation 14**

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

**Equation 15**

*The Saturation Over Liquid Water equation is:*

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

**Equation 16**

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

**Equation 17**

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

**Equation 18**

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

**Equation 19**

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

**Equation 20**

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

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

**Equation 21**

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

**Equation 22**

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

**Equation 23**

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

**Equation 24**

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

**Equation 25**

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

**Equation 26**

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

**Equation 27**

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

**Equation 28**

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

**Equation 29**

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

**Equation 30**

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

*Where:*

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

*Note: Use EER as efficiency "$\eta_C$" for kW and kWh cooling savings calculations. Use Heating Season Performance Factor (HSPF) as efficiency "$\eta_H$" for kW and kWh heating savings calculations.*

| | | |
|---|---|---|
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Residential Volume 2 Table 16); Nonresidential Volume 3 Table 32 through Table 36)* |
| *CF* | = | *Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Table 17); Nonresidential Volume 3 Tables 32 through Table 36)* |
| *Volts* | = | *Measured voltage (volts) on single-phase electric power leads to AC components* |
| *Amps* | = | *Measured current flow (amps) on single-phase electric power leads to AC components* |
| *PF* | = | *Power factor stipulated based on motor type (see Table 3)* |
| $V_1$, $V_2$, $V_3$ | = | *Measured voltage, line to line on each of the three electric power leads ($V_1$, $V_2$, $V_3$) to AC components for three-phase loads* |
| $A_1$, $A_2$, $A_3$ | = | *Measured current flow (Amps) on each line ($A_1$, $A_2$, $A_3$) of the three power leads to AC components for three-phase loads* |

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

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

## Energy and Demand Savings Tables

### *Efficiency Loss Factors*

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

**Table 2. AC Tune-Up Efficiency Loss Factors**

| Market sector | Refrigerant charge adjusted |
|---|---|
| Residential | No |
| | Yes |
| Commercial | No |
| | Yes |

### *Power Factors*

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

**Table 3. Recommended Power Factors for AC Components**

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

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

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

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

### *Cooling Load Calculation*

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

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

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

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

**Table 5. EER Adjustment Factor and Capacity Adjustment Factor Constants**

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

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

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

### *Metering Plan*

### Equipment Required

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

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

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

**Table 7. AC Tune-Up Toolkit Components**

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

## Metering Schedule

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

### Equipment Accuracy

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

**Table 8. Measurement Resolution and Accuracy**

| Device | Model number | Measurement | Resolution | Accuracy |
|---|---|---|---|---|
| Inspection scope | Testo 318-V | Visual coil inspection | N/A | N/A |
| Anemometer | Testo 417[6] | Air flow velocity | 0.01m/s | ±0.1m/s+1.5% of reading |
| Manometer | Testo 510[6] | Differential pressure | 0.01 inH2O | ±0.01 inH2O (0-0.12 inH2O), ±0.02 inH2O (0.13-0.40 inH2O), ±(0.04 inH2O +1.5 % of reading) (rest of range) |
| Refrigerant system analyzer | Testo 556[6] | Refrigerant temperature | 0.1°F | ±0.6°F ±1 digit |
| | | Refrigerant pressure | 0.1 psi | ±0.5% Full Scale |
| | Testo 560[6] | Refrigerant temperature | 0.1°F | ±0.6°F ±1 digit |
| | | Refrigerant pressure | 0.1 psi | ±0.5% Full Scale |
| | Testo 550[6] | Refrigerant temperature | 0.1°F | ±1.8°F + 1 digit |
| | | Refrigerant pressure | 0.1 psi | ±0.75% Full Scale + 1 Digit |
| | iManifold 913-M and 914-M[7] | Refrigerant temperature | 0.1°F | ±0.4°F |
| | | Refrigerant pressure | 0.1 psi | ±0.5% Full Scale |
| DB/WB thermometer | Testo 605-H2[6] | Dry-/wet-bulb temperature | 0.1°F | ±0.9°F |
| | iManifold 911-M[7] | | 0.1°F | ±0.4°F |
| Surface thermometer | Testo 905-T2[6] | Condenser ambient air temperature | 0.1°F | ±1.8°F (-58 to +212°F) |
| | iManifold 912-M[7] | | 0.1°F | ±0.4°F |
| Volt/amp meter | Fluke 27-II[8] | Voltage | 0.1 V | ±(0.5% +3) |
| | | Current | 0.01 A | ±(1.5% +2) |
| Ruler/tape measure | N/A | Air grill dimensions[9] | 1/8 in | ±1/16 in |

## Claimed Peak Demand Savings

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

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

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

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

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

Not applicable.

## Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition and applicable to the tune-up measure include the following:
- Updated demand and energy coefficients for all commercial HVAC systems.

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

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

## Relevant Standards and Reference Sources

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

## Document Revision History

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

| TRM version | Date | Description of change |
|---|---|---|
| v3.0 | 4/10/2015 | TRM v3.0 origin. |
| v3.1 | 11/05/2015 | Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match the layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History. |
| v4.0 | 10/10/2016 | Revised efficiency loss factors based on 2015 results. Added VFD motor types. |
| v5.0 | 10/10/2017 | Removed reference to deemed efficiency loss factors. Added clarity to separate units by refrigerant charge adjustments and unit size/type. Updated table references. |
| v6.0 | 10/2018 | No revisions. |
| v7.0 | 10/2019 | No revisions. |
| v8.0 | 10/2020 | No revisions. |
| v9.0 | 10/2021 | No revisions. |
| v10.0 | 10/2022 | No revisions. |

### 2.1.2 Ground Source Heat Pumps Measure Overview

**TRM Measure ID:** NR-HV-GH

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** Commercial

**Fuels Affected:** Electricity

**Decision/Action Types:** Retrofit (RET)

**Program Delivery Type:** Custom

**Deemed Savings Type:** Not applicable

**Savings Methodology:** EM&V and whole facility measurement

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

## Measure Description

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

Applicable GSHP efficient measure types include:

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

## Eligibility Criteria

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

## Baseline Condition

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

## High-Efficiency Condition

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

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

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

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

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

[11] Values from ASHRAE 90.1-2013.

## Energy and Demand Savings Methodology

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

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

## M&V Plan and M&V Report

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

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

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

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

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

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

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

**Equation 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 GSHPs is 20 years.

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

## Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ER system type conversion
- Building type
- Climate zone
- Baseline equipment type
- Baseline equipment rated cooling and heating capacities

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

- Baseline equipment 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. |
| v10.0 | 10/2022 | No revisions. |

### 2.1.3 Variable Refrigerant Flow Systems Measure Overview

**TRM Measure ID:** NR-HV-VR

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** Commercial

**Fuels Affected:** Electricity

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

**Program Delivery Type:** Custom

**Deemed Savings Type:** Not applicable

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

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

## Measure Description

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

Applicable VRF efficient measure types include:

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

## Eligibility Criteria

- This measure applies to replacing an existing HVAC system with a new VRF system or a new construction VRF system.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[14,15]

## Baseline Condition

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

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

## High-Efficiency Condition

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

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

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

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

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

| System type | Capacity (Btu/h) | Heating section type | Subcategory or rating condition | Baseline efficiencies | Source |
|---|---|---|---|---|---|
| VRF air-cooled (heating mode) | < 65,000 (cooling capacity) | | VRF multi-split system | 7.7 HSPF | ASHRAE 90.1-2013 Table 6.8.1-10 |
| | ≥ 65,000 and < 135,000 (cooling capacity) | | VRF multi-split system 47$^{0}$F db/43$^{0}$F wb outdoor air | 3.3 $COP_H$ | |
| | | | VRF multi-split system 17$^{0}$F db/15$^{0}$F wb outdoor air | 2.25 $COP_H$ | |
| | ≥ 135,000 (cooling capacity) | | VRF multi-split system 47$^{0}$F db/43$^{0}$F wb outdoor air | 3.2 $COP_H$ | |
| | | | VRF multi-split system 17$^{0}$F db/15$^{0}$F wb outdoor air | 2.05 $COP_H$ | |
| VRF water-source (heating mode) | < 135,000 (cooling capacity) | – | VRF multi-split system 68$^{0}$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$^{0}$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 Core Concepts EVO 10000-1:2022.

## M&V Plan and M&V Report

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

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

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

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

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

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

**Equation 39**

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

*Where:*

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

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

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

**Equation 40**

*Where:*

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

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

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

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

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

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

**Equation 41**

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

**Equation 42**

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

**Equation 43**

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

**Equation 44**

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

**Equation 45**

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

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

**Equation 46**

*Where:*

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

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

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

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

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

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

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

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

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

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

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

## Deemed Energy and Demand Savings

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

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

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

## Measure Life and Lifetime Savings

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

## Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ER, ROB, NC, system type conversion
- Building type
- Climate zone
- System type (VRF AC, VRF HP air-cooled, VRF HP water-source)
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed number of units
- Installed equipment type

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

- Installed rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For other building types only**: Description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

## References and Efficiency Standards

## Petitions and Rulings

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

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 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. |
| v10.0 | 10/2022 | Clarify no M&V plan requirement for deemed path. Add system type to tracking requirements. |

## 2.2 M&V: WHOLE HOUSE

### 2.2.1 Residential New Construction Measure Overview

**TRM Measure ID:** R-HS-NH

**Market Sector:** Residential

**Measure Category:** Whole house

**Applicable Building Types:** Single-family; manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Types:** New construction (NC)

**Program Delivery Type:** Custom

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

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

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

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

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

- BeOpt[18]
- RESNET accredited software
- Hourly analysis programs tested in accordance with ASHRAE 140 and meeting the requirements of ASHRAE 90.1 Appendix G (i.e., DOE-2, EnergyPlus, HAP, TRACE, IESVS, etc.)[19]

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

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

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

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

## Measure Description

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

## Eligibility Criteria

This measure does not apply to existing construction: only residential new construction projects completed in a given program year are eligible.[20]

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

## Baseline Condition[21]

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

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

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

Accordingly, baseline parameters and key model input values for new single-family detached homes and residential multifamily buildings three stories or less are detailed in Table 14. Baseline parameters and key model input values for new residential multifamily buildings of more than three stories (and portions thereof/units within) are detailed in Table 15.

Exception:[22] Multifamily buildings with 4 or 5 stories above-grade[23] where dwelling units occupy 80 percent or more of the occupiable square footage of the building may select the most appropriate baseline condition. When evaluating mixed-use buildings for eligibility, exclude commercial/retail space when assessing whether the 80 percent threshold has been met.

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

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

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

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

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

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

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

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

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

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

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

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

| Baseline and dwelling parameters and characteristics | Reference home specification/value |
|---|---|
| **HVAC commissioning** | |
| Grade III (untested/commissioned by rater)[27] | Same as as-built |
| **Dehumidification system** | |
| None, except where a dehumidification system is specified by the rated home, in which case:[28]<br><br>Type: Stand-alone dehumidifier of same type (portable or whole-home) as the Rated Home<br><br>Capacity: Same as rated home<br><br>Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows:<br>25.00 or less: 0.79 liters/kWh<br>25.01-35.00: 0.95 liters/kWh<br>35.01-54.00: 1.04 liters/kWh<br>54.01-74.99: 1.20 liters/kWh<br>75.00 or more: 1.82 liters/kWh<br><br>Dehumidistat setpoint: 60 percent RH | Same as as-built |
| **Water heating system** | |
| DHW fuel type | Same as as-built |
| DHW water heater location | Same as as-built, except when as-built location is in a sealed attic, then located in a vented attic |
| DHW capacity (gallons) | Same as as-built for storage-type units; assume a 40-gallon storage water heater when as-built water heater is instantaneous |
| DHW energy factor (UEF) | Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[29]) as of April 16, 2015 |

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

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

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

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

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

| Baseline and dwelling parameter and characteristics | Baseline specification/value |
|---|---|
| **Envelope** | |
| Unit type | Multifamily building |
| Number of stories above grade 1 | Same as as-built |
| Foundation type | Same as as-built |
| Number of bedrooms | Same as as-built |
| Total conditioned floor area | Same as as-built |
| Total conditioned volume | Same as as-built |
| Wall height per floor | Same as as-built |
| Window distribution (N, S, E, W) | Same as as-built |
| Percentage of window-to-floor area | Same as as-built |
| Front door orientation | Same as as-built |
| Aspect ratio (length/width) | Use the same estimated average aspect ratio for both baseline and as-built; however, it is recommended to use the actual aspect ratio when actual house footprint dimensions are available |

| Baseline and dwelling parameter and characteristics | Baseline specification/value |
|---|---|
| Roof solar absorptivity | Same as as-built; when as-built data is not available, use 0.75 |
| Attic insulation U-value | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Cathedral ceiling insulation U-value | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Percentage cathedral ceilings | Same as as-built |
| Wall construction | 2x4 light gauge metal framing – 16 inch on center spacing |
| Wall framing fraction | 23 percent |
| Wall insulation | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Door R-value | Same as as-built. |
| Floor insulation | ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Rim joist | Same as wall insulation |
| Window U-factor | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Window SHGC | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| Air infiltration | Same as proposed |
| Mechanical ventilation | See ASHRAE 90.1-2013, Appendix G |
| Slab edge insulation | See ASHRAE 90.1-2013, Tables 5.5-1 through 5.5-8, based on climate zone |
| **HVAC equipment** | |
| HVAC equipment type | See ASHRAE 90.1-2013, Table G3.1.1A/G3.1.1B |
| Cooling capacity | Same as as-built or simulated to reflect reference home load, not to exceed 20 percent difference |
| Heating capacity | Same as as-built or simulated to reflect reference home load, not to exceed 20 percent difference |
| Cooling efficiency | See ASHRAE 90.1-2013, Section 6.8 |
| Heating efficiency | See ASHRAE 90.1-2013, Section 6.8 |
| Thermostat type | Same as as-built |
| Heating setpoint (occupied/unoccupied) | 70°F/70°F |
| Cooling setpoint (occupied/unoccupied) | 78°F/80°F |

| Baseline and dwelling parameter and characteristics | Baseline specification/value |
|---|---|
| **HVAC commissioning** | |
| Grade III (untested/commissioned by rater)[30] | Same as as-built |
| **Dehumidification system** | |
| None, except where a dehumidification system is specified by the rated home, in which case:[31]<br><br>Type: Stand-alone dehumidifier of same type (portable or whole-home) as the rated home<br><br>Capacity: Same as rated home<br><br>Efficacy: Integrated energy factor (liters/kWh) determined as a function of capacity in pints/day, as follows:<br>25.00 or less: 0.79 liters/kWh<br>25.01-35.00: 0.95 liters/kWh<br>35.01-54.00: 1.04 liters/kWh<br>54.01-74.99: 1.20 liters/kWh<br>75.00 or more: 1.82 liters/kWh<br><br>Dehumidistat setpoint: 60 percent RH | Same as as-built |
| **Water heating system** | |
| DHW fuel type | Same as as-built |
| DHW capacity (gallons) | Same as as-built for storage; assume a 50-gallon storage water heater when as-built water heater is instantaneous |
| Energy factor (EF) | See ASHRAE 90.1-2013, Table 7.8 |
| DHW temperature | 120°F |
| DHW pipe insulation | None |
| Low-flow showerheads | None |
| **Lighting** | |
| High-efficacy lamps | 0.51 Watts per $ft^2$ |

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

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

## High-Efficiency Condition

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

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *House Simulation Modeling*

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

### *Energy Savings Methodology*

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

### *Summer Demand Savings Methodology*

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

### *Winter Demand Savings Methodology*

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

### *Post-Processing for Calculating Demand and Energy Savings*

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

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

## Deemed Energy and Demand Savings Tables

Not applicable.

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

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

## Measure Life and Lifetime Savings

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

## Program Tracking Data and Evaluation Requirements

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

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

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

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

- DHW pipe insulation
- Number of low-flow showerheads and flow rate
- Number of low-flow faucets and flow rate

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

### *Files to Submit for EM&V Review*

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

- RESNET accredited software: http://www.resnet.us/professional/programs/energy_rating_software
- ASHRAE 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*
- ASHRAE 140, Standard Method of Test for the Evaluation of Building Energy Analysis Programs
- ENERGY STAR® Multifamily High Rise Program Simulation Guidelines
- International Code Council, *2015 International Energy Conservation Code*.

## Document Revision History

**Table 16. M&V Residential New Construction Revision History**

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

| TRM version | Date | Description of change |
|---|---|---|
| v8.0 | 10/2020 | For reference home specification, added IECC 2015 for mechanical ventilation and federal standard efficiency for appliances. |
| v9.0 | 10/2021 | For reference home specification, added HVAC commissioning and dehumidification system. |
| v10.0 | 10/2022 | Updated references to current relevant standards. |

## 2.2.2 Smart Home Energy Management System (SHEMS) Measure Overview

**TRM Measure ID:** R-HS-SH

**Market Sector:** Residential

**Measure Category:** Whole house

**Applicable Building Types:** Single-family; manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Types:** New construction and retrofit

**Program Delivery Type:** Custom

**Deemed Savings Type:** Look-up tables

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

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

### Measure Description

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

### Eligibility Criteria

The measure applies to all residential applications.

### Baseline Condition

The baseline condition is assumed to be uncontrolled loads.

### High-Efficiency Condition

The high-efficiency condition is loads controlled by SHEMS.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings*

Annual energy (kWh) savings are calculated as follows.

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

**Equation 47**

*Where*:

$kWh_{connected}$ = *Average annual energy consumption of lighting and plug loads connected to SHEMS (see Table 17)*

$ERP$ = *Energy reduction percentage (see Table 17)*

$IEF_E$ = *Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 18)*

$ISR$ = *In-service rate, the percentage of incentivized units that are rebated, installed and in use; default = 0.97*

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

**Table 17. SHEMS: Default Total Kilowatt–hour Connected and ERP Results**[32]

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

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

**Table 18. SHEMS: Interactive Effects for Cooling Energy Savings & Heating Energy Penalties[33]**

| $IEF_E$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.91 | 1.00 | 1.05 | 1.11 | 0.97 |
| Electric resistance heat with AC | 0.65 | 0.80 | 0.90 | 1.00 | 0.75 |
| Electric resistance heat with no AC | 0.57 | 0.69 | 0.76 | 0.83 | 0.65 |
| No heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[34] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

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

### *Demand Savings*

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

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

**Equation 48**

*Where*:

$Hours$ = *Annual hours per year controlled by SHEMS (Default = 4,380[35])*

$CF$ = *Coincidence factor (see Table 19)*

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

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

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

**Table 19. SHEMS: Coincidence Factors**[36]

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

## Upstream/Midstream Program Assumptions

Upstream/midstream delivery of SHEMS should generally follow the same guidance to calculate savings using the Unknown (per Smart Switch) and Unknown (per Smart Plug) default assumptions for $kWh_{connected}$ and $ERP$, provided in Table 17.

## Deemed Energy and Demand Savings Tables

Not applicable.

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

Not applicable.

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

## Measure Life and Lifetime Savings

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

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

## Petitions and Rulings

Not applicable.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 20. SHEMS: Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM 10.0 origin. |

## 2.3 M&V: BUILDING ENERGY CODES

### 2.3.1 Residential Energy Code Compliance Enhancement Measure Overview

**TRM Measure ID:** R-EC-RC

**Market Sector:** Residential

**Measure Category:** Energy code compliance enhancement

**Applicable Building Types:** All residential

**Fuels Affected:** Electricity

**Decision/Action Types:** New construction

**Program Delivery Type:** Custom

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

**Savings Methodology:** Custom

## Measure Description

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

## Eligibility Criteria

This measure does not apply to existing construction: only residential new construction and major renovation projects completed in an energy code evaluation cycle are eligible to be included in the potential savings calculations. Furthermore, only program activities operating within the state will be considered for attributable savings.

## Baseline Condition

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

## High-Efficiency Condition

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

## Energy and Demand Savings Methodology

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

### ***Market Baseline***

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

The baseline is established through an in-field study or studies to examine the current state of newly constructed buildings and major renovations by conducting site visits to collect information that assesses building practices and energy-consuming equipment. The baseline study must target single-family and multifamily residential building types for that evaluation cycle, maintaining relative precision values below 20 percent (85 percent confidence interval) for relevant building types.[37]

### ***Potential Energy Savings***

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

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

### ***Compliance Adjustment Factor (CAF)***

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

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

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

### ***Gross Code Energy Savings***

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

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

### ***Naturally Occurring Market Adoption (NOMA)***

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

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

### ***Net Code Energy Savings***

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

### ***Attribution Factor (AF)***

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

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

### ***Allocation***

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

### ***Delphi Panel Overview***

A Delphi panel is an acceptable data collection method to inform the development of factors in the savings framework. The panel is expected to consist of 10–15 industry experts, including builders, raters, engineers, code officials, consultants, and academics, preferably from the relevant jurisdiction(s). The panel should access all relevant and necessary information in the implementation plan and supporting documentation; including baseline study results, new construction and major renovation data, survey responses, and all evidence collected by the utility to support its energy compliance enhancement efforts. For more information on the Delphi process, see the Illinois TRM v10, Vol. 4, Section 6.6.[38]

## Energy Savings Methodology

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

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

**Equation 49**

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

**Equation 2**

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

**Equation 3**

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

**Equation 4**

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

**Equation 5**

*Where:*

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

## Summer Demand Savings Methodology

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

## Winter Demand Savings Methodology

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

[38] 2022 Illinois Statewide Technical Reference Manual, v10.0, Volume 4, Section 6.6: Structured Expert Judgment Approaches. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010122_v10.0_Vol_4_X-Cutting_Measures_and_Attach_09242021.pdf.

## Deemed Energy and Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

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

## Program Tracking Data and Evaluation Requirements

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

- Building type
- Quantity
- Building area
- Climate/weather zone
- Building code jurisdiction
- Compliance enhancement activity log

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

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

- Allocation factor
- Allocation

## Petitions and Rulings

Not applicable.

## Relevant Standards and Reference Sources

Not applicable.

## Document Revision History

**Table. Residential Energy Code Compliance Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 11/2022 | TRM 10.0 origin |

## 2.4 M&V: RENEWABLES

## 2.4.1 Residential Solar Photovoltaics (PV) Measure Overview

**TRM Measure ID:** R-RN-PV

**Market Sector:** Residential

**Measure Category:** Renewables

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

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

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

**Savings Methodology:** Model-calculator (PVWatts®)

### Measure Description

This section summarizes savings calculations for solar photovoltaic (PV) standard offer, market transformation, and pilot programs. The primary objective of these programs is to achieve cost-effective energy savings and peak demand savings. Participation in the solar photovoltaic program involves the installation of a PV system. The method uses a simulation tool, the National Renewable Energy Laboratory's (NREL) PVWatts® Calculator[39], to calculate energy savings. Lookup tables are used to determine deemed summer and winter peak demand savings.

### Eligibility Criteria

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

### Baseline Condition

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

### High-Efficiency Condition

Not applicable.

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

## Energy and Demand Savings Methodology

All PV systems shall be modeled using the current version of the NREL PVWatts® calculator. Energy savings are estimated using the default weather data source (currently TMY2) offered by PVWatts®.[40] Demand savings use lookup tables derived from PVWatts®, which uses the NREL National Solar Radiation Database (NSRDB) weather data sources for the location of the project.

## Savings Algorithms and Input Variables

### *All Installations*

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

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

**Table 21. Module Type Options**

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

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

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

## Annual Energy Savings (kWh)

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

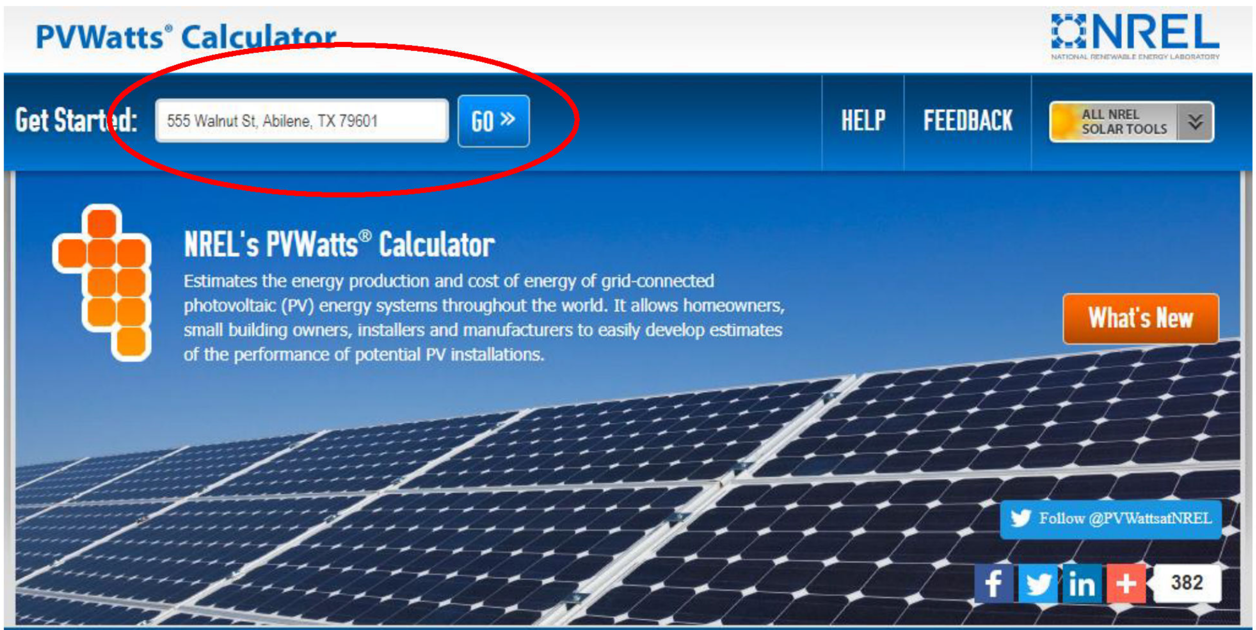
For systems with multiple arrays, users should derive annual energy savings for each array separately and sum them to obtain the total annual energy savings.

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

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

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

**Figure 1. PVWatts® Input Screen for Step 1**




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

**Figure 2. PVWatts® Resource Data Map**

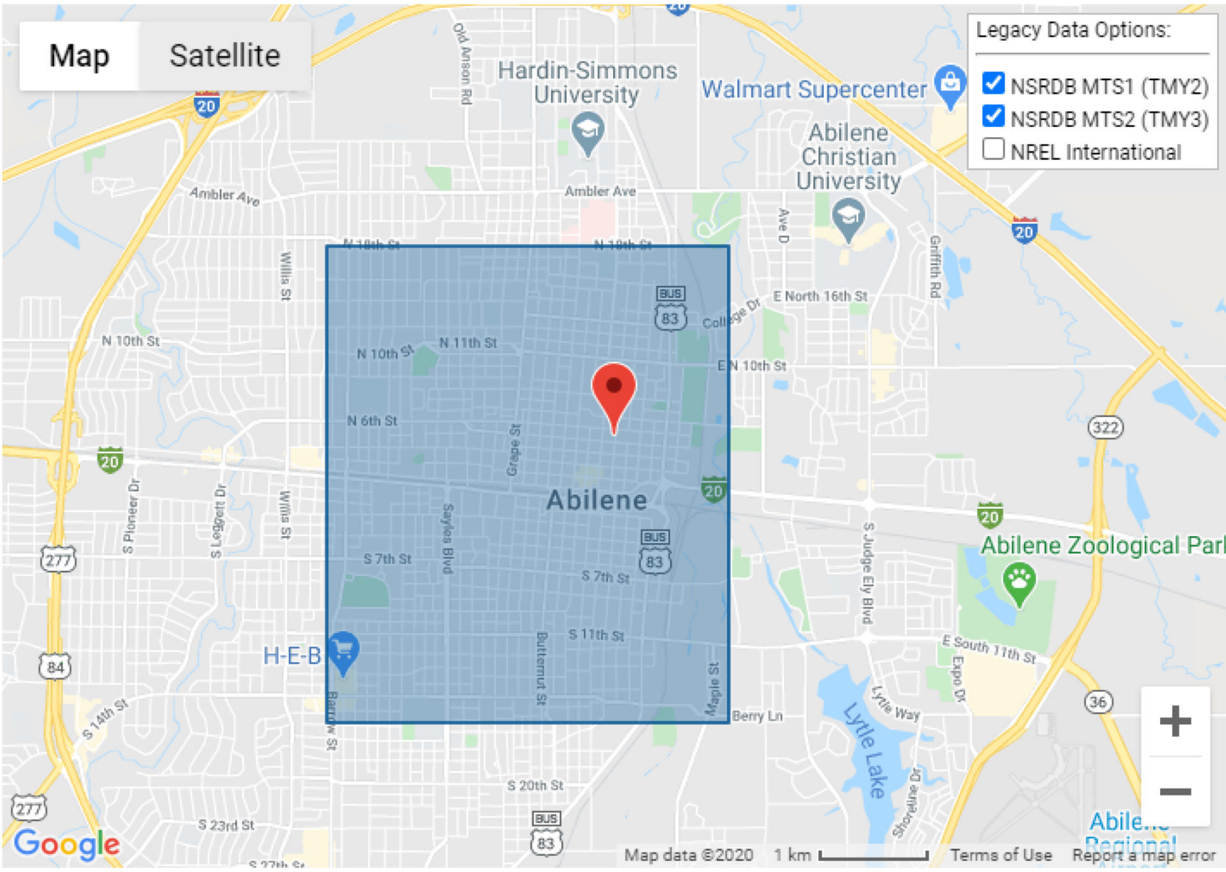
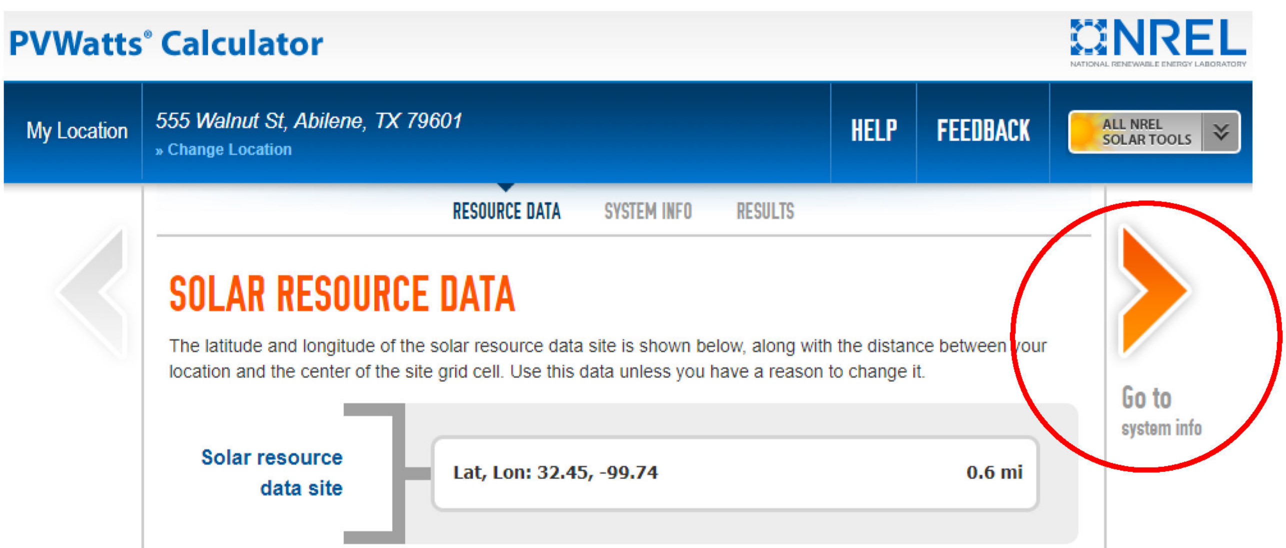


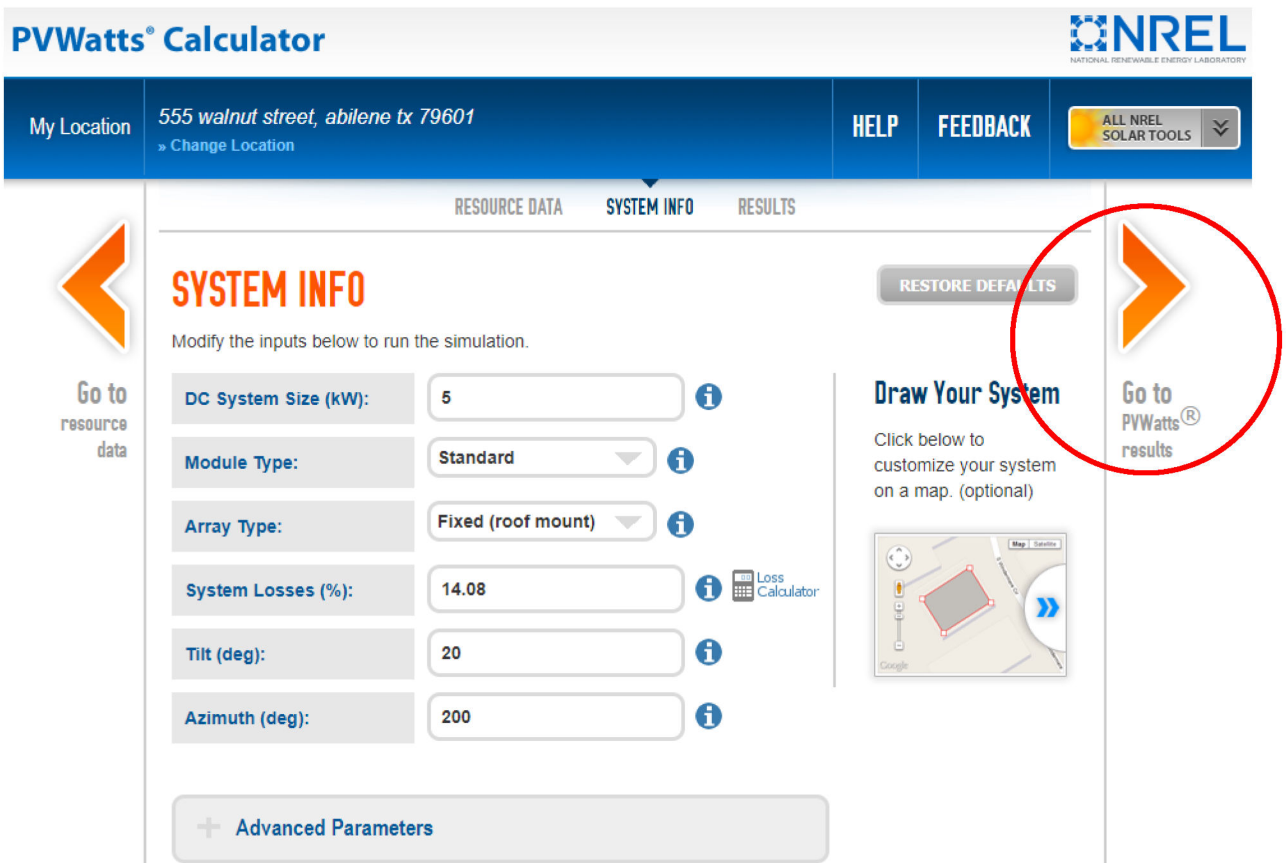

**Figure 3. PVWatts® Input Screen for Step 2**



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

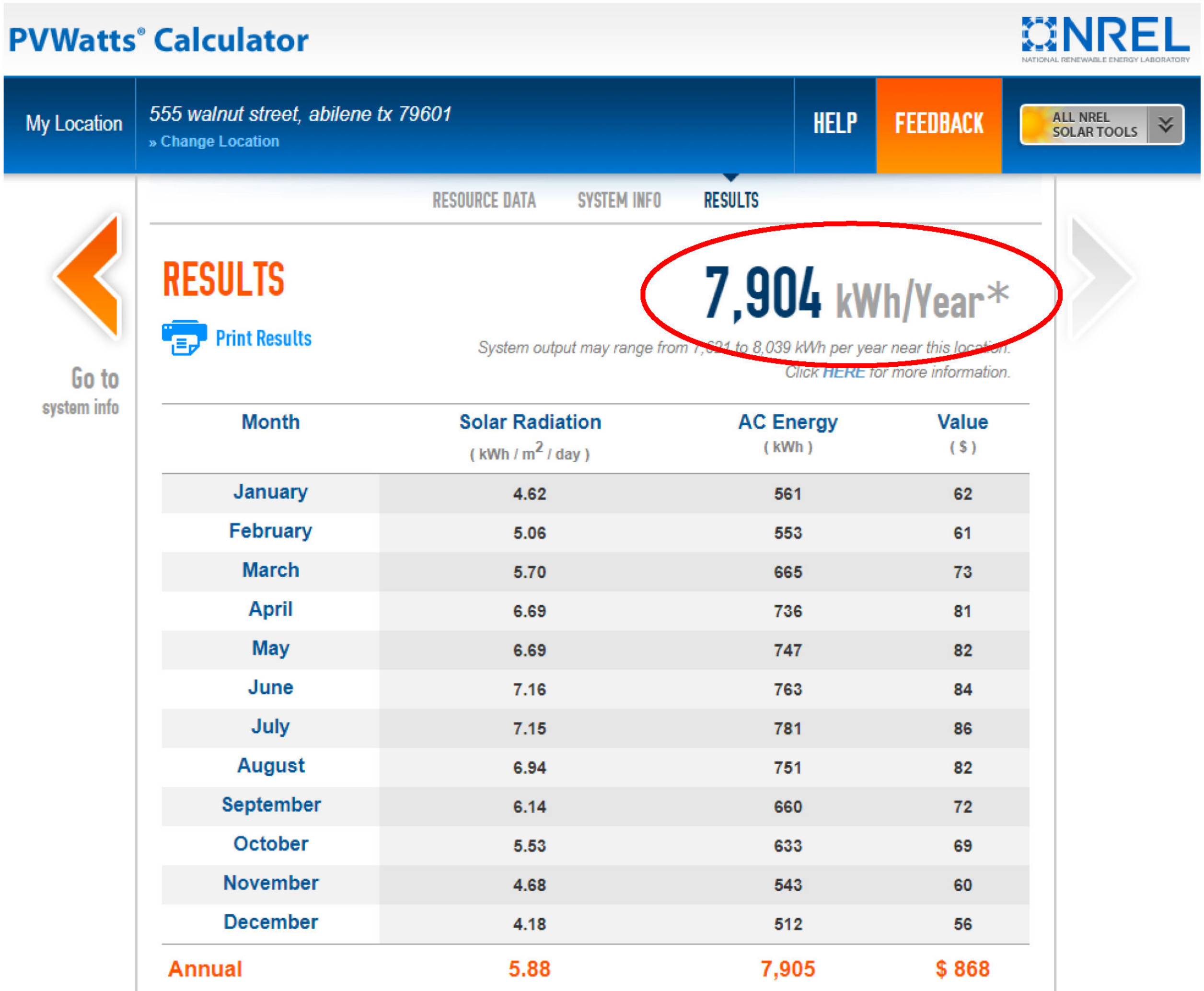
All other details (*System Losses*, *Advanced Parameters*, and *Initial Economics*) are left at default values. Once entered, the user presses "Go to PVWatts® results." See Figure 4 below.

**Figure 4. PVWatts® Input Screen for Step 3**




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

## Figure 5. PVWatts® Output Screen for Step 4


PVWatts® Calculator

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

My Location | 555 walnut street, abilene tx 79601 | » Change Location

HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

7,904 kWh/Year*

System output may range from 7,631 to 8,039 kWh per year near this location.

Click HERE for more information.

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

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

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

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

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

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

## Summer Demand Savings Methodology

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

### *Deemed Summer Demand Savings*

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

**Equation 50**

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

In rare cases, residential systems using trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may use the Alternative Method described on page 75.

## 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 22 through Table 31) provided below. Deemed winter demand savings are the product of the system's DC system size and the appropriate lookup table value.

### *Deemed Winter Demand Savings*

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

**Equation 51**

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

In rare cases, residential systems using trackers or systems for which deemed savings lookup values are not available due to extreme array tilt or azimuth may use the Alternative Method described on page 75.

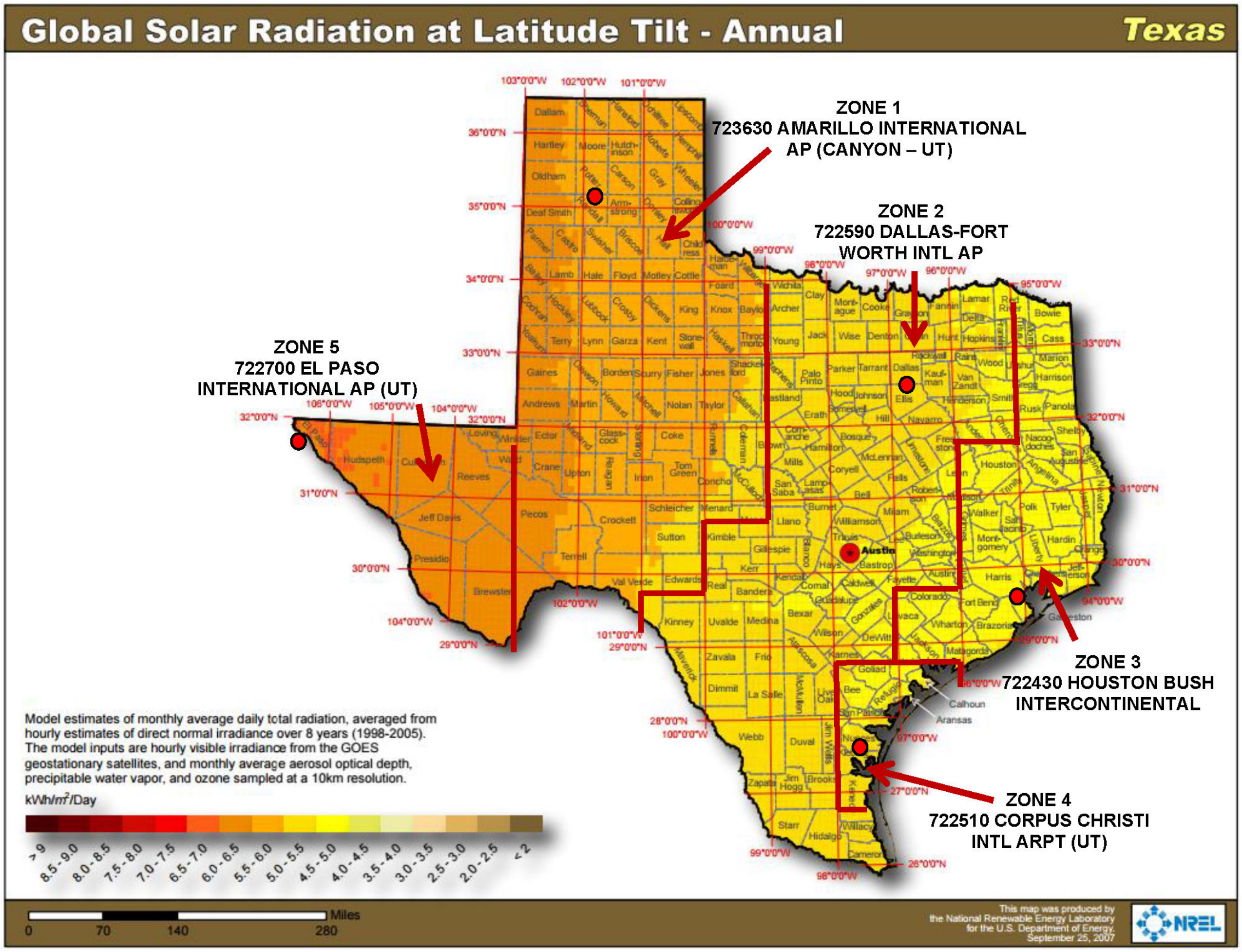
## Deemed Energy Savings Tables

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**[41]




## 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 22 through Table 31 present lookup values to determine deemed summer and winter demand savings given various array tilt/azimuth combinations. The values in the tables express summer and winter peak demand savings as a percentage of an array's DC rating at standard test conditions (STC).

Some rooftops are essentially flat but have a slight tilt (< 7.5 degrees) to facilitate runoff. If the azimuth of a slightly tilted (< 7.5 degrees) array falls outside the 67.5 - 292.5-degree azimuth ranges provided in the lookup tables below, the user should apply the deemed savings factors from the first line of the appropriate tables, corresponding to a tilt of 0 degrees. For example, in Amarillo, the summer demand factor for an array with a tilt of 4 degrees and an azimuth of 0 degrees (e.g., slightly tilted to the north) would be 48 percent, as shown in Table 22.

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

Table 22. 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 23. 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 24. 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 25. 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 26. 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 27. 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% |