of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on below freezing conditions using the regular HEAT setting. Contractors installing a new heat pump thermostat with equipment install shall advise customer of correct thermostat usage.

For early retirement projects, to receive savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 24 years for ACs and 20 years for HPs. Otherwise, claim savings for a replace-on-burnout project. Additional guidance for systems applying the default age is provided in the Savings Algorithms and Input Variables section.

The replacement of an evaporative cooler with a refrigerated system is eligible where the decision to change equipment types predates or is independent of the decision to install efficient equipment and should be claimed against the new construction baseline.

The replacement of a room AC with a central or mini-split AC or HP is eligible and should be claimed against the new construction baseline. Refer to the Replace-on-burnout or Early Retirement of an Electric Resistance Furnace section for guidance about the appropriate heating baseline for residences with electric resistance heat. Under this scenario, no savings should be awarded for rightsizing.

New construction projects are not eligible to receive deemed savings for system rightsizing.[165]

For system upsizing, savings should generally be claimed against the new construction baseline. However, upsizing is allowed for the following scenarios. In these cases, savings may be claimed against the applicable replace-on-burnout or early retirement scenario if the specified conditions are met. For these scenarios, savings must be determined using the lower pre tonnage.

- Replacing a single larger capacity system with multiple smaller capacity systems where the total pre and post tonnage are within ½ ton.[166] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.
- Replacing a single-stage system with a multi-stage system operating at variable speeds where the total pre and post tonnage are with ½ ton.[167] This scenario does not apply to the replacement of a multi-stage unit with another multi-stage unit.

[165] For projects using a custom baseline, see TRM ~~Volume~~ v4.0.

[166] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

[167] This exception is allowed to account for efficiency improvements due to operating at variable speeds that are not reflected in the current savings methodology.

- If a Manual J load calculation is completed and included with project documentation, upsizing will be allowed where the total pre and post tonnage are within one ton.[168] This guidance is also extended to the previous scenarios when a Manual J is provided.

Additionally, low-income or hard-to-reach programs may use the electric resistance baseline for the following two scenarios. The electric resistance baseline may be used for systems upsized by no more than a half-ton in lieu of the new construction baseline. Under this scenario, cooling savings should be claimed against the new construction baseline using the installed (higher) capacity. Heating savings should be claimed against the electric resistance baseline using the existing (lower) capacity. Documentation should be aligned with the rightsizing and electric resistance baseline requirements outlined in this measure. The second scenario is for a major multifamily renovation when a centralized system, such as a boiler, is replaced with individual heat pumps. For this scenario, the electric resistance baseline may be claimed in lieu of new construction only if the building owner can document intent to install electric resistance furnaces without program intervention. The cooling savings should still be claimed against the new construction baseline. Documentation should follow early retirement and electric resistance baseline requirements.

When replacing a single unit with multiple units where the capacity is the same or has been downsized, savings should be calculated using the total system pre and post capacity. Again, if the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

Baseline Condition

New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source AC or HP

New construction baseline efficiency values for ACs or HPs are compliant with the current federal standard,[169,170] effective January 1, 2023. The baseline is assumed to be a new system with an AHRI-listed SEER2 rating consistent with the values listed in Table 40Table 40 and Table 41Table 41. These baselines are also applicable to HP installations replacing ACs with central gas heat, evaporative coolers with central, space, or no heating, or room/window ACs with central, space, or no heating.

For replace-on-burnout projects, the cooling baselines are reduced by 4.3% percent. This value is based on Energy Systems Laboratory (ESL) survey data and incorporates an adjustment to the baseline SEER2/EER2 value to reflect the percentage of current replacements that do not

[168] This exception is allowed to account for efficiency improvements due to replacing a unit that was operating longer than designed to keep up with actual site load conditions.

[169] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

[170] Walter-Terrinoni, Helen, "New U.S.US Energy Efficiency Standards and Refrigerants for Residential ACs and Heat Pumps." Air-Conditioning, Heating, & Refrigeration Institute (AHRI). February 1, 2022.

include the installation of an AHRI-matched system.[171,172] Heating baselines were not included in original ESL survey data and are not adjusted.

For early retirement projects, baselines are defined in Table 40~~Table 40~~ and Table 41~~Table 41~~ based on the applicable federal standard base on manufacture year. These baselines have been converted to SEER2, EER2, and HSPF2 by extrapolating from known values referenced in the current federal standard. Systems manufactured as of January 1, 2023, are not eligible for early retirement.

For all systems with a part-load efficiency rating of 15.2 SEER2 or higher, the full-load efficiency baseline is reduced to 9.8 EER2, consistent with the EER2 federal standard specified for the Southwest region. While this standard does not directly apply to Texas, it is used here to recognize a reduced full-load allowance for systems achieving higher part-load efficiency ratings. This value is not reduced based on ESL survey data. Where applicable, the reduced 9.8 EER2 baseline should be applied in lieu of the EER2 baseline value presented in Table 40~~Table 40~~ and T**able** 41~~Table 41~~ except where the specified baseline EER2 value is lower than 9.8 EER2.

Replace-on-Burnout or Early Retirement of an Electric Resistance Furnace

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[173] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[174] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters should calculate savings using a HP baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.412.[175] Projects in which an electric resistance furnace is replaced, either in replace-on-burnout or early retirement scenarios, use this baseline for heating-side savings.

[171] Frontier Energy on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). “Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780.” Public Utility Commission of Texas. Approved August 27, 2009. https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

[172] The original petition defines the reduced baseline as 12.44 SEER compared to a 13 SEER federal standard. This deemed value was converted to a percentage reduction to accommodate a transition from SEER to SEER2. No EER adjustment is discussed in the original petition because the previous deemed savings structure only awarded savings based on SEER ratings. However, supporting documentation of the original filing makes it clear that the adjustment is appropriate for both part- and full-load cooling efficiency values. Therefore, the deemed percentage reduction is applied to both SEER2 and EER2 ROB baselines.

[173] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[174] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[175] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.412.

Table 40. Central and Mini-Split ACs—Baseline Efficiencies

Project type	Capacity (Btu/hr)	Cooling mode
New cConstruction, split air conditioners	< 45,000	14.3 SEER2 11.7 EER2
	> 45,000	13.8 SEER2 11.2 EER2
New construction, packaged air conditioners	All	13.4 SEER2 10.9 EER2
Replace-on-burnout, split air conditioners	< 45,000	13.7 SEER2 11.2 EER2
	> 45,000	13.2 SEER2 10.7 EER2
Replace-on-burnout, packaged air conditioners	All	12.8 SEER2 10.4 EER2
Early retirement, air conditioners (manufactured 1/1/2015 through 12/31/2022)	All	12.8 SEER2 10.4 EER2
Early retirement, air conditioners (when applying default age)[176]	All	12.3 SEER2 10.0 EER2
Early retirement, air conditioners (manufactured 1/23/2006 through 12/31/2014)	All	11.9 SEER2 9.7 EER2
Early retirement, air conditioners (manufactured before 1/23/2006)	All	9.1 SEER2 7.4 EER2
All systems rated at 15.2 SEER2 or higher[177]	All	9.8 EER2

Table 41. Central and Mini-Split HPs—Baseline Efficiencies

Project type	Cooling mode	Heating mode
New construction, split heat pumps	14.3 SEER2 11.7 EER2	7.5 HSPF2
New construction, packaged heat pumps	13.4 SEER2 10.9 EER2	6.7 HSPF2
Replace-on-burnout, split heat pumps	13.7 SEER2 11.2 EER2	7.5 HSPF2

[176] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006-2014 and 2015-2022.

[177] When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

Project type	Cooling mode	Heating mode
Replace-on-burnout, packaged heat pumps	12.8 SEER2 10.4 EER2	6.7 HSPF2
Early retirement, split heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2 10.4 EER2	6.9 HSPF2
Early retirement, packaged heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2 10.4 EER2	6.7 HSPF2
Early retirement, split heat pumps (when applying default age)[178]	12.3 SEER2 10.0 EER2	6.7 HSPF2
Early retirement, packaged heat pumps (when applying default age)[179]	12.3 SEER2 10.0 EER2	6.6 HSPF2
Early retirement, heat pumps (manufactured 1/23/2006 through 12/31/2014)	11.9 SEER2 9.7 EER2	6.5 HSPF2
Early retirement, heat pumps (manufactured before 1/23/2006)	9.1 SEER2 7.4 EER2	5.7 HSPF2
All systems rated at 15.2 SEER2 or higher[180]	9.8 EER2	—
Early retirement, electric resistance furnace[181]	—	3.412 HSPF2

High-Efficiency Condition

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER2 and HSPF2 requirements but do not comply with the EER2 requirements outlined in Table 40~~Table 40~~ and Table 41~~Table 41~~ may still be eligible to claim savings. Systems with qualifying SEER2 and HSPF2 energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems, but not summer demand savings where the EER2 rating does not comply with the minimum requirement.

Rated system cooling and heating efficiencies must exceed the minimum efficiencies specified in Table 40~~Table 40~~ and Table 41~~Table 41~~. Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the

178 Baseline efficiencies are calculated by taking the average the early retirement categories for 2006—2014 and 2015—2022.

179 Ibid.

180 When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 -EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

181 When installing a heat pump replacing a split air conditioner with an electric resistance furnace, the reduced 3.412 HSPF2 heating baseline efficiency should be applied in lieu of the applicable value presented earlier in the table.

results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

For reference, both ENERGY STAR®[182] and the Consortium for Energy Efficiency (CEE)[183] offer suggested guidelines for high-efficiency equipment.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

For early retirement or rightsizing projects, attempt to determine the rated capacity of the existing unit. The rated capacity may be found on the manufacturer specification sheet for the existing unit if the new system is not available on the AHRI or DOE CCMS directories. If the model number of the existing unit is unobtainable or if the manufacturer specification sheet cannot be found, use nominal tonnage for both the existing and new unit. Never use nominal tonnage for the existing unit in combination with rated tonnage for the new unit, which can lead to overstated savings. Additionally, never use nominal tonnage to determine savings for projects where no early retirement or rightsizing has occurred.

For early retirement, if age is unknown, assume a default age equal to the replaced unit estimated useful life (EUL) resulting in a remaining useful life (RUL) of 7 (ACs) or 6 years (HPs). Default age may be used exclusively if applied consistently for all early retirement projects. This is the only scenario where an early retirement baseline can be applied to systems older than 24 years for ACs and 20 years for HPs. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Default early retirement baselines are specified in Table 40~~Table 40~~ and Table 41~~Table 41~~ for use with the default age.

Energy Savings Algorithms

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

Equation 23

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

Equation 24

$$Energy\ (Heating)\ [kWh_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kW}{1{,}000\ W}$$

Equation 25

[182] ENERGY STAR® Heating & Cooling, https://www.energystar.gov/products/products_list.
[183] CEE Program Resources, http://www.cee1.org/content/cee-program-resources.

Demand Savings Algorithms

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

Equation 26

$$Peak\ Demand\ (\text{Winter})[kW_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times DF_H \times \frac{1\ kW}{1{,}000\ W}$$

Equation 27

Where:

$Cap_{C/H,pre}$ = For early retirement (ER), rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions; for replace-on-burnout (ROB) & new construction (NC), rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$Cap_{C/H,post}$ = Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$\eta_{baseline,C}$ = Baseline cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]

$\eta_{installed,C}$ = Rated cooling efficiency of the newly installed equipment (must exceed ROB/NC baseline efficiency standards in Table 40~~Table 40~~ and Table 41~~Table 41~~) [Btuh/W]

$\eta_{baseline,H}$ = Baseline heating efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]

$\eta_{installed,H}$ = Rated heating efficiency of the newly installed equipment (must exceed baseline efficiency standards in Table 41~~Table 41~~) [Btuh/W]

Note: Use EER2 for kW savings calculations and SEER2/HSPF2 kWh savings calculations.

$EFLH_{C/H}$ = Cooling/heating equivalent full-load hours (Table 61)

$DF_{C,/H}$ = Seasonal peak demand factor (Table 43~~Table 43~~)

Table 42. Central and Mini-Split AC/HPs—Equivalent Full Load Cooling/Heating Hours[184]

Climate zone	$EFLH_C$	$EFLH_H$
Climate Zone 1: Amarillo	1,142	1,880
Climate Zone 2: Dallas	1,926	1,343
Climate Zone 3: Houston	2,209	1,127
Climate Zone 4: Corpus Christi	2,958	776
Climate Zone 5: El Paso	1,524	1,559

Table 43. Central and Mini-Split AC/HPs—Demand Factors[185]

Season	DF
Summer[186]	0.87
Winter[187]	0.83

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

3. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
4. The remaining time in the EUL period (EUL – RUL)

Annual energy and summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

184 ENERGY STAR® Central AC/HP Savings Calculator.

185 Demand factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the demand factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

186 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115% percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a demand factor of 1/1.15 = 0.87.

187 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115% percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5—5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a demand factor of 0.96/1.15 = 0.83.

Where:

RUL = *Remaining useful life (see* Table 30 or Table 31). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. For HPs replacing an AC with an electric resistance furnace, use the AC RUL table.

EUL = *Estimated useful life = 18 years (AC); 15 years (HP)*

Table 44. Central and Mini-Split AC/HPs—RUL of Replaced AC

Age of replaced unit (years)	Remaining useful life (years)	Age of replaced unit (years)	Remaining useful life (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[188,189]	0.0
13	9.0		

Table 45. Central and Mini-Split AC/HPs—RUL of Replaced HP

Age of replaced unit (years)	Remaining useful life (years)	Age of replaced unit (years)	Remaining useful life (years)
1	13.7	12	7.9
2	12.7	13	7.6
3	12.0	14	7.0
4	11.3	15	6.0
5	10.7	16	5.0
6	10.2	17	4.0
7	9.7	18	3.0

[188] RULs are capped at the 75th percentile as determined based on DOE survival curves (see Figure 2). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

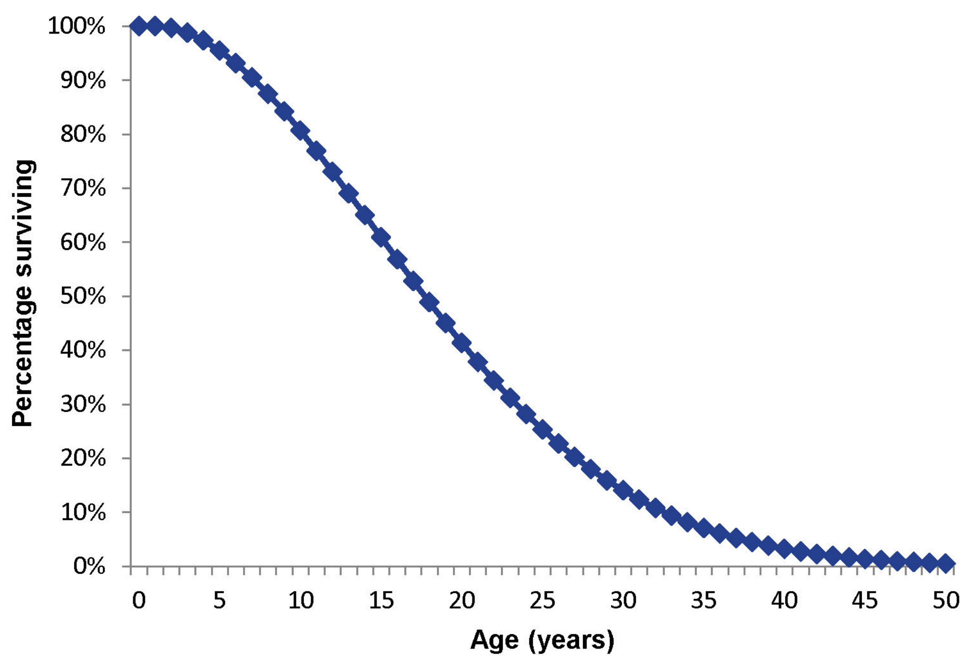
[189] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team's SharePoint.

Age of replaced unit (years)	Remaining useful life (years)
8	9.3
9	8.9
10	8.5
11	8.2
19	2.0
20	1.0
21[190]	0.0

Derivation of RULs

ACs have an estimated useful life of 18 years, and HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of ACs and HPs installed in a given year will no longer be in service, as described by the survival function Figure 7~~Figure 7~~ and Figure 8~~Figure 8~~.

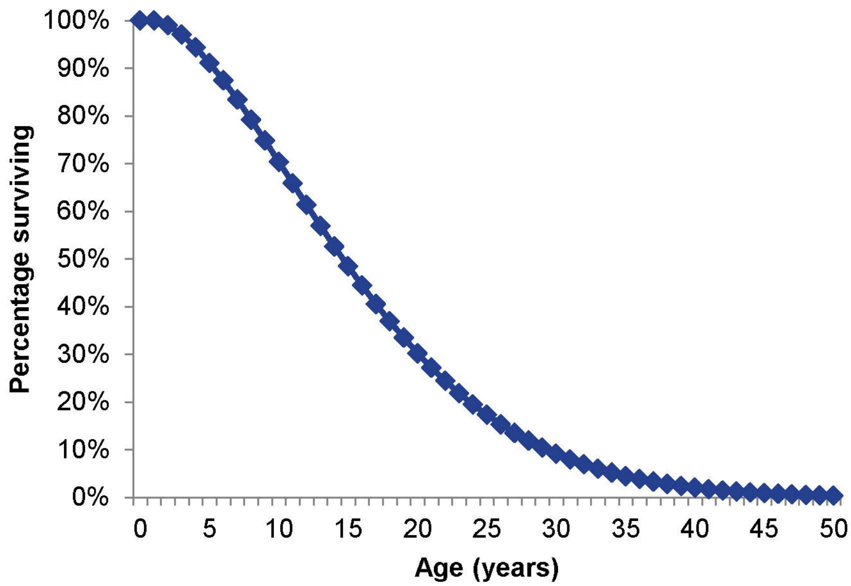
Figure 7. Central and Mini-Split AC/HPs—AC Survival Function[191]



[190] See footnotes on default age from previous table.

[191] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

Figure 8. Central and Mini-Split AC/HPs—HP Survival Function[192]



The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 7~~Figure 7~~ and Figure 8~~Figure 8~~. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving system is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

[192] Ibid.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a AC and 15 years for a HP unit based on the current DOE Final Rule standards for ACs and HPs.[193]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Air Conditioners and Heat Pumps.[194]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the newly installed unit (Btuh)
- Heating capacity of the newly installed unit (Btuh) (HPs only)
- Seasonal Energy Efficiency Ratio (SEER2) and Energy Efficiency Ratio (EER2) of the newly installed unit
- Heating Seasonal Performance Factor (HSPF2) of the newly installed unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air source HP)
    - Baseline equipment used for savings (if different from unit replaced)
- Type of unit installed (central AC, central HP, dual-fuel HP, mini-split AC, mini-split HP, DC inverter AC, DC inverter HP)
- Compressor type for newly installed unit (~~single stage~~single-stage, multi-stage)
    - Recommended to assist with development of future deemed savings for multi-stage systems operating at variable speeds
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)

[193] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[194] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program)
- Manual J load calculation (when rightsizing upward by more than ~~0.5~~one-half tons). See the Eligibility Criteria section for applicable scenarios.
- Photograph of retired cooling unit nameplate (required for all rightsizing projects and for early retirement unless default age is applied consistently across the program)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide estimated square footage of conditioned area served by the retired unit (rightsizing only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only). This requirement also applies to projects using the default age.
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment
- Proof of purchase —with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, and serial number of newly installed unit
    - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number

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 46. Central and Mini-Split AC/HPs—Revision History

v10.0	10/2022	TRM v10.0 origin.

~~2.2.4~~2.2.5 ENERGY STAR® Room Air Conditioners Measure Overview

TRM Measure ID: R-HV-RA

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

The following deemed savings values are applicable to the installation of a high-efficiency room air conditioner.

Eligibility Criteria

Installed room air conditioners (RACs) must be compliant with the current ENERGY STAR® specification for RACs.

To claim early retirement savings, the replaced unit must be functioning at the time of removal with a maximum age of 12 years.

Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit that is compliant with the current federal standard,[195] effective June 1, 2014. The standard refers to a revised efficiency rating, Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

For early retirement, the baseline efficiency is assumed to match the minimum federal standard efficiencies in place prior to June 1, 2014. Since the effective date occurred mid-year, existing systems manufactured as of 2015 are not eligible for early retirement.

[195] DOE minimum efficiency standard for residential room air conditioners. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52.

Table 47. RACs—Baseline Efficiencies for ER, ROB, and NC

Reverse cycle (yes/no)	Louvered sides (yes/no)	Capacity (Btu/hr)	Federal standard prior to June 1, 2014	Federal standard as of June 1, 2014
			ER baseline EER	ROB/NC baseline CEER
No	Yes	< 8,000	9.7	11.0
		≥ 8,000 and < 14,000	9.8	10.9
		≥ 14,000 and < 20,000	9.7	10.7
		≥ 20,000 and < 28,000	8.5	9.4
		≥ 28,000	8.5	9.0
No	No	< 8,000	9.0	10.0
		≥ 8,000 and < 11,000	8.5	9.6
		≥ 11,000 and < 14,000	8.5	9.5
		≥ 14,000 and < 20,000	8.5	9.3
		≥ 20,000	8.5	9.4
Yes	Yes	< 20,000	9.0	9.8
		≥ 20,000	8.5	9.3
Yes	No	< 14,000	8.5	9.3
		≥ 14,000	8.0	8.7
Casement-only		All capacities	8.7	9.5
Casement-slider		All capacities	9.5	10.4

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 4.2 Requirements for eligible room air conditioners effective December 20, 2020.[196] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

[196] ENERGY STAR® Room Air Conditioners Final Version 4.2 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.2%20Room%20Air%20Conditioners%20Specification_0.pdf.

Table 48. RACs—Efficient Condition Requirements

Reverse cycle (Yes/No)	Louvered sides (Yes/No)	Capacity (Btu/hr)	Minimum CEER for Uunits with connected functionality[197]	Minimum CEER for Uunits without connected functionality
No	Yes	< 8,000	11.6	12.1
		≥ 8,000 and < 14,000	11.5	12.0
		≥ 14,000 and < 20,000	11.3	11.8
		≥ 20,000 and < 28,000	9.9	10.3
		≥ 28,000	9.5	9.9
No	No	< 8,000	10.5	11.0
		≥ 8,000 and < 11,000	10.1	10.6
		≥ 11,000 and < 14,000	10.0	10.5
		≥ 14,000 and < 20,000	9.8	10.2
		≥ 20,000	9.9	10.3
Yes	Yes	< 20,000	10.3	10.8
		≥ 20,000	9.8	10.2
Yes	No	< 14,000	9.8	10.2
		≥ 14,000	9.2	9.6
Casement-only		All capacities	10.0	10.5
Casement-slider		All capacities	11.0	11.4

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

[197] Connected functionality refers to units that have been tested for demand response capabilities. These units receive a five5 percent credit toward ENERGY STAR® certification. This means they must only achieve a five5 percent improvement over the federal standard compared to ten10 percent for standard units.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{Savings,C} = CAP \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 28

Where:

CAP~~CAP~~	=	*Rated equipment cooling capacity of the installed (Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 49)*
$CEER_{Base}$	=	*Combined energy efficiency ratio of the baseline cooling equipment (Table 47)*
$CEER_{RAC}$	=	*Combined energy efficiency ratio of the installed RAC*

Table 49. RACs—Annual Operating Hours for Cooling[198]

Climate Zone	AOH_C
Climate Zone 1: Amarillo	820
Climate Zone 2: Dallas	1,374
Climate Zone 3: Houston	1,308
Climate Zone 4: Corpus Christi	2,150
Climate Zone 5: El Paso	1,204

Demand Savings Algorithms

$$kW_{Savings} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right) \times \cancel{C}DF$$

Equation 29

Where:

~~CAP~~	~~=~~	~~*Rated equipment cooling capacity of the installed RAC(Btu/hr)*~~
~~$CEER_{Base}$~~	~~=~~	~~*Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 40)*~~
~~$CEER_{RAC}$~~	~~=~~	~~*Combined Energy Efficiency Ratio of the installed RAC*~~
DF~~CF~~	=	*~~Coincidence~~Summer peak demand factor (Table 50~~Table 50~~)*

[198] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator.

Table 50. RACs—~~Coincidence~~Demand Factor~~s~~[199][200]

Season	DF
Summer[201]	0.87

~~Season~~	~~Climate zone 1: Amarillo~~	~~Climate zone 2: Dallas~~	~~Climate zone 3: Houston~~	~~Climate zone 4: Corpus Christi~~	~~Climate zone 5: El Paso~~
~~Summer~~	~~0.977~~	~~0.937~~	~~0.904~~	~~0.833~~	~~0.920~~

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period~~.~~ (EUL – RUL)

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

Where:

RUL = *Remaining useful life (see Table 51); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5 years*

EUL = *Estimated useful life = 10 years*

~~[199] See Volume 1, Appendix B of PY2022 TRM v9.~~

[200] Demand factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the demand factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[201] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent~~%~~ of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a demand factor of 1/1.15 = 0.87.

Table 51. RACs—RUL of Replaced Unit[202]

Age of replaced unit (years)	RUL (years)
1	8.0
2	7.2
3	6.2
4	5.2
5	5.2
6	5.2
7	5.2
8	5.0
9	4.0
10	3.0
11	2.0
12	1.0
13[203,204]	0.0

Derivation of RULs

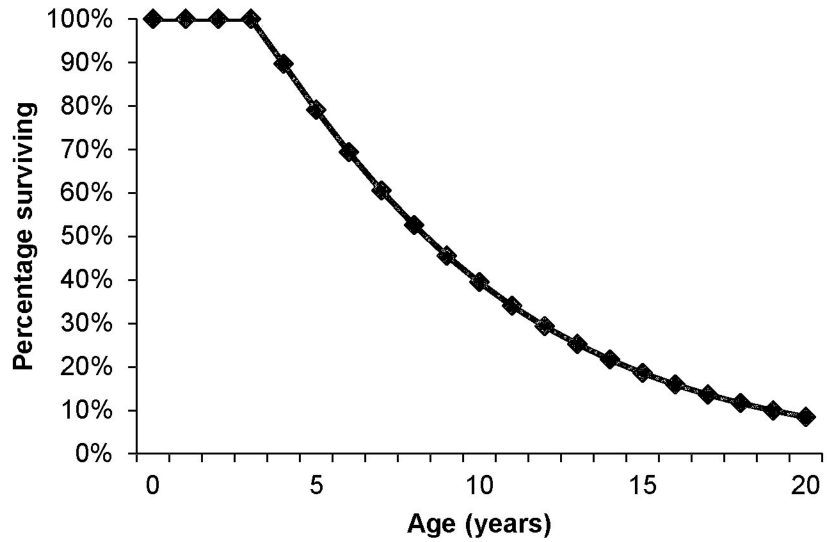
RACs have an estimated useful life of 10 years. This estimate is consistent with the age at which approximately 50 percent of the RACs installed in a given year will no longer be in service, as described by the survival function in Figure 9~~Figure 9~~.

[202] Current federal standard effective date is 6/1/2014. Since the effective date occurred mid-year, existing systems installed as of 2015 are not eligible to use the early retirement baseline and should instead use the ROB baseline.

[203] RULs are capped at the ~~75th~~ seventy-fifth percentile of equipment age, 13 years, based on DOE survival curves. Systems older than 13 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[204] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

Figure 9. RACs—Survival Function[205]



The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 3Figure 3. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving system is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 9Figure 9. The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving RACs is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = CAP \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 30

[205] Department of Energy, Federal Register, 76 FR 22454, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: https://www.regulations.gov/document/EERE-2007-BT-STD-0010-0053http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kWh_{savings,ROB} = CAP \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 31

Where:

CAP~~CAP~~	=	*Rated equipment cooling capacity of the installed RAC (Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 49)*
EER_{ER}	=	*Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 47)*
$CEER_{ROB}$	=	*Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 47)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed RAC*

Summer Demand Savings Algorithms

To calculate demand savings for the early retirement of a RAC, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

$$kW_{Savings,ER} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right) \times \not{C}DF$$

Equation 32

For the remaining time in the EUL period~~.~~, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{Savings,ROB} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right) \times \not{C}DF$$

Equation 33

Where:

DF	=	*Summer peak demand factor (*Table 50~~Table 50~~*)*

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a room air conditioning unit is 10 years based on the Technical Support Document for the current DOE Final Rule standards for RACs.

This value is consistent with the EUL reported in the Department of Energy Technical Support Document for RACs.[206]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (Btu/hr)
- Combined Energy Efficiency Ratio (CEER) of the new unit
- Age of the replaced unit (early retirement only)
- Photograph of retired unit nameplate (early retirement)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)

[206] Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013.

- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase —with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.
- New unit manufacturer, model, capacity, and serial number
    - AHRI certificate or equivalent matching manufacturer and model number
- Connected functionality status

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 52. RACs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Low-income and hard-to-reach Market Transformation section merged with main measure as “early retirement” option. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team’s memo, “Considerations for early replacement of residential equipment.” Remaining useful lifetimes updated. Updated EUL to align with median lifetime. New construction permitted to claim savings. New ENERGY STAR® standards incorporated.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Added RUL values for units with an age of one to three years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years.
v5.0	10/2017	TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone.

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Update to documentation requirements.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for units with connected functionality.
v10.0	10/2022	TRM v10.0 update. Update minimum CEER requirement for units with connected functionality. Updated coincidence factors, early retirement age eligibility, and documentation requirements.

~~2.2.5~~2.2.6 Packaged Terminal Heat Pumps Measure Overview

TRM Measure ID: R-HV-PT

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Multifamily

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal heat pumps (PTHP) replacing packaged terminal air conditioners (PTAC) with electric resistance heat. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) and replace-on-burnout (ROB), based current and previous on efficiency standards. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types are restricted to packaged terminal heat pumps. Both standard and non-standard size equipment types are covered. *Standard size* refers to equipment with wall sleeve dimensions having an external wall opening greater than, equal to 16 inches high or greater than, or equal to 42 inches wide and a cross-sectional area greater than 670 in^2. *Non-standard size* refers to equipment with existing wall sleeve dimensions having an external wall opening of fewer than 16 inches high or fewer than 42 inches wide and a cross-sectional area less than 670 in^2.

Eligibility Criteria

Existing PTAC and installed PTHP must be the primary cooling source in the residence. Installed PTHPs must be compliant with the current commercial code.

ER projects must involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a simultaneous renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.

Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[207,208]

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

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

Baseline Condition

Early Retirement

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL – RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC), and age (based on year of manufacture) of the replaced system.[209] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 53, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

When the system age is unknown, assume 15 years.[210] A default RUL may be used exclusively if applied consistently for all eligible early retirement projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing systems manufactured as of February 2013 are not eligible for early retirement.

Table 53. PTHPs—ER Baseline Efficiency Levels for Standard Size PTACs[211]

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (no built-in resistance heat)	Baseline heating efficiency (COP) (replacing built-in resistance heat)
PTAC	< 7,000	11.0	–	1.0
	7,000-15,000	12.5 – (0.213 x Cap/1000)		
	> 15,000	9.3		

209 The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

210 As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

211 ER only applies to standard size units because the minimum efficiency requirements for non-standard systems have never changed, making the ER baseline efficiency the same as for ROB.

Replace-on-Burnout

Table 54

Table 54 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for packaged terminal air-conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 54. PTHPs—ROB Minimum Efficiency Levels[212,213]

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)	Baseline heating efficiency (COP) (replacing built-in resistance heat)
PTHP	Standard size	< 7,000	11.9	3.3	1.0
		7,000-15,000	14.0 – (0.300 x Cap/1000)	3.7 – (0.052 x Cap/1000)	
		>15,000	9.5	2.9	
	Non-standard size	<7,000	9.3	2.7	
		7,000-15,000	10.8 – (0.213 x Cap/1000)	2.9 – (0.026 x Cap/1000)	
		>15,000	7.6	2.5	

212 IECC 2015 Table C403.2.3(3).

213 Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 54.

The high-efficiency retrofits must also meet the following criteria:[214]

- For ER projects only, the installed equipment cooling capacity must be within 80_-percent to 120 percent of the replaced electric cooling capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 34

$$Peak\ Demand\ (Winter)\ [kW_{Savings}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times \cancel{C}DF_{W\cancel{H}} \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 35

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

Equation 36

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

Equation 37

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

Equation 38

Where:

$Cap_{C/H,pre}$ = *For ER, rated equipment cooling/heating*[215] *capacity of the existing equipment at AHRI standard conditions*; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI standard conditions *[BTUH]; 1 ton = 12,000 Btuh*

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[214] Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend early retirement to cover PTAC/PTHP.

[215] Baseline cooling capacity refers to the rated cooling capacity of the existing PTAC. Assume baseline heating capacity is equal to rated heating capacity for newly installed PTHP.

$Cap_{C/H,post}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh*

$\eta_{baseline,C}$ = *Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 53 through Table 54)*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 53 through Table 54)*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] (~~M~~must exceed minimum requirements from Table 54)*[216]

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP] (~~Must~~ must exceed minimum requirements from Table 54)*[217]

$DF_{S/W}$ ~~$CF_{S/W}$~~ = *Summer/winter seasonal peak demand~~coincidence~~ factor for appropriate climate zone, building type, and equipment type (Table 55)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours] (Table 56)*

Table 55. PTHPs—~~Coincidence~~Demand Factors[~~218~~219]

Season	DF
Summer[220]	0.87
Winter[221]	0.83

[216] Rated efficiency is commonly reported at both 230 V and 208 V. Savings calculations should reference efficiency at 230 V, as AHRI rating conditions specify that voltage.

[217] Ibid.

~~[218] See Volume 1, Section 4 of PY2022 TRM v9.~~

[219] Demand factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the demand factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[220] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115~~%~~ percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a demand factor of 1/1.15 = 0.87.

[221] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115~~%~~ percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5—5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a demand factor of 0.96/1.15 = 0.83.

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.644	0.707	0.633	0.577	0.784
Winter	0.399	0.310	0.341	0.293	0.444

Table 56. PTHPs—Cooling/Heating EFLHs[222]

Climate zone	$EFLH_C$	$EFLH_H$
Climate Zone 1: Amarillo	1,142	1,880
Climate Zone 2: Dallas	1,926	1,343
Climate Zone 3: Houston	2,209	1,127
Climate Zone 4: Corpus Christi	2,958	776
Climate Zone 5: El Paso	1,524	1,559

The first-year savings algorithms in the above equations are used for all HVAC projects, across ROB and ER projects. However, ER projects require weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL – RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Volume 3, Appendix A.

Claimed Peak Demand Savings

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

Deemed Energy and Demand Savings Tables

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

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL is 15 years, as specified in as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[223]

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222 ENERGY STAR® Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

223 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Remaining Useful Life (RUL) for PTHP Systems

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

3. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
4. The remaining time in the EUL period (EUL – RUL)

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

Where:

RUL = *Remaining Useful Life (see Table 57); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.8 years*

EUL = *Estimated Useful Life = 15 years*

Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Table 57. PTHPs—RUL of Replaced PTAC[224,225]

Age of replaced system (years)	PTAC RUL (Years)	Age of replaced system (years)	PTAC RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18[226]	0.0

[224] PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

[225] Current federal standard effective date is 2/2013. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should instead use the ROB baseline.

[226] RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: ROB or ER
- Climate zone
- Equipment configuration category: standard/non-standard
- Baseline equipment rated cooling capacity (Btuh)
- Baseline number of units
- Installed equipment rated cooling and heating capacities
- Installed number of units
- Installed cooling and heating efficiency rating
- Installed make and model
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available) (early retirement only)
- A representative sample of photographs of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided (early retirement only)
    - If a photograph of the nameplate is unavailable or not legible, provide documentation demonstrating reason why the nameplate photo was unobtainable, including but not limited to a photo or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Documentation demonstrating the functionality of existing equipment, including but not limited to photograph demonstrating the functionality of existing equipment or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. This petition updated demand and energy coefficients for all commercial HVAC systems.

Relevant Standards and Reference Sources

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

Document Revision History

Table 58. PTHPs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Added winter demand algorithm. Updated coincidence factors and documentation requirements
v9.0	10/2021	TRM v9.0 update. Clarified early retirement age eligibility. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Clarified electric resistance baseline. Updated coincidence factors and early retirement age eligibility.

~~2.2.6~~2.2.7 ENERGY STAR® Ground Source Heat Pumps Measure Overview

TRM Measure ID: R-HV-GH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) meeting the minimum requirements of ENERGY STAR® geothermal heat pump key product criteria. The deemed savings are dependent upon the energy efficiency rating (EER) and coefficient of performance (COP) of the installed equipment. Savings calculations are presented for systems with and without desuperheaters.

Eligibility Criteria

The deemed savings apply to units with a capacity of ≤ 65,000 Btu/hour.

Energy savings for desuperheaters only apply if the desuperheater is attached to an electric storage water heater. The electric storage water heating cannot replace a gas water heater in a retrofit installation.

Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an air conditioner with an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard,[227] effective January 1, 2015.

[227] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[228] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 59. GSHPs—Baseline Efficiencies

Project type	Cooling mode[229]	Heating mode[230]
New ~~Construction~~construction	11.8 EER (14 SEER)	2.4 COP (8.2 HSPF)
ROB—air source heat pump baseline	11.2 EER (13.08 SEER)	2.4 COP (8.2 HSPF)
ROB—-air conditioner with electric resistance furnace baseline		1 COP (3.412 HSPF)

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 3.2 requirements for eligible geothermal heat pumps effective January 1, 2012.[231] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 60. GSHPs—ENERGY STAR® Requirements

Product type	Cooling mode (EER)	Heating mode (COP)
Closed loop water-to-air	17.1	3.6
Open loop water-to-air	21.1	4.1
Closed loop water-to-water	16.1	3.1
Open loop water-to-water	20.1	3.5
Direct geoexchange (DGX)	16.0	3.6

228 Frontier Energy on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780." Public Utility Commission of Texas. Approved August 27, 2009. https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

229 Code specified EER value converted to SEER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." ~~U.S.~~US Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

230 Code specified HSPF value converted to COP using COP = HSPF x 1,055 J/Btu ÷ 3,600 J/W-h = HSPF ÷ 3.412.

231 ENERGY STAR® Program Requirements Product Specification for Geothermal Heat Pumps, v3.2. https://www.energystar.gov/sites/default/files/Geothermal%20Heat%20Pump%20Version%203.2%20Final%20Specification.pdf.

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[232]

$$EER = (highest\ rated\ capacity\ EER + lowest\ rated\ capacity\ EER) \div 2$$

Equation 39

$$COP = (highest\ rated\ capacity\ COP + lowest\ rated\ capacity\ COP) \div 2$$

Equation 40

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Peak demand and annual energy savings for GSHP systems should be calculated, as shown below. Where a desuperheater is also installed, please see the Deemed Energy Savings Tables section for additional energy savings and the Deemed Summer Demand Savings Tables for additional demand savings.

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on GSHPs in Texas.[233] Desuperheater savings were calculated for each climate zone by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high-efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to the replacement of air source heat pumps with GSHPs. These estimates were found to be within 5 percent of actual post-retrofit savings. Building models were developed using TRNSYS.[234]

Using the Fort Polk models, the ORNL study assumed a baseline of a 1.5-ton, 10-SEER air source heat pump. Simulations of low-, medium-, and high-efficiency GSHPs with and without desuperheaters were compared against the baseline unit. The models were run using TMY-2 weather profiles for climate zones 1-4. Energy and demand differences between the pre- and post-retrofit models were used to estimate average savings per ton of cooling capacity.

In the 1998 analysis, low-efficiency GSHPs were assumed to be units with an EER of 12.4 and capacity of 19 kBtuh, while medium-efficiency units had an EER of 16.8 and capacity of 21 kBtuh. High-efficiency units had an EER or 18.3, with a capacity of 22 kBtuh.

[232] Geothermal Heat Pumps Key Product Criteria, https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria.

[233] Shonder, J. A., Hughes, P., and Thornton, J. Development of Deemed Energy and Demand Savings for Residential Ground Source Heat Pump Retrofits in the State of Texas. Transactions-American Society of Heating, Refrigerating, and Air Conditioning Engineers. 108, no. 1: 953-961, 2001.

[234] Klein, S. A. TRNSYS Manual: A Transient Simulation Program. Solar Engineering Laboratory, University of Wisconsin-Madison, Version 14.2 for Windows, September 1996.

These models were used to derive the energy and demand savings associated with installation of a desuperheater along with a GSHP, as shown in Table 63Table 63 and Table 64Table 64, respectively.

Energy Savings Algorithms

$$kWh_{Savings} = kWh_{Savings,C} + kWh_{Savings,H} + kWh_{desuperheater}$$

Equation 41

$$kWh_{Savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

Equation 42

$$kWh_{Savings,H} = CAP_H \times \frac{1\ kWh}{3{,}412\ Btu} \times EFLH_H \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right)$$

Equation 43

Where:

$kWh_{desuperheater}$ = *Energy savings (kWh) associated with installation of a desuperheater (see Table 63); these savings should only be added if a desuperheater is installed*

$CAP_{C/H}$ = *Rated equipment cooling/heating capacity of the installed GSHP (Btu/hr)*

$EFLH_{C/H}$ = *Equivalent full load hours for cooling/heating (Table 61)*

$SEER_{Base}$ = *Energy Efficiency Ratio of the baseline cooling equipment (Table 59Table 59)*

EER_{GSHP} = *Energy Efficiency Ratio of the installed GSHP*

COP_{Base} = *Coefficient of Performance of the baseline heating equipment (Table 59Table 59)*

COP_{GSHP} = *Coefficient of Performance of the installed GSHP*

Table 61. GSHPs—Equivalent Full Load Cooling/Heating Hours[235]

Climate zone	$EFLH_C$	$EFLH_H$
Climate Zone 1: Amarillo	1,142	1,880
Climate Zone 2: Dallas	1,926	1,343
Climate Zone 3: Houston	2,209	1,127
Climate Zone 4: Corpus Christi	2,958	776
Climate Zone 5: El Paso	1,524	1,559

Demand Savings Algorithms

$$kW_{Savings,Summer} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right) \times CDF_{SC} + kW_{desuperheater}$$

Equation 44

$$kW_{Savings,Winter} = CAP_H \times \frac{1\ kWh}{3{,}412\ Btu} \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right) \times CDF_{WH}$$

Equation 45

Where:

EER_{Base} = *Energy Efficiency Ratio of the baseline cooling equipment (see Table 59Table 59)*

$CDF_{S/WC}$ = *Coincidence FSummer/winter peak demand factors (see Table 62)*

CF_H = *Coincidence Factor = (Table 55)*

$kW_{desuperheater}$ = *Summer demand savings (kW) associated with installation of a desuperheater (see Table 64); these savings should only be added if a desuperheater is installed*

[235] ENERGY STAR® Central AC/HP Savings Calculator.

Table 62. GSHPs—DemandCoincidence Factors[236][237]

Season	DF
Summer[238]	0.87
Winter[239]	0.83

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.634	0.677	0.626	0.583	0.725
Winter	0.549	0.478	0.515	0.453	0.437

Deemed Energy Savings Tables

Table 63. GSHPs—Energy Savings for Desuperheaters per Cooling Tonnage

Climate zone	kWh/ton
Climate Zone 1: Amarillo	612
Climate Zone 2: Dallas	791
Climate Zone 3: Houston	802
Climate Zone 4: Corpus Christi	847
Climate Zone 5: El Paso	791

Deemed Summer Demand Savings Tables

Table 64. GSHPs—Summer Peak Demand Savings for Desuperheaters per Cooling Tonnage

Climate zone	kW/ton
Climate Zone 1: Amarillo	0.440
Climate Zone 2: Dallas	0.405
Climate Zone 3: Houston	0.405

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236 See Volume 1

237 Demand factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the demand factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

238 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115% percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a demand factor of 1/1.15 = 0.87.

239 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent% of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5—5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a demand factor of 0.96/1.15 = 0.83.

Climate zone	kW/ton
Climate Zone 4: Corpus Christi	0.410
Climate Zone 5: El Paso	0.405

Deemed Winter Demand Savings Tables

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a GSHP unit is 24~~20~~ years.

This value is consistent with the ~~minimum~~ life expectancy of the heat pump components reported in ~~the~~multiple Department of Energy GSHP guides. Underground ground-loop infrastructure is expected to last 25—50 years. [240,241]

Program Tracking Data and Evaluation Requirements

~~It is required that the following list of p~~Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Decision/action type (new construction, replace-on-burnout)
- Replaced unit heating type (heat pump, electric resistance furnace)
  - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes

[240] Department of Energy. Geothermal Heat Pump Energy Saver article. https://www.energy.gov/energysaver/geothermal-heat-pumps.

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

- Installed GSHP type (closed loop water-to-air, open loop water-to-air, closed loop water-to-water, open loop water-to-water, direct geoexchange)
- Rated cooling and heating capacity of the new unit (Btu/hr)
- Energy Efficiency Ratio (EER) of the new unit
- Coefficient of Performance (COP) of the new unit
- Whether a desuperheater was also installed or present
- Proof of purchase—with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, and serial number
    - AHRI certificate matching model number

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 65. GSHPs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards and alternative methodology.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updates to tracking requirements.
v8.0	10/2020	TRM v8.0 update. Updated algorithms to make units consistent.
v9.0	10/2021	TRM v9.0 update. Added clarifying language and updated algorithm units.

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 update. Updated coincidence factors and EUL.

~~2.2.7~~2.2.8 Large Capacity Split and Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: R-HV-LC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure applies to the installation of a split/packaged air conditioner (AC) or heat pump (HP) with a capacity exceeding that of a typical residential system (greater than or equal to 65,000 Btu/hr) in a retrofit or new construction application. This measure also applies to the installation of ground-source heat pumps (GSHP) with a capacity exceeding 65,000 Btu/hr.

Eligibility Criteria

- The deemed savings apply to central AC/HPs with a capacity of 65,000-240,000 Btu/hr (5.4-20 tons) and GSHPs with a capacity of 65,000-135,000 Btu/hr (5.4-11.3 tons).
- Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.
- Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[242,243]

Baseline Condition

New construction and replace-on-burnout baseline efficiency levels are provided in Table 66~~Table 66~~ and Table 67~~Table 67~~. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard, IECC 2015, and ASHRAE 90.1-2013.

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

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

Table 66. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for AC/HPs[244]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[245]
Air conditioners	> 5.4 to < 11.3	None or Electric Resistance	11.2 EER 12.8 IEER	DOE Standards/ IECC 2015
		All Other	11.0 EER 12.6 IEER	
	≥ 11.3 to ≤ 20	None or Electric Resistance	11.0 EER 12.4 IEER	
		All Other	10.8 EER 12.2 IEER	
Heat pump (cooling)[246]	5.4 to < 11.3	Heat Pump	11.0 EER 12.0 IEER	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20		10.6 EER 11.6 IEER	
Heat pump (heating)[247]	5.4 to < 11.3	Heat Pump	3.3 COP	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20		3.2 COP	

[244] IECC 2015 Table C403.2.3(1) and C403.2.3(2).

[245] These baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 431.97. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf.

[246] ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type “No Heating or Electric Resistance Heating”, excluding systems with “All Other Types of Heating”.

[247] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

Table 67. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for GSHPs[248]

System type	Capacity (Btuh)	Cooling EWT rating condition	Minimum cooling EER	Heating EWT rating condition	Minimum heating COP
Water-to-air (water loop)	≥ 65,000 and < 135,000	86°F	13.0	68°F	4.3
Water-to-air (groundwater)		59°F	18.0	50°F	3.7
Brine-to-air (ground loop)		77°F	14.1	32°F	3.2
Water-to-water (water loop)		86°F	10.6	68°F	3.7
Water-to-water (groundwater)		59°F	16.3	50°F	3.1
Brine-to-water (ground loop)		77°F	12.1	32°F	2.5

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 66~~Table 66~~ and Table 67~~Table 67~~.

For reference, both ENERGY STAR® and the Consortium for Energy Efficiency (CEE) offer suggested guidelines for high-efficiency equipment.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 46

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

Equation 47

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

Equation 48

[248] Values from ASHRAE 90.1-2013.

$$Peak\ Demand\ [kW_{Savings,C}] = Cap_C \times \left(\frac{1}{\eta_{baseline,C}} - \frac{1}{\eta_{installed,C}}\right) \times CDF_{SC} \times \frac{1\ kW}{1{,}000\ W}$$

Equation 49

$$Peak\ Demand\ [kW_{Savings,H}] = Cap_H \times \left(\frac{1}{\eta_{baseline,H}} - \frac{1}{\eta_{installed,H}}\right) \times CDF_{WH} \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 50

Where:

$Cap_{C/H}$ ~~$Cap_{C/H}$~~ = *Rated equipment cooling/heating capacity of the installed equipment at AHRI standard conditions (Btu/hr); 1 ton = 12,000 Btu/hr*

$\eta_{baseline,C}$ = *Cooling efficiency of standard equipment (Btuh/W)*

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

$\eta_{baseline,H}$ = *Heating efficiency of standard equipment (Btuh/W or COP)*

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (Btuh/W or COP)*

Note: Use EER for cooling kW and COP for heating kW and kWh savings calculations. SEER/IEER should be used to calculate cooling kWh for central ACs and HPs. EER should be used to calculate cooling kWh for GSHPs. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$COP = \frac{HSPF}{3.412}$$

Equation 51

$DF_{S/W}$ ~~$CF_{C/H}$~~ = *Summer/winter~~easonal~~ peak demand~~coincidence~~ factors (Table 68)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours (Table 69~~Table 69~~)*

Table 68. Large Capacity AC/HPs—AC/HP DemandCoincidence Factors[249][250]

Season	DF
Summer[251]	0.87
Winter[252]	0.83

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.644	0.707	0.633	0.577	0.784
Winter	0.399	0.310	0.341	0.293	0.444

Table 69. Large Capacity AC/HPs—GSHP Coincidence Factors[253]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.634	0.677	0.626	0.583	0.725
Winter	0.549	0.478	0.515	0.453	0.437

Table 69. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours[254]

Climate zone	$EFLH_C$	$EFLH_H$
Climate Zone 1: Amarillo	1,142	1,880
Climate Zone 2: Dallas	1,926	1,343
Climate Zone 3: Houston	2,209	1,127
Climate Zone 4: Corpus Christi	2,958	776
Climate Zone 5: El Paso	1,524	1,559

249 See Volume 1, Section 4 of PY2022 TRM v9.

250 Demand factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the demand factors used in TX TRM 4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

251 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 %percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a demand factor of 1/1.15 = 0.87.

252 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115% percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5—5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a demand factor of 0.96/1.15 = 0.83.

253 See Volume 1 of PY2022 TRM v9.

254 ENERGY STAR® Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a large-capacity air conditioner and 15 years for a large capacity heat pump based on the current DOE Final Rule standards for central heat pumps.[255] The EUL of a high-efficiency ground source heat pump unit is 20 years, consistent with the EUL reported in the DOE GSHP guide.[256]

These values are consistent with the EULs reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Air conditioners and Heat Pumps.[257]

Program Tracking Data and Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Decision/action type (new construction, retrofit)

[255] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.

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

[257] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

- Cooling and heating capacities (Btu/hr)
- Full-load efficiency rating (EER) of the installed unit
- Part-load efficiency rating (SEER/IEER) of the installed unit (if applicable)
- Coefficient of Performance (COP) of the unit installed (heat pumps and GSHPs only)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, capacity, and serial number
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number

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 70. Large Capacity AC/HPs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Measure removed from TRM.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. Consolidated AC and HP measures and reintroduced to TRM. Extended measure applicability to GSHPs. Updated from deemed savings to algorithm approach.
v7.0	10/2019	TRM v7.0 update. Updated documentation requirements.
v8.0	10/2020	TRM v8.0 update. Updated coincidence factors
v9.0	10/2021	TRM v9.0 update. Updated baseline efficiency table to remove categories applicable to larger capacity ranges. Added GSHP coincidence factors.

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 update. Updated coincidence factors.

~~2.2.8~~2.2.9 Evaporative Cooling Measure Overview

TRM Measure ID: R-HV-EC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculations

Savings Methodology: Engineering algorithms and estimates

Measure Description

The following deemed savings values are applicable in calculating an incentive for the installation of a direct evaporative cooler instead of a refrigerated air system in an existing or new construction home in a dwelling occupied by a residential energy consumer.

Eligibility Criteria

Direct whole-house evaporative cooling systems with a saturation efficiency of 0.85 or greater are eligible for this measure. Portable, window, indirect, and hybrid systems are not eligible.

Baseline Condition

The baseline condition is a new refrigerated air conditioner with a rated efficiency at 14 SEER, the federal minimum standard.[258] The system being replaced is likely to be a less efficient evaporative cooling system, but the alternative to the new evaporative cooling unit is a minimally efficient refrigerated air conditioning system.

High-Efficiency Condition

The high efficiency condition is a direct evaporative cooling system with a saturation efficiency of at least 0.85.

[258] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings for this measure were derived using a reference metering study of evaporative cooling projects for Xcel Energy.[259] The energy savings from the Xcel study are adjusted for climate using a cooling degree day (CDD) ratio derived from TMY 2020~~TMY3~~ weather data.[260] Demand savings are calculated using the coincidence factor for the room air conditioner measure and an EFLH estimation simulated in a calibrated BEopt model that is used for other modeled measures in the Texas TRM.

Energy Savings Algorithms

$$kWh_{Savings} = kWh_{Ref} \times \left(\frac{CDD_{Site}}{CDD_{Ref}}\right)$$

Equation 52

Where:

kWh_{Ref}	=	*Reference kWh savings from Xcel Energy metering evaluation of evaporative cooling project in Grand Junction, CO: 2,041*
CDD_{Ref}	=	*Cooling degree days for the reference location of Grand Junction, CO: 1,452*
CDD_{Site}	=	*Cooling degree days for the project site location, El Paso, TX: 2,446*

Demand Savings Algorithms

$$kW_{Savings} = \frac{kWh_{Savings}}{EFLH_{Site}} \times CF$$

Equation 53

Where:

$EFLH_{Site}$	=	*Equivalent full-load hours of an evaporative cooling system for the project site location, El Paso, TX: 1,288*[261]
CF	=	*Summer Coincidence Factor: 0.920*[262]

[259] Evaporative Cooling Rebate Program Evaluation by The Cadmus Group, Inc., January 2010, Page 64, Table 23, Savings kWh value for Grand Junction Tier 2. https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/EvaporativeCoolingProgramEvaluation.pdf.

[260] NSRDB Viewer: https://nsrdb.nrel.gov/.

[261] EFLH are calculated as the total annual kWh divided by the max kW value output by the BEopt model.

[262] Derived using room air conditioner load shape from building simulation model for Room Air Conditioner measure. This factor is only applicable to climate zone 5. See Volume 1, Section 4.

Deemed Savings Tables

Table 71. Evaporative Cooling—Deemed Savings per System

Climate zone	kWh savings	Summer kW savings	Winter kW savings
5	3,438	2.46	0

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-Evap.[263]

Program Tracking Data and Evaluation Requirements

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

- Retired system model number and serial number (if applicable)
- Installed evaporative cooler model number and serial number
- Installed evaporative cooler saturation effectiveness
- Proof of purchase —with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

[263] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Document Revision History

Table 72. Evaporative Cooling—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. No revision
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated CDD reference.

~~2.2.9~~2.2.10 ENERGY STAR® Connected Thermostats Measure Overview

TRM Measure ID: R-HV-CT

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering spreadsheets and estimates

Measure Description

Deemed savings are provided for the replacement of a standard or programmable thermostat with an ENERGY STAR® connected thermostat.

Eligibility Criteria

All residential customers with refrigerated air conditioning are eligible to claim cooling savings for this measure. Customers must have electric central heating (either an electric resistance furnace or a heat pump) to claim heating savings.

The connected thermostats measure is primarily a residential retrofit measure; savings are presented for the average efficiency ratings of installed HVAC systems. Deemed savings are also presented for new construction efficiency ratings (minimum efficiency set by Federal standards).

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on below freezing conditions using the regular HEAT setting. Contractors installing a new heat pump thermostat with equipment install shall advise customer of correct thermostat usage.

Customers that receive incentives for purchasing a thermostat device through an energy efficiency program may be able to enroll in the load management program offered by the utility at the point of purchase. Deemed demand savings can only be claimed for those customers if they participate in the peak demand events. Otherwise, these devices are only eligible for the deemed energy efficiency savings.

Baseline Condition

The baseline condition is a residential central HVAC system controlled by a thermostat that does not meet the criteria for a connected thermostat (see high efficiency condition). For connected thermostats installed in conjunction with an existing HVAC unit, the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with an average efficiency for existing HVAC units in Texas estimated as shown in

Table 73

~~Table 73~~.

Table 73. Connected Thermostats—Baseline Efficiency of Existing HVAC Systems

Application	Rating type	Efficiency value
Air conditioner/heat pump cooling mode	SEER	12.2
Heat pump heating mode	HSPF	7.6
Electric resistance heat	COP	3.41

For connected thermostats installed in conjunction with a new HVAC unit (for both retrofit and new construction applications), the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with the baseline HVAC unit efficiency being equal to the efficiency of the installed system. The efficiency ratings of newly installed HVAC units should meet or exceed minimum values set by the federal manufacturing standards in effect at the time of the installation.

High-Efficiency Condition

The high-efficiency condition is an HVAC unit being controlled by a connected thermostat compliant with the ENERGY STAR® Final Version 1.0 requirements for eligible connected thermostats effective December3, 2016.[264] A list of eligible thermostats is available on the ENERGY STAR® website.[265] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Energy and Demand Savings Methodology

Energy savings are estimated according to the program requirements established by the ENERGY STAR® program for thermostat service providers seeking certification. In addition to a series of other technical and programmatic requirements, providers must demonstrate that their thermostat services result in significant run-time reductions for the controlled cooling and heating equipment. Specifically, ENERGY STAR® provides the runtime reduction criteria reproduced in Table 74~~Table 74~~.

[264] ENERGY STAR® Program Requirements Product Specification for Connected Thermostats, v1.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0.pdf.

[265] ENERGY STAR Certified Products: ENERGY STAR Certified Smart Thermostats. Online. Available: https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results.

- The ENERGY STAR runtime reductions are translated to energy savings estimates using the following information:
- Capacity and efficiency curves for HVAC performance under different temperature conditions
- Outdoor dry bulb temperature data (binned TMY3 data) for each TRM climate zone
- Annual HVAC consumption extracted from Central Air Conditioners and Heat Pumps measure savings spreadsheets

Energy use under the range of temperature conditions is estimated for each bin in each climate zone. The base case total energy use for a system of given nominal capacity (and efficiency) is estimated by multiplying each bin's energy use estimate by the number of hours of estimated operation in that bin. Energy savings are estimated by applying the runtime reductions in Table 74~~Table 74~~ uniformly to each bin's energy use.

Demand (kW) savings are not estimated for the connected thermostats measure.

Table 74. Connected Thermostats—Runtime Reduction Criteria for ENERGY STAR® Certification

Metric	Statistical measure	Performance requirement
Annual percent run time reduction, heating (HS)	Lower 95 percent confidence limit of weighted national average	≥ 8 percent
	Weighted national average of 20th percentiles	≥ 4 percent
Annual percent run time reduction, cooling (CS)	Lower 95 percent confidence limit of weighted national average	≥ 10 percent
	Weighted national average of 20th percentiles	≥ 5 percent
Average resistance heat utilization for heat pump installations (RU)	National Mean in 5°F Outdoor Temperature Bins from 0 to 60°F	Reporting requirement

Savings Algorithms and Input Variables

Deemed Energy Savings Tables

Savings are presented in kWh per ton of HVAC system capacity. For projects where tonnage is unknown, assume a default of 3.7 tons.[266]

Table 75~~Table 75~~ presents the annual energy savings for installations in which the connected thermostat is not installed in conjunction with the installation of a new HVAC unit.

[266] Based on review of average reported cooling capacity for central air conditioners and heat pumps installed in Texas utility programs in previous program years.

Table 75. Connected Thermostats—Energy Savings for Thermostats Installed with Existing HVAC Unit (kWh/ton)

Climate zone	Cooling savings	Heating savings	
		Electric resistance heat	Heat pump
Climate Zone 1: Amarillo	121	485	199
Climate Zone 2: Dallas	196	273	99
Climate Zone 3: Houston	229	178	62
Climate Zone 4: Corpus Christi	254	120	41
Climate Zone 5: El Paso	167	283	98

When a connected thermostat is installed in conjunction with the installation of a new HVAC unit, the deemed savings are a function of the efficiency of the installed system. The deemed savings for connected thermostats installed on new HVAC units are provided in Table 76~~Table 76~~ and Table 77 ~~Table 77~~. The following savings are eligible to be claimed in both new construction programs and retrofit programs where a new HVAC system is installed.

Table 76. Connected Thermostats—Cooling Energy Savings for Thermostats Installed with New HVAC Unit (kWh/ton)

Climate zone	SEER						
	14	14.5	15	16	17	18	21
Climate Zone 1: Amarillo	108	103	99	92	81	77	66
Climate Zone 2: Dallas	174	167	161	150	131	124	107
Climate Zone 3: Houston	204	196	189	175	154	146	126
Climate Zone 4: Corpus Christi	226	217	209	194	169	160	138
Climate Zone 5: El Paso	149	143	138	128	112	106	91

Table 77. Connected Thermostats—Heating Energy Savings (HP ONLY) for Thermostats Installed with New HVAC Unit (kWh/ton)

Climate zone	Heat pump HSPF							
	8.2	8.5	8.6	8.7	9.0	9.3	9.5	9.7
Climate Zone 1: Amarillo	188	181	177	177	170	163	159	156
Climate Zone 2: Dallas	93	89	87	87	82	78	77	75
Climate Zone 3: Houston	57	55	53	53	51	48	47	46
Climate Zone 4: Corpus Christi	38	37	36	36	34	32	31	31
Climate Zone 5: El Paso	91	87	85	85	80	76	75	73

The following table describes various equipment replacement scenarios that may be encountered and specifies which baseline should be used in each case. “Existing” corresponds to the savings from Table 75~~Table 75~~. “New” corresponds to the savings from Table 76~~Table 76~~ for cooling equipment and Table 77~~Table 77~~ for heating equipment.

Table 78. Connected Thermostats—Baseline for Various Equipment Replacement Scenarios

Equipment replacement scenario	Baseline	
	Cooling	Heating
No HVAC equipment replacement	Existing	Existing
Non-condenser replacements (e.g., coil or furnace ONLY)	Existing	Existing
Air conditioner condenser replacement with gas furnace	New	No savings
Air conditioner condenser replacement with electric heat	New	Existing
Heat pump condenser replacement	New	New

For upstream programs, assume a heating type weighting of 41.8 percent gas, 49.3 percent electric resistance, and 9.0 percent heat pump heat.[267]

Table 79. Connected Thermostats—Upstream and Midstream Program Energy Savings[268] (kWh/thermostat)

Climate zone	Total energy savings
Climate Zone 1: Amarillo	1,397
Climate Zone 2: Dallas	1,256
Climate Zone 3: Houston	1,192
Climate Zone 4: Corpus Christi	1,172
Climate Zone 5: El Paso	1,166

Deemed Summer Demand Savings Tables

Summer demand savings shall not be claimed for the connected thermostats measure.

Deemed Winter Demand Savings Tables

Winter demand savings shall not be claimed for the connected thermostats measure.

Claimed Peak Demand Savings

Not applicable.

[267] Residential Energy Consumption Survey (RECS) 2015: Space heating in homes in the South and West Regions (HC6.8), February 27, 2017. https://www.eia.gov/consumption/residential/data/2015/.
[268] Assuming smart thermostat is installed in conjunction with an existing 3.7-ton HVAC unit.

Example Deemed Savings Calculation

Example 1. A connected thermostat is installed on an existing 3.5-ton heat pump in climate zone 2.

$$Cooling\ Savings\ = 196\frac{kWh}{ton} \times 3.5tons = 686\ kWh$$

$$Heating\ Savings\ = 99\frac{kWh}{ton} \times 3.5tons = 347\ kWh$$

$$kWh\ savings = 686 + 347 = 1{,}033\ kWh$$

$$Summer\ kW\ savings = 0\ kW$$

$$Winter\ kW\ savings = 0\ kW$$

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-ProgTstat.[269]

Program Tracking Data and Evaluation Requirements

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

All program types:

- Climate zone
- Number of smart thermostats sold/installed
- Smart thermostat manufacturer and model number

Additional requirements for all program types other than upstream/midstream:

- HVAC system type (AC/HP)
- Determine whether HVAC condenser was replaced in conjunction with the thermostat
- HVAC capacity (tons)
- HVAC cooling efficiency (SEER) – only if installed with a new HVAC system
- HVAC heating efficiency (HSPF) – only if installed with a new heat pump

[269] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Heating type (gas, electric resistance, heat pump, none)
- Proof of purchase —with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

- Docket No. 48265. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. Petition to Approve Deemed Savings for New Nonresidential Door Air Infiltration, Nonresidential Door Gaskets, and Residential ENERGY STAR Connected Thermostats. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

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

Document Revision History

Table 80. Connected Thermostats—Revision History

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 revision. Updated documentation requirement.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. Provided guidance about emergency heat settings and updated EUL reference. Added clarification to prevent double counting of savings with smart thermostat load management measure.
v10.0	10/2022	TRM v10.0 update. No revision.

~~2.2.10~~2.2.11 Smart Thermostat Load Management Measure Overview

TRM Measure ID: R-HV-TD

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Measurement and verification

Measure Description

Deemed demand savings are provided for calling load management events on smart thermostats[270] in summer afternoons. A load management event is a process through which a utility may optimize available resources by sending a signal to customers' smart thermostats. The signal modifies the smart thermostats temperature setting to reduce overall load demand from central refrigerated air conditioning.

Eligibility Criteria

All Texas residential customers with smart thermostats participating in climate zone 5 load management events are eligible to claim demand savings for this measure.

Customers that receive incentives for purchasing a thermostat device through an energy efficiency program may be able to enroll in the load management program offered by the utility at the point of purchase. Deemed demand savings can only be claimed for those customers if they participate in the peak demand events. Otherwise, these devices are only eligible for the deemed energy efficiency savings.

Baseline Condition

The baseline condition is a heating, ventilation, and air conditioning (HVAC) unit operating in the absence of the load management event and subsequent load management activities.

[270] In this case, smart thermostats are internet-enabled devices that control a home's heating and air conditioning and can be remotely controlled by El Paso Electric Company for load management events.

High-Efficiency Condition

The high-efficiency condition is an HVAC unit being controlled by a smart thermostat and participating in a load management event.

Energy and Demand Savings Methodology

Demand savings were calculated using the "High 3 of 5 Baseline with Day-of Adjustment" method adopted in the Texas Technical Reference Manual Version 5.0 (TRM 5.0). This method considered the five most recent non-event non-holiday weekdays preceding an event and used data from the three days with the highest load within those five days to establish the baseline. "Day-of" adjustments were used to scale the baseline load estimate to the load conditions on the day of the event using data from the two hours prior to the time on the event day when participants were notified of the pending call for curtailment. In this specific program, customers were likely to experience a pre-cool period lasting up to one hour prior to the event. Therefore, the adjustment period was set as the two-hour period three hours prior to the event.

Interval metering devices were installed on a sample of households to record 15-minute interval kW demand of each house. Consumption data were recorded for a total of 50 homes in Texas. Among these 50 homes, 43 have un-anonymized thermostat run-time data, which allow linking interval consumption data with run-time data for each home. Data for customers in the sample was recorded beginning June 23, 2017. The deemed demand savings presented below were derived from these 43 homes in the summer 2018 data.

Event-level savings are calculated by multiplying kW savings per device by the number of participating devices for each event. Devices that participated no less than 50 percent of the total event duration are identified as participating devices. The average of the events' savings represents the program year savings.

Energy savings are not estimated through this specific measure.

Savings Algorithms and Input Variables

The demand algorithms and associated input variables are listed below:

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

Equation 54

Where:

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

Deemed Energy Savings Tables

Energy savings shall not be claimed using the methodology described in this measure.

Deemed Summer Demand Savings Tables

Table 81. Smart Thermostat Load Management—Deemed kW Savings per Device

Climate zone	kW/device
5	1.45

Deemed Winter Demand Savings Tables

Winter demand savings shall not be claimed using the methodology described in this measure.

Claimed Peak Demand Savings

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

Example Deemed Savings Calculation

Example 1. A smart thermostat is installed in a home participating in summer load management events:

$$Summer\ kWsavings = 1.45\ kW$$

$$Winter\ kW\ savings = 0\ kW$$

$$kWh\ savings = 0\ kWh$$

Example 2. Suppose ten~~10~~ events were called in an entire summer with participation counts listed in the table below. The total program year demand savings would be the average of the event-level savings.

Table 82. Smart Thermostat Load Management—Example Total Program Year Demand Savings Calculation

Event number	Texas		Event-level demand savings (kW)
	Deemed savings per device (kW)	Participating device number	
Event 1	1.45	600	870
Event 2	1.45	671	973
Event 3	1.45	744	1,079
Event 4	1.45	819	1,188
Event 5	1.45	868	1,259
Event 6	1.45	975	1,414
Event 7	1.45	826	1,198
Event 8	1.45	910	1,320
Event 9	1.45	804	1,166
Event 10	1.45	704	1,021
Total Program Year Demand Savings (kW):			1,149

Measure Life and Lifetime Savings

The estimated useful life (EUL) is one year for smart thermostat load management.

Program Tracking Data and Evaluation Requirements

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

- A list of all load management events affecting residential participants, describing their date, the time the event started, and the time the event ended.
- List of targeted smart thermostats in each event and unique identifier for each device.
- Participation status for targeted thermostats (e.g., participant and non-participant as described below), runtime data, or other information to assign participation status (e.g., duration of participation, offline, opted-out).
    - Participants are smart thermostats that participated no less than 50 percent of the total event duration.
    - Devices that opted out after participating for no less than 50 percent of the total event duration may be included in the participants list for that specific event.
    - All other devices that participated for less than 50 percent of the total event duration or were offline are considered non-participants and should be excluded from the participants list and savings calculation for that event.
- Summary of savings calculations and rounding practices.
    - Data rounding to the nearest whole number should only occur at the event and program levels for residential load management programs (NOT at the customer level). Utilities that prefer not to round the savings should document that in their calculations and inform the EM&V team (see Volume 5 section 3.1 for more details).

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 83. Smart Thermostat Load Management—Revision History

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. Updates to calculated savings.
v8.0	10/2020	TRM v8.0 update. Updated description and tracking requirements.
v9.0	10/2021	TRM v9.0 update. Added clarification to prevent double counting of savings with smart thermostat load management measure.
v10.0	10/2022	TRM v10.0 update. No revision.

~~2.2.11~~2.2.12 Duct Sealing Measure Overview

TRM Measure ID: R-HV-DS

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems in homes or converted residences with central air conditioning. The standard approach to estimate savings in this measure is based on the results obtained via pre- and post-leakage testing as defined in this measure. In lieu of leakage testing, savings for eligible duct sealing projects may be claimed using the alternate approach specified in this measure.

Eligibility Criteria

All single-family customers with ducted central refrigerated air conditioning or evaporative cooling are eligible to claim cooling savings for this measure. Customers must have ducted central heating with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. The specified deemed savings are not applicable to multifamily customers or to residences with space (non-central or ducted) air conditioning or heating.

For the standard approach with leakage testing, duct leakage should be assessed following the Building Performance Institute (BPI) standards. Duct leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[271]

[271] "Technical Standards for the Building Analyst Professional", Building Performance Institute (BPI), v1/4/12, Page 1 of 17, states:
"Health and Safety: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling."*
http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Building%20Analyst%20Professional.pdf.

Utility program manuals should be consulted for health and safety considerations related to the implementation of duct efficiency measures and/or testing procedures.

Duct sealing is a residential retrofit measure only and does not apply to new construction.

Baseline Condition

The savings calculation methods for this measure (when implemented with duct leakage testing) are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[272] For homes with an initial leakage rate greater than 35 percent of total fan flow, savings will be awarded with respect to this cap rather than the initial leakage. Data from nearly 28,000 single-family and mobile home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[273]

Engineering calculations show that the interior temperature in those settings that exceed 38 percent total leakage would be above the thermally acceptable comfort levels published by ASHRAE in its 2009 Fundamentals publication. The proposed pre-installation leakage limits will help ensure that the deemed savings are an accurate reflection of the program's impacts and that the program focuses its efforts on scenarios where leakage conditions are likely to persist if unaddressed for several years.

Low-income customers[274] are exempt from the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow.

While these baseline criteria were applied in deriving the deemed savings for the alternate approach (without duct leakage testing), it is not necessary to determine the pre-installation leakage rate for projects claiming the alternate deemed savings.

High-Efficiency Condition

Materials used should be long-lasting materials, such as mastics, UL 181A or UL 181B approved foil tape or aerosol-based sealants. Fabric-based duct tape is not allowed.

The selected methodology for estimating duct sealing deemed savings according to the standard approach requires duct leakage-to-outside testing using a combination duct pressurization and house pressurization.

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[272] Total Fan Flow = Cooling Capacity (tons) x 400 cfm/ton.

[273] Based on data collected by Frontier Energy for investor-owned utilities in Texas.

[274] Low-income customers are income-eligible customers served through a targeted low-income energy efficiency program as described in 25.181(r). This may also apply to income-eligible customers served through a hard-to-reach program that is also delivered following the guidelines in 25.181(r). https://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.181/25.181.pdf.

Duct Leakage Testing (Standard Approach)

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. For this measure, leakage-to-outside must be directly measured. The project sponsor shall use the Combination Duct Blaster™ (or equivalent) and blower door method. Prior to beginning any installations, the project sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician Excellence (NATE) certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[275]

Categorizing Achieved Duct Leakage Reduction (Absent Leakage Testing)

Participating energy efficiency service providers (EESPs) electing not to perform leakage testing should nevertheless provide an estimate of the expected outcome of the leakage reduction work performed: projects should be characterized according to contractor estimation of whether the work required should result in a ***low***, ***average***, or ***high reduction*** in duct system leakage. EESPs should take the following considerations into account in assessing the likely leakage reduction achieved in a given project:

- The number and size of repaired leaks
- Leak location: a leak in an attic joint will cause more energy loss than a joint that leaks to conditioned space
- Supply/return: supply-side leaks, particularly in the return air plenum and near the air handling unit can be especially problematic, as they tend to draw additional unconditioned air into the system.

Systems that were not initially very leaky and in which few joints and supply vents were sealed should be characterized as low reduction. Jobs with a typical number of supply vents and joints sealed, and in which the supply air return or the return air plenum were sealed, should be characterized as average reduction. Jobs requiring significant interventions to eliminate large or numerous leaks should be considered high reduction.

The following table provides a guideline for selecting an appropriate leakage category. How the category is determined may fluctuate on a per-home basis.

[275] See RESNET Technical Committee, Proposed Amendment: Chapter 8 RESNET Standards, 800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing; Section 803.2 and Table 803.1. https://www.resnet.us/wp-content/uploads/Chapter-Eight-22RESNET-Standard-for-Performance-Testing-and-Work-Scope-Enclosure-and-Air-Distribution-Leakage-Testing22.pdf.

Table 84. Duct Sealing—Leakage Categorization Guide[276]

Category	Duct location	Duct insulation value	Leakage characteristics[277]
Low	> 90 percent conditioned	> R7	Some observable leaks
			Substantial leaks
		R4 - R7	Some observable leaks
			Substantial leaks
		< R4	Some observable leaks
			Substantial leaks
	50-90 percent conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
Average	> 90 percent conditioned	> R7	Catastrophic leaks
		R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	50-90 percent conditioned	> R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
		< R4	Substantial leaks
	< 50 percent conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
High	50-90 percent conditioned	R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	< 50 percent conditioned	~~R4 - R7~~ > R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
			Catastrophic leaks
		< R4	Substantial leaks
			Catastrophic leaks

[276] Based on typical distribution efficiency assumptions from the Building Performance Institute (BPI) Technical Standards for the Heating Professional, November 20, 2007, page 7. http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Heating%20Professional.pdf.

[277] Catastrophic leaks are defined by BPI as disconnected ducts, missing end-caps, and other catastrophic holes.

Energy and Demand Savings Methodology

Savings may be claimed according to either the standard approach (with duct leakage testing) or the alternate approach, according to the following sections.

Standard Approach (with Duct Leakage Testing)

The annual energy and summer and winter peak demand savings to be claimed according to the standard approach for this measure shall be calculated as a function of the reduction in duct leakage achieved, using the energy and demand savings coefficients from Table 85~~Table 85~~ through Table 87~~Table 87~~ for the climate zone in which the project was implemented and the type of heating equipment in the project home.

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the reduction in duct leakage achieved (in CFM_{25}). Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the base case duct leakage rate was set to 8 CFM_{25} per 100 square feet. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 6 CFM_{25} per 100 square feet. Results from running the change case model provide estimated hourly energy use for the prototypical home after treatment. A comparison of these two runs provides the deemed savings estimates.

Deemed savings are presented as a function of the CFM_{25} reduction achieved, as demonstrated by leakage to outside testing using the Combination Duct Blaster^{TM} (or equivalent) and Blower Door method. The kWh and kW per CFM_{50} values represented by the V_E, V_S, and V_W coefficients are derived by taking the difference between annual energy use and summer and winter peak demand, as estimated by the two model runs and normalizing to the CFM_{25} reduction achieved.

Deemed Energy Savings Tables

Table 85~~Table 85~~ presents the annual energy savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate annual energy savings for duct leakage reduction:

$$Deemed\ Energy\ Savings\ (kWh) = \left(DL_{pre} - DL_{post}\right) \times V_E$$

Equation 55

Where:

DL_{pre} = *Pre-improvement duct leakage at 25 Pa (cu. ft./min)*

DL_{post} = *Post-improvement duct leakage at 25 Pa (cu. ft./min)*

$V_{E,C}$ = *Cooling Energy Savings Coefficient in Table 85*

$V_{E,H}$ = *Heating Energy Savings Coefficient in Table 85*

Table 85. Duct Sealing—Energy Savings V_E per CFM_{25} Reduction

Climate zone	$V_{E,C}$: Cooling savings		$V_{E,H}$: Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	0.82	0.21	0.07	2.75	0.71
Zone 2: Dallas	1.05	–	0.03	1.19	0.31
Zone 3: Houston	1.23	–	0.02	0.85	0.26
Zone 4: Corpus Christi	1.46	–	0.01	0.61	0.19
Zone 5: El Paso	1.20	0.38	0.03	1.44	0.37

Deemed Summer Demand Savings Tables

Table 86Table 86 presents the summer peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed summer demand savings for duct leakage reduction:

$$Deemed\ Summer\ Demand\ Savings\ (kW) = (DL_{pre} - DL_{post}) \times V_S$$

Equation 56

Where:

DL_{pre} = *Pre-improvement duct leakage at 25 Pa (cu. ft./min)*

DL_{post} = *Post-improvement duct leakage at 25 Pa (cu. ft./min)*

V_S = *Summer Demand Savings Coefficient (see Table 86Table 86)*

Table 86. Duct Sealing—Summer Demand Savings V_S per CFM_{25} Reduction

Climate zone	Summer kW impact per CFM_{25} reduction	
	Refrigerated	Evaporative
Climate Zone 1: Amarillo	9.28E-04	2.29E-04
Climate Zone 2: Dallas	8.47E-04	–
Climate Zone 3: Houston	1.06E-03	–
Climate Zone 4: Corpus Christi	6.72E-04	–
Climate Zone 5: El Paso	7.66E-04	1.86E-04

Deemed Winter Demand Savings Tables

Table 87~~Table 87~~ presents the winter peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed winter demand savings for duct leakage reduction:

$$Deemed\ Winter\ Demand\ Savings\ (kW) = \left(DL_{pre} - DL_{post}\right) \times V_W$$

Equation 57

Where:

DL_{pre} = *Pre-improvement duct leakage at 25 Pa (cu. ft./min)*

DL_{post} = *Post-improvement duct leakage at 25 Pa (cu. ft./min)*

V_W = *Winter Demand Savings Coefficient (see Table 87)*

Table 87. Duct Sealing—Winter Demand Savings V_W per CFM_{25} Reduction

Climate zone	kWh impact per CFM_{25} reduction		
	Gas	Resistance	Heat pump
Climate Zone 1: Amarillo	4.38E-06	8.49E-04	1.46E-04
Climate Zone 2: Dallas	1.22E-06	9.96E-04	6.98E-04
Climate Zone 3: Houston	8.60E-06	8.61E-04	5.02E-04
Climate Zone 4: Corpus Christi	1.18E-05	6.71E-04	4.06E-04
Climate Zone 5: El Paso	6.68E-06	2.81E-04	6.69E-05

Alternate Approach (No Duct Leakage Testing)

The following savings tables are provided for projects implemented without performing leakage testing, accounting for the application of pre-retrofit leakage caps to not hard-to-reach (HTR) projects. The annual energy and summer and winter peak demand savings to be claimed according to the alternate approach for this measure shall be taken from Table 85~~Table 85~~ through Table 87~~Table 87~~ for the climate zone in which the project was implemented and the type of heating equipment in the project home.

While savings for multiple duct systems are additive for the standard approach, the following savings are specified per home when using the alternate approach and should not be multiplied by the number of treated duct systems.

NOTE: This approach is only available to programs with an incentive structure that varies by leakage category. Additionally, energy efficiency service providers (EESPs) should not alternate between the standard and alternative approaches during the same program year. Utilities should either restrict all participants within an individual program to one approach or the other, or they should restrict individual EESPs to one approach or the other across all program types.

Hard-to-Reach (HTR) and Targeted Low-Income Programs

Deemed Energy Savings Tables (Alternate Approach)

Table 88. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), HTR Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	204	52	17	685	177
2	Average	323	83	28	1,083	280
3	High	514	132	44	1,725	445

Table 89. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), HTR Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	262	–	7	297	77
2	Average	413	–	12	468	122
3	High	659	–	19	746	194

Table 90. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), HTR Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	307	–	5	212	65
2	Average	484	–	8	335	102
3	High	771	–	13	533	163

Table 91. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), HTR Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	364	–	2	152	47
2	Average	575	–	4	240	75
3	High	916	–	6	383	119

Table 92. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), HTR Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	299	95	7	359	92
2	Average	472	150	12	567	146
3	High	753	238	19	903	232

Deemed Summer Demand Savings Tables (Alternate Approach)

Table 93. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), HTR Alternate Approach

Category	Refrigerated	Evaporative
Low	0.23	0.06
Average	0.37	0.09
High	0.58	0.14

Table 94. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), HTR Alternate Approach

Category	Refrigerated	Evaporative
Low	0.21	–
Average	0.33	–
High	0.53	–

Table 95. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), HTR Alternate Approach

Category	Refrigerated	Evaporative
Low	0.26	–
Average	0.42	–
High	0.66	–

Table 96. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), HTR Alternate Approach

Category	Refrigerated	Evaporative
Low	0.17	–
Average	0.26	–
High	0.42	–

Table 97. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), HTR Alternate Approach

Category	Refrigerated	Evaporative
Low	0.19	0.05
Average	0.30	0.07
High	0.48	0.12

Deemed Winter Demand Savings Tables (Alternate Approach)

Table 98. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), HTR Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.21	0.04
Average	0.00	0.33	0.06
High	0.00	0.53	0.09

Table 99. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), HTR Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.25	0.17
Average	0.00	0.39	0.27
High	0.00	0.62	0.44

Table 100. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), HTR Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.21	0.13
Average	0.00	0.34	0.20
High	0.01	0.54	0.31

Table 101. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), HTR Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.17	0.10
Average	0.00	0.26	0.16
High	0.01	0.42	0.25

Table 102. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), HTR Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.07	0.02
Average	0.00	0.11	0.03
High	0.00	0.18	0.04

All Other Programs

Deemed Energy Savings Tables (Alternate Approach)

Table 103. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	187	48	16	628	162
2	Average	300	77	26	1,005	259
3	High	428	110	37	1,437	371

Table 104. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	240	–	7	272	71
2	Average	384	–	11	435	113
3	High	549	–	16	622	162

Table 105. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	281	–	5	194	59
2	Average	449	–	7	310	95
3	High	643	–	10	444	136

Table 106. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	333	–	2	139	43
2	Average	533	–	4	223	69
3	High	763	–	5	319	99

Table 107. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), Alternate Approach

Category	Assessed leakiness	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
1	Low	274	87	7	329	84
2	Average	438	139	11	526	135
3	High	627	199	16	752	193

Deemed Summer Demand Savings Tables (Alternate Approach)

Table 108. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), Alternate Approach

Category	Refrigerated	Evaporative
Low	0.21	0.05
Average	0.34	0.08
High	0.48	0.12

Table 109. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), Alternate Approach

Category	Refrigerated	Evaporative
Low	0.19	–
Average	0.31	–
High	0.44	–

Table 110. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), Alternate Approach

Category	Refrigerated	Evaporative
Low	0.24	–
Average	0.39	–
High	0.55	–

Table 111. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), Alternate Approach

Category	Refrigerated	Evaporative
Low	0.15	–
Average	0.25	–
High	0.35	–

Table 112. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), Alternate Approach

Category	Refrigerated	Evaporative
Low	0.17	0.04
Average	0.28	0.07
High	0.40	0.10

Deemed Winter Demand Savings Tables (Alternate Approach)

Table 113. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.19	0.03
Average	0.00	0.31	0.05
High	0.00	0.44	0.08

Table 114. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.23	0.16
Average	0.00	0.36	0.25
High	0.00	0.52	0.36

Table 115. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.20	0.11
Average	0.00	0.31	0.18
High	0.00	0.45	0.26

Table 116. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.15	0.09
Average	0.00	0.25	0.15
High	0.01	0.35	0.21

Table 117. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), Alternate Approach

Category	Heating system type		
	Gas	Electric resistance	Heat pump
Low	0.00	0.06	0.02
Average	0.00	0.10	0.02
High	0.00	0.15	0.03

Claimed Peak Demand Savings

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

Example Deemed Savings Calculation

Example 1. Using the **standard approach**, a 1,700 square foot home with a 3.5-ton central air conditioner and a gas furnace in Climate Zone 3 is found to have a pre-retrofit duct leakage rate of 600 CFM_{25}. After sealing leaks, duct leakage is estimated at 100 CFM_{25}. The project is completed in a non-HTR program.

$$Max\ Initial\ Leakage\ Rate\ = \left(400\frac{CFM}{ton}\ \times\ 3.5tons\right) \times\ 35\% = 490\ CFM_{25}$$

$$Reported\ Initial\ Leakage\ = Min\ (600, 490) = 490\ CFM_{25}$$

$$DL_{pre} - DL_{post} = (490 - 100) = 390 CFM_{25}$$

$$kWh\ savings = (1.23 + 0.02)\ \times\ 390 = 488 kWh$$

$$Summer\ kW\ savings = 1.06\ \times\ 10^{-3}\ \times\ 390 = 0.41\ kW$$

$$Winter\ kW\ savings = 8.60\ \times\ 10^{-6}\ \times\ 390 = 0.003\ kW$$

Example 2. Using the **alternate approach**, a duct sealing project is completed on a home of any square footage with a central heat pump of any tonnage in Climate Zone 3. The duct system is categorized as 50-90 percent in conditioned space with an existing duct insulation value of R4-R7 and substantial leaks. Therefore, that home is categorized as an average leakage home. No leakage testing is performed. The project is completed in an HTR program. All savings are taken directly from deemed savings lookup tables.

$$kWh\ savings = 484 + 102 = 586\ kWh$$

$$Summer\ kW\ savings = 0.42\ kW$$

$$Winter\ kW\ savings = 0.20\ kW$$

Additional Calculators and Tools

There is a calculator to estimate the energy and demand savings associated with this measure using the algorithms described in the previous subsection.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a duct sealing measure is 18 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-DuctSeal-BW.[278]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Cooling Type (central refrigerated, evaporative cooling, none)
- Heating type (central gas furnace, central electric resistance furnace, heat pump, none)
    - Additional documentation is required to validate resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach)
- Cooling capacity of home HVAC units (tons)

EESPs claiming savings according to duct leakage testing:

- Pre-improvement duct leakage at 25 Pa (cu. ft./min)
- Post-improvement duct leakage at 25 Pa (cu. ft./min)
- Pre- and post-photos of leakage test readings

EESPs claiming savings without performing leakage testing should provide:

- Description of the leakage severity in the home (low, average, or high)
- Description of location and condition of ducts:
    - Duct location (>90 percent conditioned, 50-90 percent conditioned, <50 percent conditioned)
    - Existing duct insulation value (>R7, R4-R7, <R4)
- Leakage characteristics (some observable leaks, substantial leaks, catastrophic leaks)
- Other relevant details that may assist with validating claimed leakage category (recommended)

[278] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Description and photos of interventions taken (both pre and post condition), such as newly sealed joints, supply vents, and other relevant leaks sealed
- Incentive rate structure: incentive should be paid per home and should not vary by leakage category to avoid providing an incentive to overstate the existing leakage category.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

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

Document Revision History

Table 118. Duct Sealing—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor formatting changes, and language introduced to provide further direction for low-income customers and testing procedure. Contractors now required to track cooling capacity of HVAC equipment. Language added to reflect updates to federal standards for central heat pumps and central air conditioners.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Update of reference sources for air temperatures and densities, heating degree-days. Cooling demand savings required to be claimed.
v4.0	10/10/2016	TRM v4.0 update. Approach changed from algorithm-based to deemed savings coefficients estimated using building simulation models. Updated energy and demand savings. Added separate savings for homes with evaporative cooling. Updated measure description to eliminate eligibility for homes without a central AC, but with a ducted heating system.
v5.0	10/2017	TRM v5.0 update. Remove PY 2017 option to use energy and demand adjustment factors in combination with algorithm methodology from TRM v3.1. ~~Added alternative approach to bypass the need to complete leakage testing in guidance memo to follow.~~

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 update. Added alternative approach to bypass the need to complete leakage testing based on precedingin guidance memo to follow.
v7.0	10/2019	TRM v8.0 update. Added clarifying language on incentive rate per home.
v8.0	10/2020	TRM v8.0 update. Updated eligibility and documentation requirements for electric resistance heat.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Corrected typo in leakage categorization guide.

2.3 RESIDENTIAL: BUILDING ENVELOPE

2.3.1 Air Infiltration Measure Overview

TRM Measure ID: R-BE-AI

Market Sector: Residential Low-Income and Hard-to-Reach

Measure Category: Building Envelope

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

This measure involves the implementation of interventions to reduce the rate of air infiltration into residences. Pre- and post-treatment blower door air pressure readings are required to confirm air leakage reduction. The standard approach for estimating savings in this measure is based on the results obtained via pre- and post-leakage testing as defined in this measure.

Eligibility Criteria

Savings in this measure apply to low-income (LI) and hard-to-reach (HTR) customers only. Cooling savings apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Heating savings apply to customers with a central furnace (gas or electric resistance) or a heat pump in their homes. Customers who participate in HTR or LI programs are also eligible to claim heating or cooling savings for homes heated with gas or electric resistance space heaters and/or cooled by one or more room air conditioners by applying an adjustment to deemed savings for the specified system.

There is an upper limit of 4.6 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate on eligible projects. For homes where the pre-retrofit leakage exceeds this limit, savings will be awarded against the leakage cap.

Utilities may require certification or competency testing of personnel who will perform the blower door tests Air leakage should be assessed through testing following Building Performance Institute (BPI) standards. In some limited cases, where testing is not possible or unsafe (e.g., due to potential presence of asbestos), a visual assessment may be satisfactory. The air leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[279] Utilities' program manuals should be consulted for health and safety considerations related to the implementation of air sealing measures.

Only structures with electric refrigerated air conditioning systems are eligible.

Baseline Condition

The baseline for this measure is the existing leakage rate of the treated residence. The existing leakage rate should be capped to account for the fact that the deemed savings values per CFM_{50} leakage reduction are only applicable up to a point where the existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.

Baseline assumptions used in the development of these deemed savings are based on a conversion from $ACH_{Natural}$. ASHRAE Handbook: Fundamentals specifies that more than 80 percent of sampled low-income housing had a pre-leakage rate at or below 1.75 $ACH_{Natural}$.[280] $ACH_{Natural}$ was converted to CFM_{50}/sq. ft. using Equation 58.

$$CFM_{50,pre} = \frac{ACH_{Natural,pre}\ x\ h\ x\ N}{60}$$

Equation 58

Where:

$ACH_{Natural,pre}$ = *1.75 representing greater than 80 percent of sampled homes*

h = *Ceiling height (ft.) = 8.5 (default)*[281]

N = *N factor for single story normal shielding (Table 119) = 18.5*

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 4.6 CFM_{50}/sq. ft.. Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or where blower door tests were improperly conducted, these savings should only be applied starting at a baseline CFM_{50}/sq. ft. of 4.6 or lower.

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279 The Building Performance Institute, Inc. (BPI) Standard Reference: Building Performance Institute Technical Standards for the Building Analyst Professional, v2/28/05mda, Page 1 of 17, states: "Health and Safety*:* Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling."*

280 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12.

281 Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[282] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[283] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

High-Efficiency Condition

Blower door air pressure measurements must also be used to ensure that post-treatment air infiltration rates are not less than those set forth by the standard in Equation 59~~Equation 59~~, based on floor area and the number of bedrooms.[284] These calculated minimum CFM_{50} values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. At the utility's discretion, this minimum CFM_{50} requirement may be enforced as an eligibility requirement. Otherwise, savings may be claimed for projects where the measured final infiltration rate is less than the minimum allowable ventilation rate if the following conditions are met:

- Mechanical ventilation is present or introduced in compliance with ASHRAE 62.2-2019
- Post-treatment infiltration rate is reported as the actual measured CFM50 result
- Savings are calculated using the TRM minimum allowable ventilation rate with no additional savings claimed for CFM reduction below this amount

Where higher occupant densities are known, the minimum rate shall be increased by 7.5 CFM_{Nat} for each additional person. A CFM_{Nat} value can be converted to CFM_{50} by multiplying by the appropriate N factor (Table 119).

$$Min\ CFM_{50} = [0.03 \times A_{Floor} + 7.5 \times OCC] \times N$$

Equation 59

Where:

Min CFM_{50}	=	*Minimum final ventilation rate (CFM_{50})*
A_{Floor}	=	*Floor area (sq. ft.)*
OCC	=	*BR + 1, where BR is the number of bedrooms; if number of home occupants is known to exceed BR + 1, occupancy should be used instead*
N	=	*N factor (*Table 119*)*

282 Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

283 Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

284 ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

Table 119. Air Infiltration—N Factors[285]

Shielding	Number of stories		
	1 story	2 story	3+ stories
Well shielded	22.2	17.8	15.5
Normal	18.5	14.8	13.0
Exposed	16.7	13.3	11.7

The maximum CFM reduction percentage[286] is capped at 30 percent. It is important to note that the minimum ventilation rate specified earlier in this section still applies for cases where the maximum 30 percent CFM reduction cannot be achieved due to the post CFM value being limited by the minimum allowable post CFM value provisioned for safety reasons.

The TRM stipulates an upper limit of 4.6 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate as part of eligibility criteria. For homes where the pre-retrofit leakage exceeds this limit, energy and demand savings must be calculated using the pre-measure-installation leakage cap. Therefore, when the pre-retrofit leakage is capped, energy and demand savings can only be claimed for a 30 percent reduction in CFM compared to the capped pre-CFM value. When the pre-retrofit leakage is not capped, energy and demand savings can only be claimed for a 30 percent reduction in CFM compared to the tested, actual pre-retrofit infiltration rate of the home.

The TRM requires all contractors to provide sufficient evidence (e.g., pictures capturing the scope/type of retrofit implemented and blower door test readings) for all homes.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the leakage reduction achieved (in CFM_{50}).[287] Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the base case air infiltration rate was set to 20 ACH_{50}. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 3 ACH_{50}.

285 Krigger, J. and Dorsi, C.,"Residential Energy: Cost Savings and Comfort for Existing Buildings". A-11 Building Tightness Limits, p. 284. Use Zone 2 for Texas climate.

286 CFM reduction percentage is calculated as: (pre-CFM value – post-CFM value) / pre-CFM value

287 Model testing indicates a straight-line relationship between demand and energy savings achieved and CFM50 reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

Deemed savings are presented as a function of the CFM_{50} reduction achieved, as demonstrated by blower door testing. The kWh and kW per CFM_{50} values represented by the V_E, V_S, and V_W coefficients are derived by taking the difference between annual energy use and summer and winter peak demand as estimated by the two model runs and normalizing to the CFM_{50} reduction achieved. The pre- and post-treatment ACH_{50} values (20 and 3, respectively) are converted to CFM_{50} by multiplying the pressurized air-change rate by the volume of the model home and dividing by 60 (minutes/hour).

Deemed Energy Savings Tables

Table 120~~Table 120~~ presents the energy savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

$$Deemed\ Energy\ Savings = \Delta CFM_{50} \times \left(V_{E,C} \times CAF + V_{E,H}\right)$$

Equation 60

Where:

ΔCFM_{50}	=	*Air infiltration reduction in cubic feet per minute at 50 Pascal*
$V_{E,C}$	=	*Corresponding cooling savings value in Table 120*
CAF	=	*Cooling savings adjustment factor for homes with room air conditioners; set to 1.0 for homes with refrigerated air or set to 0.6 for homes with one or more room air conditioners*
$V_{E,H}$	=	*Corresponding heating savings value in Table 120*

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 120~~Table 120~~ by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 120~~Table 120~~ by a factor of 0.24.[288]

Table 120. Air Infiltration—Energy Savings V_E per CFM_{50} Reduction

Climate zone	$V_{E,C}$: Cooling savings	$V_{E,H}$: Heating savings		
	Refrigerated air	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	0.12	0.09	1.92	0.78
Zone 2: Dallas	0.27	0.04	1.10	0.45
Zone 3: Houston	0.22	0.02	0.63	0.25
Zone 4: Corpus Christi	0.39	0.02	0.55	0.21
Zone 5: El Paso	0.07	0.03	0.88	0.34

288 This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Deemed Summer Demand Savings Tables

Table 121~~Table 121~~ presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed summer demand savings for air infiltration improvements.

$$Deemed\ Summer\ Demand\ Savings = \Delta CFM_{50} \times V_S \times CAF$$

Equation 61

Where:

ΔCFM_{50}	=	*Air infiltration reduction in cubic feet per minute at 50 Pascal*
V_S	=	*Corresponding value in Table 121*
CAF	=	*Cooling savings adjustment factor for homes with room air conditioners; set to 1.0 for homes with refrigerated air or set to 0.6 for homes with one or more room air conditioners*

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 121~~Table 121~~ by a factor of 0.6.

Table 121. Air Infiltration—Peak Summer Demand Savings V_S per CFM_{50} Reduction

Climate zone	Summer kW impact per CFM_{50} reduction
Climate Zone 1: Amarillo	1.64E-04
Climate Zone 2: Dallas	2.10E-04
Climate Zone 3: Houston	1.90E-04
Climate Zone 4: Corpus Christi	2.24E-04
Climate Zone 5: El Paso	9.40E-05

Deemed Winter Demand Savings Tables

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 122~~Table 122~~ by a factor of 0.24. For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 122~~Table 122~~ by a factor of 0.24.

Table 122~~Table 122~~ presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed winter demand savings for air infiltration improvement:

$$Deemed\ Winter\ Demand\ Savings = \Delta CFM_{50} \times V_W$$

Equation 62

Where:

ΔCFM_{50}	=	*Air infiltration reduction in cubic feet per minute at 50 Pascal*
V_W	=	*Corresponding value in* Table 122~~Table 122~~

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 122~~Table 122~~ by a factor of 0.24.[289]

Table 122. Air Infiltration—Peak Winter Demand Savings V_W per CFM_{50} Reduction

Climate zone	Winter kW impact per CFM_{50} reduction	
	Electric resistance	Heat pump
Climate Zone 1: Amarillo	9.42E-04	5.48E-04
Climate Zone 2: Dallas	1.25E-03	6.93E-04
Climate Zone 3: Houston	8.61E-04	4.41E-04
Climate Zone 4: Corpus Christi	7.81E-04	3.60E-04
Climate Zone 5: El Paso	2.92E-04	1.19E-04

Claimed Peak Demand Savings

Refer to Volume 1, Section 4.

Example Deemed Savings Calculation

Example 1. A contractor uses a blower door test to estimate 12,000 CFM_{50} of pre-retrofit air leakage in a 2,200 square foot, 2-story, 3-bedroom home in climate zone 4 with a heat pump. The home is located in a normally shielded area. After identifying and sealing leaks, she performs another blower door test and measures 8,000 CFM_{50} of air leakage.

$$Max\ Initial\ Leakage\ Rate = 4.6 \times 2{,}200 = 10{,}120\ CFM_{50}$$

$$Reported\ Initial\ Leakage = Min\ (12{,}000, 10{,}120) = 10{,}120 CFM_{50}$$

$$Capped\ Post\ Retrofit\ Leakage = 10{,}120 \times (1 - 0.3) = 7{,}084\ CFM_{50}$$

$$Reported\ Post\ Retrofit\ Leakage = Max\ (8{,}000, 7{,}084) = 8{,}000\ CFM_{50}$$

$$Min.Post\ Retrofit\ Leakage\ (safety) = [0.03 \times 2{,}200 + 7.5 \times 4] \times 14.8 = 1{,}421\ CFM_{50}$$

$$\Delta CFM_{50} = (10{,}120 - 8{,}000) = \mathit{2{,}120}$$

$$kWh\ savings = (0.39 + 0.21) \times 2{,}120 = \mathit{1{,}272}\ kWh$$

[289] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

$$Summer\ kW\ savings = 2.24 \times 10^{-4} \times 2{,}120 = 0.47\ kW$$

$$Winter\ kW\ savings = 3.60 \times 10^{-4} \times 2{,}120 = 0.76\ kW$$

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-Wthr.[290]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); representative sampling is allowed for multifamily complexes
- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories
- Number of occupants
- Pre- and post-photos of blower door test readings
- Representative photos of leak repairs

[290] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003, Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

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

Document Revision History

Table 123. Air Infiltration—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. Revision of minimum ventilation requirements, pre-retrofit cap on infiltration levels, Climate Zone 5 savings values for homes with heat pumps, and tracking number of bedrooms and occupants in a house.
v3.1	11/05/2015	TRM v3.1 update. Provided clarification around effects of occupancy on minimum final ventilation.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Introduced new protocols related to maximum CFM reduction percentage and its associated documentation requirements. Added a new example for calculating savings.

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 update. Added alternative approach to bypass the need to complete leakage testing in guidance memo to follow.
v6.0	11/2018	TRM v6.0 update. Removed alternative approach allowance at this time. Clarified the eligibility of projects where CFM_{post} falls below the minimum ventilation rate requirement.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Reduced leakage cap and updated documentation requirements. Updated eligibility to only LI/HTR. Added space heat adjustment factor and electric resistance documentation requirement.
v9.0	10/2021	TRM v9.0 update. Updated savings calculation example and EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.

2.3.2 Ceiling Insulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

Savings are estimated for insulation improvements to the ceiling area above a conditioned space in a residence.

Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM climate zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

Baseline Condition

Ceiling insulation levels encountered in existing homes can vary significantly, depending on factors such as the age of the home, type of insulation installed, and level of attic use (equipment, storage, etc.). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from sparsely insulated (R-5) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The current average ceiling insulation level at participating homes is to be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing insulation is or has been removed during measure implementation, the existing R-value for claiming savings shall be based upon the R-value of the existing insulation prior to removal.

In the event there are varying levels of existing insulation, an area-weighted U-factor can be used to find the effective R-value across the treated area. The U-factor should be taken from the existing insulation only. This approach can be used in single attic spaces, and savings should be estimated separately for independent spaces where there are separate heating or cooling methods (e.g., additions).

Area-Weighted U-Factor Calculation Method

$$U_A = [U_1 \times Area_1 + \mathrm{U}_2 \times \mathrm{Area}_2 + \ldots]/\,[\mathrm{Area}_1 + \mathrm{Area}_2 + \ldots]$$

$$Effective\ Rvalue = \frac{1}{U_A}$$

Equation 63

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[291] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[292] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

High-Efficiency Condition

A minimum ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation. Contractors should estimate post-retrofit R-values according to the average insulation depth achieved across the area treated and the R per-inch of the insulation material installed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone was modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22. These modifications are shown in Table 124.

The model runs are used to estimate peak demand and energy use in the modeled home at each of the base case ceiling insulation levels. The change-case models were run with the ceiling insulated to R-30.

291 Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

292 Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

Table 124. Ceiling Insulation—Prototypical Home Characteristics

Shell characteristic	Value	Source
Base ceiling insulation	< R5 R5-R8 R9-R14 R15-R22	Existing insulation level
Change ceiling insulation	R-30	R-30 retrofit insulation level consistent with DOE recommendations

Deemed Energy Savings Tables

Table **125**~~Table 125~~ through Table 129, present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table **125**~~Table 125~~ through Table 131~~Table 131~~ by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table **125**~~Table 125~~ through Table 131~~Table 131~~ by a factor of 0.24.[293]

Table 125**. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Energy Savings (kWh/sq. ft.)**

Ceiling insulation base R-value	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
< R-5	0.41	0.12	0.12	3.07	1.31
R-5 to R-8	0.28	0.08	0.08	2.16	0.92
R-9 to R-14	0.15	0.04	0.05	1.17	0.50
R-15 to R-22	0.06	0.02	0.02	0.51	0.22

293 This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Table 126. **Ceiling Insulation—Climate Zone 2: Dallas, R-30 Energy Savings (kWh/sq. ft.)**

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5	0.67	0.07	1.90	0.79
R-5 to R-8	0.46	0.05	1.34	0.55
R-9 to R-14	0.25	0.03	0.72	0.30
R-15 to R-22	0.11	0.01	0.32	0.13

Table 127. **Ceiling Insulation—Climate Zone 3: Houston, R-30 Energy Savings (kWh/sq. ft.)**

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5	0.68	0.05	1.30	0.53
R-5 to R-8	0.46	0.03	0.92	0.37
R-9 to R-14	0.24	0.02	0.50	0.20
R-15 to R-22	0.10	0.01	0.22	0.09

Table 128. **Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Energy (kWh/sq. ft.)**

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
R-5	0.52	0.03	0.89	0.34
R-5 to R-8	0.35	0.02	0.62	0.24
R-9 to R-14	0.18	0.01	0.33	0.13
R-15 to R-22	0.08	0.00	0.14	0.06

Table 129. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Energy Savings (kWh/sq. ft.)

Ceiling insulation base R-value	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
< R-5	0.63	0.21	0.07	1.96	0.81
R-5 to R-8	0.43	0.15	0.05	1.40	0.57
R-9 to R-14	0.23	0.08	0.03	0.75	0.31
R-15 to R-22	0.10	0.03	0.01	0.33	0.13

Scale-Down/Up Factors for Energy Savings: Insulation to Below or Above R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale-down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale-up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$Energy\ Savings\ (kWh) = \left\{R30\ Savings/ft^2 + \left[S_{D/U} \times (R_{Achieved} - 30)\right]\right\} \times A$$

Equation 64

Where:

R30 Savings/sq. ft. = *Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 125 through Table 129*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 130 or Table 131*

$R_{Achieved}$ = *Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)*

A = *Treated area (sq. ft.)*