Where:

RUL = *Remaining Useful Life (see Table 68~~Table 68~~ or Table 69~~Table 69~~) or if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of ~~8~~7.0 (ACs) or 6.0 years (HPs). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. 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. For HPs replacing an AC with an electric resistance furnace, use the RUL table from the Central AC measure instead.*

EUL = *Estimated Useful Life = 18 years (AC); 15 years (HP)*

Table 68. Central AC/HPs—Remaining Useful Life of Replaced AC[105]

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[106,107]	0.0
13	9.0		

[105] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[106] RULs are capped at the 75th percentile of equipment age, 25 years, as determined based on DOE survival curves (see Figure 2). Systems older than 25 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[107] 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.

Table 69. Central AC/HPs—Remaining Useful Life of Replaced HP[108]

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
8	9.3	19	2.0
9	8.9	20	1.0
10	8.5	21[109,110]	0.0
11	8.2		

Derivation of RULs

Central ACs have an estimated useful life of 18 years, and central HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the central ACs and HPs installed in a given year will no longer be in service, as described by the survival function Figure 2 and Figure 3~~Figure 3~~.

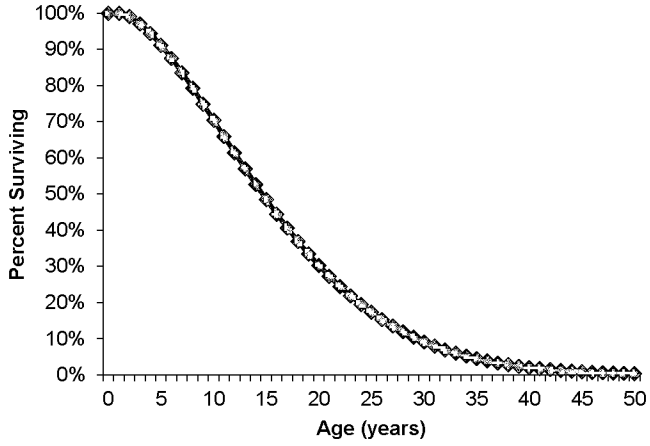
[108] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[109] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 3~~Figure 3~~). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[110] 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.

Figure 2. Central AC/HPs—AC Survival Function ~~for Central ACs~~[111]

Figure 3. Central AC/HPs—HP Survival Function ~~for Central HPs~~[112]



[111] 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.

[112] Ibid.

The method for estimating the remaining useful life (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 3~~Figure 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.

Deemed Energy Savings Tables[113]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[114] Both cooling and heating savings are specified according to AHRI rated cooling capacity.

Deemed Summer Demand Savings Tables[115]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[116] Summer demand savings are specified according to AHRI rated cooling capacity.

Deemed Winter Demand Savings Tables[117]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[118] Winter demand savings are specified according to AHRI rated cooling capacity.

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.

---

[113] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

[114] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

[115] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

[116] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

[117] Rated capacity ranges are specified with a 5 percent tolerance in accordance with AHRI Standard 210/240 to account for systems that are rated slightly below the applicable nominal capacity. AHRI Standard 210/240. Table J1. http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_210-240_2017.pdf.

[118] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a central AC and 15 years for a central HP unit based on the current DOE Final Rule standards for central ACs and HPs.[119]

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.[120]

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~~/heating~~ capacity of the newly installed unit (btuh)
- Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of the newly installed unit
- Heating Seasonal Performance Factor (HSPF) 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)

  ~~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~~
- Type of unit installed (central AC, central HP, dual-fuel HP)
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.

[119] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. ~~Accessed 10/21/2014.~~ 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.

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

- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program~~or rightsizing~~)
- Photograph of retired cooling unit nameplate (rightsizing or early retirement unless default EUL is applied consistently across the program~~, rightsizing), or electric resistance baseline)~~
    - 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)
- 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

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition) [121].

[121] Air Conditioning Contractors of America (ACCA) online store. https://www.acca.org/store#/productDetail/DB68FDFC-BB20-E511-80F5-C4346BAC9A78/.

Document Revision History

Table 70. Residential Central ~~Heat Pumps~~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. 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.
v3.1	11/05/2015	TRM v3.1 update. Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of early retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.
v4.0	10/10/2016	TRM v4.0 update. Added RUL value for units with an age of one year. 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. Updated savings for 15.0-15.9 SEER range.
v5.0	10/2017	TRM v5.0 update. Switched to air conditioner capacity and EIR curve coefficients for estimated heat pump cooling savings. Updated energy savings to use TMY3 temperature bin hours. Updated demand savings for compliance with current peak definition. Added 12.44 SEER and 6.8 HSPF baseline savings tables previously referencing earlier version of TRM. Updated baseline to include replacing air conditioners with gas heat.
v6.0	11/2018	TRM v6.0 update. Updated baseline and eligibility requirements. Added rightsizing savings for replace on burnout in winter demand tables. Added language clarifying use of rated capacity vs nominal and updated the deemed savings tables to show rated Btuh. Clarified required documentation for early retirement.
v7.0	10/2019	TRM v7.0 update. Consolidated central air conditioner and heat pump measures. Moved deemed savings tables to Appendix A. Updated eligibility for low-income and hard-to-reach.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Updated electric resistance baseline documentation.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for systems where EER does not meet CEE Tier 0 requirements.

2.2.5 Mini-Split Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: R-HV-MS

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, direct Install (early retirement)

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering spreadsheets and estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new mini-split air conditioner (AC) or heat pump (HP) in an existing building, or the installation of a new mini-split ~~air conditioner~~AC or HP in a new residential construction. Downsized systems that are right-sized per a heat load calculation are also eligible. This measure also applies to the installation of DC inverter systems that meet all existing measure eligibility criteria.

Additional savings may be available for duct removal in combination with the installation of a ductless mini-split. In these cases, refer to the Duct Sealing measure and follow the savings methodology (standard approach) using a value of 0 CFM as the post-improvement duct leakage. Leakage testing must be performed on the existing ductwork to claim savings for duct removal.

Eligibility Criteria

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings. Gas furnaces are not eligible to be awarded savings for replacement through this measure.

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[122,123]. Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination 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.

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

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 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 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.

The replacement of a room ~~air conditioner~~AC with a ~~central~~ mini-split ~~air conditioner~~AC or ~~heat pump~~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.

Replacement of an evaporative cooler with a mini-split 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.

New construction projects are not eligible to receive deemed savings for system rightsizing.[124] For system upsizing, savings should generally be claimed against the new construction baseline. However, when upsizing while going from a single larger capacity system to multiple smaller capacity systems, savings may be claimed against the applicable replace-on-burnout or early retirement baseline if the total pre and post tonnage are within ½ ton.[125] For this scenario, savings must be looked up using the lower pre-tonnage. If the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

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

[124] For projects using a custom baseline see TRM Volume 4.
[125] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

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 looked up using the total system pre and post capacities. 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 minimum standard,[126] effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to ~~central~~ mini-split 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 (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.[127]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER. Systems manufactured as of January 1, 2015 are not eligible for early retirement.

For ROB projects, heating baseline efficiency values for HPs are compliant with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems, or 8.0 for packaged systems. This baseline reflects updates to federal standards that took effect on January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[128] For ER projects where the existing system was installed on or after January 23, 2006, the heating baseline efficiency is assumed to be an HSPF of 7.7 based on the federal minimum standard in effect from January 23, 2006, through

---

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

[127] 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. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

[128] *10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule*. Online. Available: https://www.govinfo.gov/content/pkg/CFR-2016-title10-vol3/xml/CFR-2016-title10-vol3-part430.xml.

December 31, 2014.[129] For ER projects where the existing system was installed before January 23, 2006, the heating baseline efficiency is reduced to 6.8 HSPF based on the federal minimum standard in effect prior to January 23, 2006.

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.[130] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[131] 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 ~~heat pump~~HP baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.41.[132] 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.

For ROB projects, cooling savings are the same as for new construction and ROB of an air-source HP. For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER.

Table 71. Mini-Split AC/HPs—Baseline Efficiencies

Project type	Cooling mode	Heating mode
New construction	14 SEER	8.2 HSPF
Replace-on-burnout, heat pump	13.08 SEER	8.2 HSPF
Replace-on-burnout, electric resistance furnace		3.41 HSPF
Early retirement, heat pump (as of 1/23/2006)	12.44 SEER	7.7 HSPF
Early retirement, electric resistance furnace (as of 1/23/2006)		3.41 HSPF
Early retirement, heat pump (before 1/23/2006)	10 SEER	6.8 HSPF
Early retirement, electric resistance furnace (before 1/23/2006)		3.41 HSPF

High-Efficiency Condition

Table 65~~Table 65~~ displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier ~~1~~ 0 systems as of January 1, ~~2009~~2015. Energy efficiency service providers are expected to at least comply with the latest CEE Tier ~~1~~ 0 requirements.

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER and HSPF requirements but do not comply with the EER requirements outlined in Table 65~~Table 65~~ may still be eligible to claim savings. Systems with

[129] Ibid.
[130] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[131] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[132] 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 = 3.41.

qualifying SEER and HSPF 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 EER does not comply with the below requirement.
~~No full-load efficiency requirement is specified in the current federal standard. Therefore, systems with qualifying SEER and HSPF energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems where the EER does not comply with the below requirement.~~

Table 72. Mini-Split AC/HPs— System CEE Tier 0 Requirements[133]

SEER	EER	HSPF
14.5	12.0	8.5

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~~t~~ condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. ~~-~~The DOE CCMS listing provides documentation of the 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Replace-on-Burnout or New Construction

Energy, summer demand, and winter demand savings were estimated using the AC and HP performance curves developed by the National Renewable Energy Laboratory[134] for typical units in each of the following SEER ranges:

- Baseline units
- 14.5–14.9
- 15.0–15.9
- 16.0–16.9
- 17.0–17.9
- 18.0–20.9
- 21.0 and above

14.5–16.9 SEER units were assumed to be single stage. 17.0 and above SEER units were assumed to be multi-stage cooling units.

[133] CEE Residential High Efficiency Central Air Conditioners and Air Source Heat Pumps Specification, January 1, 2015. https://library.cee1.org/content/cee-residential-high-efficiency-central-air-conditioners-and-air-source-heat-pumps-specifica.

[134] D. Cutler et al. Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations. National Renewable Energy Laboratory. NREL/TP-5500-56354. January 2013. Tables 12 and 13. http://www.nrel.gov/docs/fy13osti/56354.pdf.

These performance curves provide the capacity and efficiency of the ACs and HPs operating in cooling mode across a wide range of outside air temperatures. Unit loading was estimated as a function of outside air temperature, and hours of cooling mode operation under different loadings were estimated using bin weather data for each weather zone. In heating mode, predicted HVAC operation was limited to meeting 77 percent of load, using a factor applied in Manual J to correlate design load hours to equivalent full load hours under actual operating conditions. This approach accounts for the observation that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings were estimated according to the expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Heating mode capacity was related to rated cooling capacity using the rated capacity in the cooling and heating mode of the residential market HP products of four major manufacturers according to data exported from AHRI. Data was exported from the AHRI directory, and the average ratio for each equipment size of heating capacity to cooling capacity was multiplied by the rated (cooling side) capacity to estimate the HP capacity. HP system output was then compared to its loading under design conditions.

The model uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

$$y = a + b \times T_{EWB} + c \times T_{EWB}^2 + d \times T_{ODB} + e \times T_{ODB}^2 + f \times T_{EWB} \times T_{ODB}$$

Equation 31

Table 73. Mini-Split AC/HPs—Capacity Curve Coefficients[135]

	Cooling			Heating		
		Multi-stage/speed			Multi-stage/speed	
Coeff.	Single stage	Low	High	Single stage	Low	High
a	3.670270705	3.940185508	3.109456535	0.566333415	0.335690634	0.306358843
b	-0.098652414	-0.104723455	-0.085520461	-0.000744164	0.002405123	0.005376987
c	0.000955906	0.001019298	0.000863238	-0.0000103	-0.0000464	-0.0000579
d	0.006552414	0.006471171	0.00863049	0.009414634	0.013498735	0.011645092
e	-0.0000156	-0.00000953	-0.000021	0.0000506	0.0000499	0.0000591
f	-0.000131877	-0.000161658	-0.000140186	-0.00000675	-0.00000725	-0.0000203

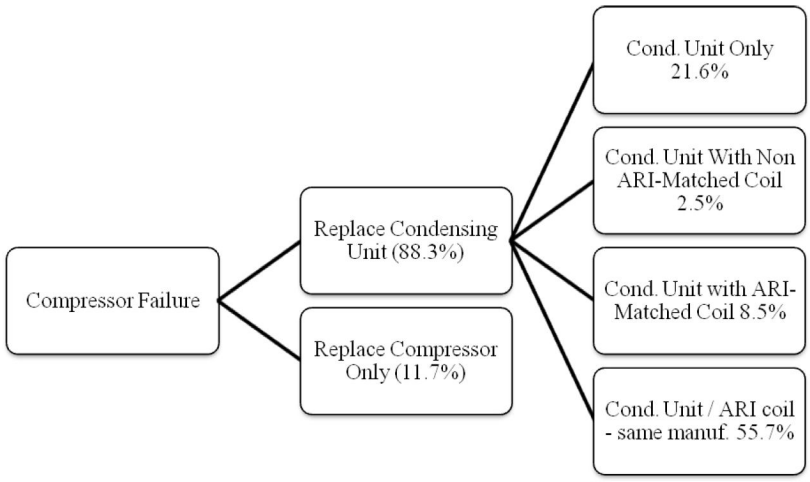
[135] Using air conditioner capacity curve coefficients for heat pump cooling savings.

Table 74. Mini-Split AC/HPs—EIR Curve Coefficients[136]

	Cooling			Heating		
		Multi-stage/speed			Multi-stage/speed	
Coeff.	Single stage	Low	High	Single stage	Low	High
a	-3.302695861	-3.87752688	-1.990708931	0.718398423	0.36338171	0.981100941
b	0.137871531	0.164566276	0.093969249	0.003498178	0.013523725	-0.005158493
c	-0.001056996	-0.001272755	-0.00073335	0.000142202	0.000258872	0.000243416
d	-0.012573945	-0.019956043	-0.009062553	-0.005724331	-0.009450269	-0.005274352
e	0.000214638	0.000256512	0.000165099	0.00014085	0.000439519	0.000230742
f	-0.000145054	-0.000133539	-0.0000997	-0.000215321	-0.000653723	-0.000336954

To estimate the baseline SEER value for retrofit installations, Texas A&M's Energy Systems Laboratory (ESL) surveyed dealers across the State to determine installation practices. The research found that in the event of a compressor failure out of warranty, dealers replaced the compressor 11.7 percent of the time, and replaced the condensing unit 88.3 percent of the time. Further, the condensing unit replacements consist of condensing unit-only replacements, replacements with mismatched evaporator coils, and replacements with matching evaporator coils. The percentages for these installations are as follows:

Figure 4. Mini-Split AC/HPs—Unit Replacement Percentages upon Compressor Failure



Source: Docket No. 36780

[136] Using air conditioner capacity EIR coefficients for heat pump cooling savings.

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER and that the SEER of a condensing unit installed without a matching coil would be 85 percent of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given by the following equation:

$$SEER_{Base} = \left(SEER_{Compressor\ Replacement}\right) \times (Actual\ \%\ Compressor\ Replacement) + \left(SEER_{Condenser\ Replacement}\right) \times (Actual\ \%\ Condenser\ Replacement) + \left(SEER_{System\ Replacement}\right) \times (Actual\ \%\ System\ Replacement)$$

Equation 32

Substituting ESL SEER estimates and survey data provides the following baseline SEER estimate:

$$SEER_{Base} = (9.5) \times (11.7\%) + (11.05) \times (24.1\%) + (13.5) \times (64.2\%) = 12.44$$

Adjusting for the increased 14 SEER baseline:

$$SEER_{Base} = (10.5) \times (11.7\%) + (11.9) \times (24.1\%) + (14) \times (64.2\%) = 13.08$$

In new construction, there is no possibility of a partial system (e.g., condensing unit-only) change out, so the 13.08 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government's minimum efficiency standard of 14 SEER.

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 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.

Where:

RUL = *Remaining Useful Life (see Table 75 or Table 76); if unknown, assume the age of the replaced unit is equal to the EUL, resulting in a default RUL of 7.0 (ACs) or 6.0 years (HPs). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. 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. 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 75. Mini-Split AC/HPs—Remaining Useful Life of Replaced ACs[137]

Age of replaced unit (years)	Remaining useful life (years)
1	16.8
2	15.8
3	14.9
4	14.1
5	13.3
6	12.6
7	11.9
8	11.3
9	10.8
10	10.3
11	9.8
12	9.4
13	9.0
14	8.6
15	8.2
16	7.9
17	7.6
18	7.0
19	6.0
20	5.0
21	4.0
22	3.0
23	2.0
24	1.0
25[138,139]	0.0

[137] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline and instead should use ROB baseline.

[138] RULs are capped at the 75th percentile of equipment age, 25 years, as determined based on DOE survival curves (see Figure 5~~Figure 5~~). Systems older than 25 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[139] 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.

Table 76. Mini-Split AC/HPs—Remaining Useful Life of Replaced HPs[140]

Age of replaced unit (years)	Remaining useful life (years)
1	13.7
2	12.7
3	12.0
4	11.3
5	10.7
6	10.2
7	9.7
8	9.3
9	8.9
10	8.5
11	8.2
12	7.9
13	7.6
14	7.0
15	6.0
16	5.0
17	4.0
18	3.0
19	2.0
20	1.0
21[141,142]	0.0

Derivation of RULs

~~Central~~ Mini-split ACs have an estimated useful life of 18 years, and ~~central~~ mini-split HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the ~~central~~ ACs and HPs installed in a given year will no longer be in service, as described by the survival function in Figure 5~~Figure 5~~ and Figure 6~~Figure 6~~.

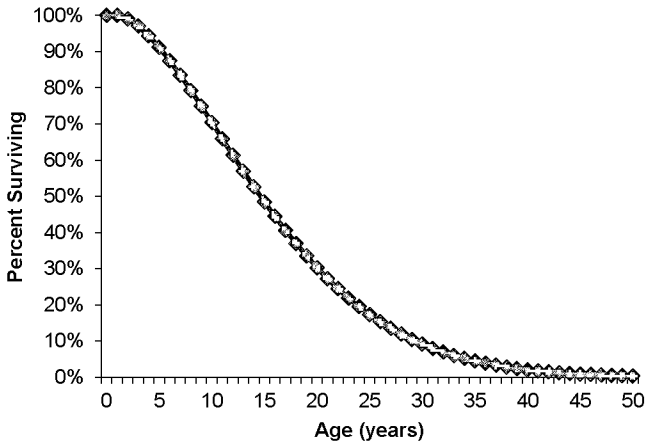
[140] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use ROB baseline instead.

[141] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 6~~Figure 6~~). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[142] 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.

Figure 5. Mini-Split AC/HPs—AC Survival Function[143]

Figure 6. Mini-Split AC/HPs—HP Survival Function [144]



[143] 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.

[144] 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.

The method for estimating the remaining useful life (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 5~~Figure 5~~ and Figure 6~~Figure 6~~. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving systems 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[145]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[146] Both cooling and heating savings are specified for AHRI rated cooling capacity.

Deemed Summer Demand Savings Tables[147]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[148] Summer demand savings are specified according to AHRI rated cooling capacity.

Deemed Winter Demand Savings Tables[149]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[150] Winter demand savings are specified according to AHRI rated cooling capacity.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

---

[145] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).
[146] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.
[147] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).
[148] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.
[149] Rated capacity ranges are specified with a 5 percent tolerance in accordance with AHRI Standard 210/240 to account for systems that are rated slightly below the applicable nominal capacity. AHRI Standard 210/240. Table J1. http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_210-240_2017.pdf.
[150] Savings tables are also provided in Excel format at the Texas Efficiency website. http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a mini-split~~central~~ AC and 15 years for a mini-split~~central~~ HP unit based on the current DOE Final Rule standards for central ACs and HPs.[151]

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.[152]

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~~/heating~~ capacity of the installed unit (btuh)
- Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of the installed unit
- Heating Seasonal Performance Factor (HSPF) of the 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)
    - ~~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~~
- Type of unit installed (mini-split AC, mini-split HP, DC inverter AC, DC inverter HP)
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.
- Retired unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early ~~retirement~~ retirement unless default EUL is applied

[151] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. ~~Accessed 10/21/2014.~~ 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.

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

consistently across the program~~or rightsizing~~)

- Photograph of retired cooling unit nameplate (rightsizing or early retirement unless default EUL is applied consistently across the program~~or rightsizing~~)
    - 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)
- 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
- When claiming savings for duct removal in combination with the installation of a ductless mini-split:
    - Pre-improvement duct leakage at 25 Pa (cu. ft./min)
    - Pre and post photos demonstrating removal of existing ductwork

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition).[153]

[153] Air Conditioning Contractors of America (ACCA) online store. https://www.acca.org/store#/productDetail/DB68FDFC-BB20-E511-80F5-C4346BAC9A78/.

Document Revision History

Table 77. Residential ~~Large Capacity~~Mini-Split AC/HPs 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. Updated electric resistance baseline documentation.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for systems where EER does not meet CEE Tier 0 requirements.

2.2.6 Large Capacity Split and Packaged Air Conditioners and Heat Pumps ~~Large Capacity Split System and Single-Package 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.[154,155]

Baseline Condition

New construction and replace-on-burnout baseline efficiency levels are provided in Table 78~~Table 78~~ and Table 79~~Table 79~~. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard, IECC 2015, and ASHRAE 90.1-2013.

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

Table 78. Large Capacity AC/HPs—Baseline Efficiency Levels for NC and ROB for AC/HP[156]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[157]
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)[158]	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)[159]	5.4 to < 11.3	Heat Pump	3.3 COP	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20		3.2 COP	

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

[157] 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.

[158] 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".

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

Table 79. Large Capacity AC/HPs—Baseline Efficiency Levels for NC and ROB for GSHPs[160]

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

Packaged and split-systems must exceed the minimum efficiencies specified in Table 78~~Table 78~~ and Table 79~~Table 79~~.

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 33

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

Equation 34

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

Equation 35

[160] Values from ASHRAE 90.1-2013.

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

Equation 36

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

Equation 37

Where:

$Cap_{C/H}$ = *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 38

$CF_{C/H}$ = *Seasonal peak coincidence factor (Table 80)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours (*Table 82~~Table 82~~*)*

Table 80. Large Capacity AC/HPs—AC/HP Coincidence Factors ~~by Climate Zone~~[161]

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

[161] See Volume 1, Section 4.

Table 81. Large Capacity AC/HPs—GSHP Coincidence Factors[162]

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 82. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours[163]

Climate zone	$EFLH_C$	$EFLH_H$
Climate zone 1: Panhandle	1,142	1,880
Climate zone 2: North	1,926	1,343
Climate zone 3: South	2,209	1,127
Climate zone 4: Valley	2,958	776
Climate zone 5: West	1,524	1,559

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.

[162] See Volume 1

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

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.[164] The EUL of a high-efficiency ground source heat pump unit is 20 years, consistent with the EUL reported in the DOE GSHP guide.[165]

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.[166]

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)
- 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.

---

[164] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. ~~Accessed 10/21/2014.~~ https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.

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

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

Relevant Standards and Reference Sources

- ACCA Manual J Residential Load Calculation (8th Edition)[167]
- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.

Document Revision History

Table 83. ~~Residential~~ 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.

[167] https://www.acca.org/store#/storefront.

2.2.7 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.[168,169]

[168] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[169] 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.[170] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 84, 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.[171] 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 84. ER Baseline Efficiency Levels for Standard Size PTACs[172]

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (no built-in resistance heat)	Baseline heating efficiency (COP) (with built-in resistance heat)
PTAC	< 7,000	11.0	--	1.0
	7,000-15,000	$12.5 - (0.213 \times \text{Cap}/1000)$		
	> 15,000	9.3		

Replace-on-Burnout

Table 85

[170] 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.

[171] 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.

[172] 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.

~~Table 85~~ 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 85. ROB Minimum Efficiency Levels for PTHPs[173,174]

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTHP	Standard Size	< 7,000	11.9	3.3
		7,000-15,000	$14.0 - (0.300 \times \text{Cap}/1000)$	$3.7 - (0.052 \times \text{Cap}/1000)$
		>15,000	*9.5*	*2.9*
	Non-Standard Size	<7,000	*9.3*	*2.7*
		7,000-15,000	$10.8 - (0.213 \times \text{Cap}/1000)$	$2.9 - (0.026 \times \text{Cap}/1000)$
		>15,000	*7.6*	*2.5*

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 85.

The high-efficiency retrofits must also meet the following criteria:[175]

- 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

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

Equation 39

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

Equation 40

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

Equation 41

[173] IECC 2015 Table C403.2.3(3).
[174] 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.
[175] Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend early retirement to cover PTAC/PTHP.

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

Equation 42

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

Equation 43

Where:

$Cap_{C/H,pre}$	=	*For ER, rated equipment cooling/heating[176] 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*
$Cap_{C/H,post}$	=	*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 84 through Table 85)*
$\eta_{baseline,H}$	=	*Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 84 through Table 85)*
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] (Must exceed minimum requirements from Table 85)*[177]
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum requirements from Table 85)*[178]
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor for appropriate climate zone, building type, and equipment type (Table 86)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours] (Table 87)*

[176] 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.
[177] Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.
[178] Ibid.

Table 86. PTHP Coincidence Factors[179]

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 87. ~~-~~PTHP Cooling/Heating EFLHs[180]

Climate zone	$EFLH_C$	$EFLH_H$
Climate zone 1: Panhandle	1,142	1,880
Climate zone 2: North	1,926	1,343
Climate zone 3: South	2,209	1,127
Climate zone 4: Valley	2,958	776
Climate zone 5: West	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

~~*Effective*~~ *Estimated Useful Life (EUL)*

The EUL ~~of PTHP units~~ is 15 years, as specified in as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[181]~~DEER 2014.~~

[179] See Volume 1, Section 4.
[180] ENERGY STAR® Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.
[181] 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:

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 88); 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 88. Remaining Useful Life of ER PTAC Systems[182,183]

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[184]	0.0

[182] PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.
[183] 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.
[184] 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 and heating capacities (btuh)
- Baseline number of units
- Baseline cooling and heating efficiency rating
- 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

- ANSI/ASHRAE/IES Standard 90.1-2001 through ASHRAE 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=46.
- 2015 International Energy Conservation Code. Table C403.2.3(3).

Document Revision History

Table 89. Residential Packaged Terminal Heat Pumps 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.

2.2.8 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 ~~room air conditioners~~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,[185] 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.

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

Table 90. ~~Room Air Conditioner~~ RAC 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

ENERGY STAR® specifications effective October 26, 2015, are provided in Table 91~~Table 91~~ as the efficient condition.[186] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 91. ~~Room Air Conditioner~~ RAC Efficient Condition Specifications

Reverse cycle (Yes/No)	Louvered ~~Sides~~ sides (Yes/No)	Capacity (Btu/hr)	Units with connected functionality[187]	Units without connected ~~functionality~~ ~~Minimum CEER as of October 26, 2015~~
No	Yes	< 8,000	11.6	12.1
		≥ 8,000 and < 14,000	11.5	12.0

[186] ENERGY STAR® Product Specification for Room Air Conditioners: https://www.energystar.gov/products/heating_cooling/air_conditioning_room/key_product_criteria.~~,~~

[187] Connected functionality refers to units that have been tested for demand response capabilities. These units receive a 5% credit toward ENERGY STAR® certification. This means they must only achieve a 5% improvement over the federal standard compared to 10% for standard units.

Reverse cycle (Yes/No)	Louvered ~~Sides sides~~ (Yes/No)	Capacity (Btu/hr)	Units with connected functionality[150]	Units without connected functionality~~Minimum CEER as of October 30, 2015~~
		≥ 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

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 44

Where:

CAP	=	*Rated equipment cooling capacity of the installed (Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 92)*
$CEER_{Base}$	=	*Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 90)*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed ~~room air conditioner~~RAC*

Table 92. ~~Room Air Conditioner~~RAC Annual Operating Hours for Cooling[188]

Climate zone	AOH_C
Climate zone 1: Panhandle	820
Climate zone 2: North	1,374
Climate zone 3: South	1,308
Climate zone 4: Valley	2,150
Climate zone 5: West	1,204

Demand Savings Algorithms

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

Equation 45

Where:

CAP = *Rated equipment cooling capacity of the installed ~~room air conditioner~~ RAC (Btu/hr)*

$CEER_{Base}$ = *Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 90)*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed ~~room air conditioner~~RAC*

CF = *Coincidence Factor = (Table 93~~Table 93~~)*

Table 93. ~~Room Air Conditioners~~RACs—Coincidence Factors[189]

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:

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)

[188] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator.~~.~~
[189] See Volume 1, Appendix B.

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 94); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years*

EUL = *Estimated Useful Life = 10 years*

Table 94. Remaining Useful Life (RUL) of Replaced ~~Room Air Conditioner~~RAC[190]

Age of replaced unit (years)	RUL (years)	Age of replaced unit (years)	RUL (years)
1	8.0	8	5.0
2	7.2	9	4.0
3	6.2	10	3.0
4	5.2	11	2.0
5	5.2	12	1.0
6	5.2	13[191,192]	0.0
7	5.2		

Derivation of RULs

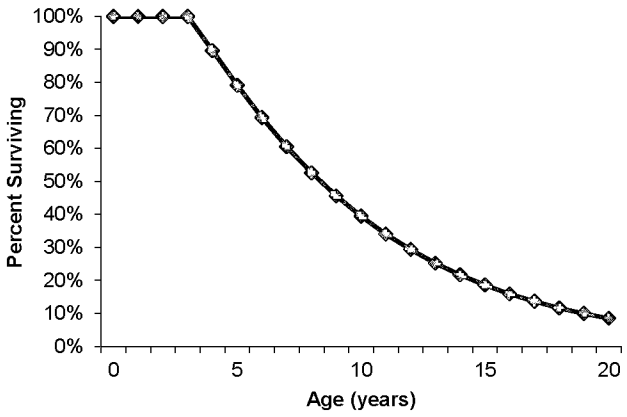
~~Room air conditioner~~RACs have an estimated useful life of 10 years. This estimate is consistent with the age at which approximately 50 percent of the ~~room air conditioner~~RACs installed in a given year will no longer be in service, as described by the survival function in Figure 7~~Figure 7~~.

[190] 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.

[191] RULs are capped at the 75th 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.

[192] 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 7. Survival Function for ~~Room Air Conditioner~~RACs[193]



The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function.

Figure 7

~~Figure 7~~. The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving ~~room air conditioner~~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 46

[193] 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: http://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 47

Where:

CAP	=	*Rated equipment cooling capacity of the installed ~~room air conditioner~~ RAC(Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 92)*
$CEER_{ROB}$	=	*Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 90)*
EER_{ER}	=	*Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 90)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed ~~room air conditioner~~RAC*

Summer Demand Savings Algorithms

To calculate demand savings for the early retirement of a ~~room air conditioner~~ 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:

$$kW_{Savings,ER} = CAP \times \frac{1\,kW}{1{,}000\,W} \times \left(\frac{1}{EER_{ER}} - \frac{1}{EER_{RAC}}\right) \times CF$$

Equation 48

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

$$kW_{Savings,ROB} = CAP \times \frac{1\,kW}{1{,}000\,W} \times \left(\frac{1}{EER_{ROB}} - \frac{1}{EER_{RAC}}\right) \times CF$$

Equation 49

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 ~~room air conditioner~~RACs.

This value is consistent with the EUL reported in the Department of Energy Technical Support Document for ~~Room Air conditioner~~RACs.[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 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)

[194] Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. https://beta.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

- The applicable version of the ENERGY STAR® specifications and requirements for ~~room air conditioner~~RACs
- Code of Federal Regulations, 10 CFR 430.32(b)

Document Revision History

Table 95. ~~Residential Room Air Conditione~~RACrs 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.

TRM version	Date	Description of change
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. 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.

2.2.9 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 96~~Table 96~~.

Table 96. Baseline Efficiency of Existing HVAC Systems

Application	Efficiency Rating	Efficiency
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 an ENERGY STAR® connected thermostat. Details about the ENERGY STAR® connected thermostats specification are available on the program website[195], as is a list of program-certified thermostats.[196]

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 97~~Table 97~~.

- 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

[195] ENERGY STAR Certified Products: Connected Thermostats Specification V1.0. Online. Available: https://www.energystar.gov/products/spec/connected_thermostats_specification_v1_0_pd. ~~Accessed: January 26, 2018.~~

[196] ENERGY STAR Certified Products: ENERGY STAR Certified Smart Thermostats. Online. Available: https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results. ~~Accessed: January 26, 2018~~.

- 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 97~~Table 97~~ uniformly to each bin's energy use.

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

Table 97. Connected Thermostats—Runtime Reduction Criteria for ENERGY STAR® Certification

Metric	Statistical measure	Performance requirement
Annual Percent Run Time Reduction, Heating (HS)	Lower 95% Confidence Limit of Weighted National Average	≥ 8%
	Weighted National Average of 20th Percentiles	≥ 4%
Annual Percent Run Time Reduction, Cooling (CS)	Lower 95% Confidence Limit of Weighted National Average	≥ 10%
	Weighted National Average of 20th Percentiles	≥ 5%
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.[197]

Table 98~~Table 98~~ 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.

[197] 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 98. Connected Thermostats—Energy Savings for Thermostats Installed with Existing HVAC Unit (kWh/ton)

Region	Cooling savings	Heating savings	
		Electric resistance heat	Heat pump
Climate zone 1: Panhandle	121	485	199
Climate zone 2: North	196	273	99
Climate zone 3: South	229	178	62
Climate zone 4: Valley	254	120	41
Climate zone 5: West	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 99 and Table 100. The following savings are eligible to be claimed in both new construction programs and retrofit programs where a new HVAC system is installed.

Table 99. Connected Thermostats—Cooling Energy Savings for Thermostats Installed with New HVAC Unit (kWh/ton)

Region	SEER						
	14	14.5	15	16	17	18	21
Zone 1: Panhandle	108	103	99	92	81	77	66
Zone 2: North	174	167	161	150	131	124	107
Zone 3: South	204	196	189	175	154	146	126
Zone 4: Valley	226	217	209	194	169	160	138
Zone 5: West	149	143	138	128	112	106	91

Table 100. Connected Thermostats—Heating Energy Savings (HP ONLY) for Thermostats Installed with New HVAC Unit (kWh/ton)

Region	Heat pump HSPF							
	8.2	8.5	8.6	8.7	9.0	9.3	9.5	9.7
Zone 1: Panhandle	188	181	177	177	170	163	159	156
Zone 2: North	93	89	87	87	82	78	77	75
Zone 3: South	57	55	53	53	51	48	47	46
Zone 4: Valley	38	37	36	36	34	32	31	31
Zone 5: West	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 98. “New” corresponds to the savings from Table 99 for cooling equipment and Table 100 for heating equipment.

Table 101. 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 ~~wtih~~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% gas, 49.3% electric resistance, and 9.0 percent heat pump heat.[198]

Table 102. Connected Thermostats—Upstream and Midstream Program Energy Savings[199] (kWh/thermostat)

Region	Total energy savings
Climate zone 1: Panhandle	1,397
Climate zone 2: North	1,256
Climate zone 3: South	1,192
Climate zone 4: Valley	1,172
Climate zone 5: West	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.

[198] 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/.
[199] 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.[200] ~~for a connected thermostat is 11 years.~~

~~This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).~~[201]

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)

[200] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[201] ~~Database for Energy Efficiency Resources (DEER). http://www.deeresources.com/~

- 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
- 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

Not applicable.

Document Revision History

Table 103. Residential ENERGY STAR® 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.

2.2.10 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[202] 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.

[202] 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% 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 50

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 104. Smart Thermostat Load Mgmt—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:

$$Summer\ kW savings = 1.45\ kW$$

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

$$kWh\ savings = 0\ kWh$$

Example 2. Suppose 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 105. Smart Thermostat Load Mgmt—Example Total Program Year Demand Savings Calculation

	Texas		
Event number	Deemed savings per device (kW)	Participating device number	Event-level demand savings (kW)
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. ~~The EUL for this measure is 1 year.~~

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% of the total event duration.
    - Devices that opted out after participating for no less than 50% 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% 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

Not applicable.

Document Revision History

Table 106. Residential 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.

2.2.11 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 newly- constructioned 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[203], the federal minimum standard.[204] 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.

---

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

[204] 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.[205] The energy savings from the Xcel study are adjusted for climate using a cooling degree day (CDD) ratio derived from TMY3 weather data. 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 51

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 52

Where:

$EFLH_{Site}$ = *Equivalent full-load hours of an evaporative cooling system for the project site location, El Paso, TX: 1,288.*[206]

CF = *Summer Coincidence Factor: 0.920*[207]

---

[205] 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. ~~Accessed November 2018.~~

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

[207] 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 107. 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.[208] ~~for an evaporative cooling unit is 15 years.~~

~~This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).~~[209]

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.

[208] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[209] ~~Database for Energy Efficient Resources (DEER). http://www.deeresources.com/.~~

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 108. Residential 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.

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.[210] 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% of sampled low-income housing had a pre-leakage rate at or below 1.75 $ACH_{Natural}$.[211] $ACH_{Natural}$ was converted to CFM_{50}/sq. ft. using Equation 53.

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

Equation 53

Where:

$ACH_{Natural,pre}$	=	*1.75 representing greater than 80% of sampled homes*
h	=	*Ceiling height (ft.) = 8.5 (default)*[212]
N	=	*N factor for single story normal shielding (Table 109) = 18.5*

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 4.6 CFM_{50}/ft^2. 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}/ft^2 of 4.6 or lower.

---

[210] 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.*"

[211] 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12.

[212] 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.[213] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[214] 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 54~~Equation 54~~, based on floor area and the number of bedrooms.[215] 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 109).

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

Equation 54

Where:

Min CFM_{50}	=	*Minimum final ventilation rate (CFM_{50})*
A_{Floor}	=	*Floor area (ft^2)*
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 109*)*

[213] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[214] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[215] ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

Table 109. Air Infiltration – N Factors[216]

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[217] 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}).[218] 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}.

[216] 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. http://www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf.

[217] CFM reduction percentage is calculated as: (pre CFM value – post CFM value) / pre-CFM value

[218] Model testing indicates a ~~straight line~~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 110~~Table 110~~ 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 55

Where:

ΔCFM_{50}	=	*Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*
$V_{E,C}$	=	*Corresponding cooling savings value in Table 110*
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 110*

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 110~~Table 110~~ by a factor of 0.6. ~~Similarly~~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 110~~Table 110~~ by a factor of 0.24.[219]

Table 110. Air Infiltration—Energy Savings V_E per CFM_{50} Reduction

	$V_{E,C}$: Cooling savings	$V_{E,H}$: Heating savings		
Climate zone	Refrigerated air	Gas	Electric resistance	Heat pump
Zone 1: Panhandle	0.12	0.09	1.92	0.78
Zone 2: North	0.27	0.04	1.10	0.45
Zone 3: South	0.22	0.02	0.63	0.25
Zone 4: Valley	0.39	0.02	0.55	0.21
Zone 5: West*	0.07	0.03	0.88	0.34

[219] 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 111~~Table 111~~ 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 56

Where:

ΔCFM_{50}	=	*Air infiltration reduction in cubic feet per minute at 50 Pascal*
V_S	=	*Corresponding value in Table 111*
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 111~~Table 111~~ by a factor of 0.6.

Table 111. Air Infiltration—Peak Summer Demand Savings V_S per CFM_{50} Reduction

Region	Summer kW impact per CFM_{50} reduction
Climate zone 1: Panhandle	1.64E-04
Climate zone 2: North	2.10E-04
Climate zone 3: South	1.90E-04
Climate zone 4: Valley	2.24E-04
Climate zone 5: West	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 112~~Table 112~~ 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 112~~Table 112~~ 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 112 by a factor of 0.24.

Table 112~~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 112 by a factor of 0.24.~~

~~Table 112~~ 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 57

Where:

ΔCFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_W = *Corresponding value in* Table 112~~Table 112~~

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 112~~Table 112~~ by a factor of 0.24.[220]

Table 112. Air Infiltration—Peak Winter Demand Savings V_W per CFM_{50} Reduction

Region	Winter kW impact per CFM_{50} reduction	
	Electric resistance	Heat pump
Climate zone 1: Panhandle	9.42E-04	5.48E-04
Climate zone 2: North	1.25E-03	6.93E-04
Climate zone 3: South	8.61E-04	4.41E-04
Climate zone 4: Valley	7.81E-04	3.60E-04
Climate zone 5: West	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 ~~well-~~normally shielded area. After identifying and sealing leaks, she performs another blower door test and measures 8,000 CFM_{50} of air leakage.

$$Max\ Initial\ Leakage\ Rate\ = 5.24.6 \times 2{,}200 = 11{,}44010{,}120\ CFM_{50}$$

$$Reported\ Initial\ Leakage\ = Min\ (12{,}000, 11{,}40010{,}120) = 10{,}12011{,}440\ CFM_{50}$$

[220] 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.

$$Capped\ Post\ Retrofit\ Leakage\ = \sout{11,400}10{,}120 \times (1 - \sout{0.43}) = \sout{6,864}7{,}084\ CFM_{50}$$

$$Reported\ Post\ Retrofit\ Leakage\ = Max\ (8{,}000, \sout{6,864}7{,}084) = 8{,}000\ CFM_{50}$$

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

$$\Delta CFM_{50} = (\sout{11,440}10{,}120 - 8{,}000) = \sout{3,440}2{,}120$$

$$kWh\ savings = (0.39 + 0.21) \times \sout{3,440}2{,}120 = \sout{2,064}1{,}272\ kWh$$

$$Summer\ kW\ savings = 2.24 \times 10^{-4} \times \sout{3,440}2{,}120 = 0.\sout{77}47\ kW$$

$$Winter\ kW\ savings = 3.60 \times 10^{-4} \times \sout{3,440}2{,}120 = \sout{1.24}0.76\ kW$$

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.[221] ~~for air infiltration reduction.~~

~~This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources.[222]~~

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)

[221] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
~~[222] Database for Energy Efficiency Resources (DEER). http://www.deeresources.com/.~~

- Number of bedrooms
- Number of stories
- Number of occupants
- Pre- and post-photos of blower door test readings
- Representative photos of leak repairs

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

Not applicable.

Document Revision History

Table 113. Residential 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.

TRM version	Date	Description of change
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.
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, 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.

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

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

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

Equation 58

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[223] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[224] 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 114.

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.

[223] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[224] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

Table 114. 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 115 through Table 119, 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 115 through Table 121~~Table 121~~ ~~Table 121~~ by a factor of 0.6. ~~Similarly~~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 115 through Table 121~~Table 121~~ ~~Table 121~~ by a factor of 0.24.[225]

Climate Zone 1: Panhandle Region

Table 115. Ceiling Insulation—Climate Zone 1: Panhandle Region—Deemed Annual Energy Savings for (kWh/sq. ft.)

Ceiling insulation base R-value	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	0.41~~0.28~~	0.12~~0.08~~	0.12~~0.08~~	3.07~~2.16~~	1.31~~0.92~~
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

[225] 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.

Climate Zone 2: North Region

Table 116. Ceiling Insulation—Climate Zone 2: North Region—Deemed Annual Energy Savings(kWh/sq. ft.)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5≤ R-8	0.670.46	0.070.05	1.901.34	0.790.55
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

Climate Zone 3: South Region

Table 117. Ceiling Insulation—Climate Zone 3: South Region—Deemed Annual Energy Savings (kWh/sq. ft.)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5≤ R-8	0.680.46	0.050.03	1.300.92	0.530.37
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

Climate Zone 4: Valley Region

Table 118. Ceiling Insulation—Climate Zone 4: Valley Region—Deemed Annual Energy (kWh/sq. ft.)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
, R-5≤ R-8	0.520.35	0.030.02	0.890.62	0.340.24
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

Climate Zone 5: West Region

Table 119. Ceiling Insulation—Climate Zone 5: West Region—Deemed Annual 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~~≤ R-8~~	0.63~~0.43~~	0.21~~0.15~~	0.07~~0.05~~	1.96~~1.40~~	0.81~~0.57~~
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.

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

Equation 59

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 115 through Table 119*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 120 or Table 121*

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

A = *Treated area (ft²)*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 120. Ceiling Insulation—Energy Scale-down Factors: Ceiling Insulation to Less Than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
1	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
2	6.66E-03	N/A	7.11E-04	2.00E-02	8.20E-03
3	6.22E-03	N/A	4.67E-04	1.38E-02	5.47E-03
4	4.92E-03	N/A	2.44E-04	9.04E-03	3.47E-03
5	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 121. ~~-~~Ceiling Insulation—Energy Scale-up Factors: Insulating to Greater Than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
1	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
2	4.45E-03	N/A	4.82E-04	1.33E-02	5.47E-03
3	4.00E-03	N/A	2.97E-04	9.19E-03	3.66E-03
4	3.24E-03	N/A	1.62E-04	5.99E-03	2.30E-03
5	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 122~~Table 122~~ through Table 126~~Table 126~~ present the summer demand savings (kW/sq. ft.) associated with ceiling insulation for the five Texas climate zones.

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 the appropriate cooling value in the refrigerated air column in Table 122~~Table 122~~ through Table 128~~Table 128~~ ~~Table 128~~ by a factor of 0.6.

Climate Zone 1: Panhandle Region

Table 122. Ceiling Insulation – Climate Zone 1: Panhandle Region—Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Refrigerated air	Evaporative cooling
< R-5	8.00E-04	2.25E-04
R-5 to≤ R-8	4.50E-04	1.47E-04
R-9 to R-14	2.33E-04	7.16E-05
R-15 to R-22	1.02E-04	2.87E-05

Climate Zone 2: North Region

Table 123. Ceiling Insulation—Climate Zone 2: North Region—Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings (kW/sq. ft.)
< R-5	9.00E-04
R-5 to≤ R-8	5.17E-04
R-9 to R-14	2.67E-04
R-15 to R-22	1.15E-04

Climate Zone 3: South Region

Table 124. Ceiling Insulation—Climate Zone 3: South Region—Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings (kW/sq. ft.)
< R-5	6.25E-04
R-5 to≤ R-8	5.51E-04
R-9 to R-14	2.87E-04
R-15 to R-22	1.22E-04

Climate Zone 4: Valley Region

Table 125. Ceiling Insulation—Climate Zone 4: Valley Region—Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings (kW/sq. ft.)
< R-5	4.75E-04
R-5 to≤ R-8	3.40E-04
R-9 to R-14	1.79E-04
R-15 to R-22	7.95E-05

Climate Zone 5: West Region

Table 126. Ceiling Insulation—Climate Zone 5: West Region—Deemed Summer Demand Savings (kW/sq. ft)

Ceiling insulation base R-value	Refrigerated air	Evaporative cooling
< R-5	8.00E-04	2.23E-04
R-5 to≤ R-8	4.72E-04	1.53E-04
R-9 to R-14	2.38E-04	6.25E-05
R-15 to R-22	1.03E-04	2.09E-05

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

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

Table 127. Ceiling Insulation—Summer Peak Demand Scale-Down Factors: Insulating to Less than R-30 (kW/sq. ft./ΔR)

Climate zone	Refrigerated air	Evaporative cooling
1	6.41E-06	1.97E-06
2	7.30E-06	N/A
3	7.91E-06	N/A
4	5.20E-06	N/A
5	6.41E-06	1.97E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

Table 128. Ceiling Insulation—Summer Peak Demand Scale-Up Factors: Insulating to Greater than R-30 (kW/sq. ft./ΔR)

Climate zone	Refrigerated air	Evaporative cooling
1	4.22E-06	1.89E-06
2	4.92E-06	N/A
3	5.92E-06	N/A
4	3.47E-06	N/A
5	4.22E-06	1.89E-06

Deemed Winter Demand Savings Tables

Table 129~~Table 129~~ through Table 133~~Table 133~~ present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

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 129~~Table 129~~ through Table 135~~Table 135~~ ~~Table 135~~ by a factor of 0.24.[226]

Climate Zone 1: Panhandle Region

Table 129. Ceiling Insulation—Climate Zone 1: Panhandle Region—Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5	4.25E-05	9.75E-04	8.00E-04
R-5 to≤ R-8	2.51E-05	8.74E-04	4.53E-04
R-9 to R-14	1.37E-05	4.56E-04	2.38E-04
R-15 to R-22	4.72E-06	1.95E-04	1.01E-04

Climate Zone 2: North Region

Table 130. Ceiling Insulation—Climate Zone 2: North Region—Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5	3.50E-05	1.30E-03	8.25E-04
R-5 to≤ R-8	2.79E-05	9.84E-04	6.60E-04
R-9 to R-14	1.45E-05	5.13E-04	3.51E-04
R-15 to R-22	6.42E-06	2.23E-04	1.52E-04

Climate Zone 3: South Region

Table 131. Ceiling Insulation—Climate Zone 3: South Region – Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5	4.25E-05	1.15E-03	6.75E-04
R-5 to ≤ R-8	2.91E-05	7.71E-04	4.49E-04
R-9 to R-14	1.39E-05	4.01E-04	2.35E-04
R-15 to R-22	5.36E-06	1.74E-04	1.03E-04

[226] 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.

Climate Zone 4: Valley Region

Table 132. Ceiling Insulation—Climate Zone 4: Valley Region—Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5	2.50E-05	8.25E-04	4.50E-04
R-5 to≤ R-8	2.18E-05	6.31E-04	3.03E-04
R-9 to R-14	1.13E-05	3.28E-04	1.57E-04
R-15 to R-22	5.71E-06	1.44E-04	6.95E-05

Climate Zone 5: West Region

Table 133. Ceiling Insulation—Climate Zone 5: West Region—Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5	2.25E-05	5.75E-04	2.25E-04
R-5 to ≤R-8	1.14E-05	3.72E-04	1.57E-04
R-9 to R-14	5.38E-06	1.79E-04	7.54E-05
R-15 to R-22	2.26E-06	7.41E-05	3.11E-05

Scale-Down/Up Factors for Demand Reduction: 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 summer peak demand savings.

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

Equation 60

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 122 through Table 126 or Table 129 through Table 133*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 127 and Table 128 (Summer) or Table 134 and Table 135 (Winter)*

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

A = *Treated area (ft^2)*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings per square foot of treated ceiling area.

Table 134. Ceiling Insulation—Winter Peak Demand Scale-Down Factors: Insulating to Less than R-30 (kW/sq. ft./ΔR)

Climate zone	Gas	Electric resistance	Heat pump
1	4.29E-07	1.21E-05	6.30E-06
2	3.97E-07	1.40E-05	9.55E-06
3	3.05E-07	1.10E-05	6.53E-06
4	3.19E-07	9.18E-06	4.32E-06
5	4.29E-07	1.21E-05	6.30E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

Table 135. Ceiling Insulation—Winter Peak Demand Scale-up Factors: Insulating to greater than R-30(kW/sq. ft./ ΔR)

Climate zone	Gas	Electric resistance	Heat pump
1	2.76E-07	7.85E-06	4.19E-06
2	2.57E-07	8.33E-06	4.80E-06
3	2.19E-07	7.33E-06	4.46E-06
4	1.72E-07	5.79E-06	2.72E-06
5	2.76E-07	7.85E-06	4.19E-06

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 (Scale-Up). A home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 400 square feet from a baseline of R-1 to an efficient condition of R-38.

$$Cooling\ kWh\ savings\ per\ sq.ft. = 0.21 + 7.63x10^{-4} \times (38 - 30)$$
$$= 0.22 \sout{0.32 + 7.63x10^{-4} \times (38 - 30) = 0.33}\ kWh/sq.\ ft.$$

$$Heating\ kWh\ savings\ per\ sq.ft. = 1.96 + 2.18x10^{-2} \times (38 - 30)$$
$$= 2.13 \sout{2.95 + 2.18x10^{-2} \times (38 - 30) = 3.12}\ kWh/sq.\ ft.$$

$$kWh\ savings = (0.22 + 2.13) \times 400 = 940 \sout{(0.33 + 3.12) \times 400 = 1{,}381}\ kWh$$

$$Summer\ kW\ savings\ per\ sq.ft. = 2.23 \times 10^{-4} + 1.89 \times 10^{-6} \times (38 - 30)$$
$$= 2.38 \sout{3.25 \times 10^{-4} + 1.89 \times 10^{-6} \times (38 - 30) = 3.41} \times 10^{-4}\ kW/sq.\ ft.$$

$$Summer\ kW\ savings = 2.38 \times 10^{-4} \times 400 = 0.10 \sout{3.41 \times 10^{-4} \times 400 = 0.14}\ kW$$

$$Winter\ kWsavings\ per\ sq.ft = 5.75 \times 10^{-4} + 7.85 \times 10^{-5} \times (38 - 30)$$
$$= 1.20 \times 10^{-3} \sout{8.13 \times 10^{-4} + 7.85 \times 10^{-5} \times (38 - 30)}$$
$$\sout{= 8.76 \times 10^{-4}}\ kW/sq.\ ft.$$

$$Winter\ kW\ savings = 1.20 \times 10^{-3} \times 400 = 0.48 \sout{8.76 \times 10^{-4} \times 400 = 0.35}\ kW$$

Example 2 (Scale-Down). A home in Climate Zone 3 with an air-source heat pump insulates 550 square feet from a baseline of R-5 to an efficient condition of R-28.

$$Cooling\ kWh\ savings\ per\ sq.ft. = 0.46 + 5.47 \times 10^{-3} \times (28 - 30) = 0.45\ kWh/sq.ft.$$

$$Heating\ kWh\ savings\ per\ sq.ft. = 0.37 + 3.66 \times 10^{-3} \times (28 - 30) = 0.36\ kWh/sq.ft.$$

$$kWh\ savings = (0.45 + 0.36) \times 550 = 446.4\ kWh$$

$$Summer\ kW\ savings\ per\ sq.ft. = 5.51 \times 10^{-4} + 7.91 \times 10^{-6} \times (28 - 30)$$
$$= 5.35 \times 10^{-4}\ kW/sq.ft.$$

$$Summer\ kW\ savings = 5.35 \times 10^{-4} \times 550 = 0.29\ kW$$

$$Winter\ kW\ savings\ per\ sq.ft. = 4.49 \times 10^{-4} + 6.53 \times 10^{-6} \times (28 - 30)$$
$$= 4.36 \times 10^{-4}\ kW/sq.ft.$$

$$Winter\ kW\ savings = 4.36 \times 10^{-4} \times 550 = 0.24\ kW$$

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[227] the estimated useful life is 25 years for ceiling insulation.

[227] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLife StudyLightsandHVACGDS_1Jun2007.pdf.

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
- Base R-value of original insulation
- R-value of installed insulation
- Cooling type (evaporative cooling, 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); sampling is allowed for multifamily complexes
- Square footage of ceiling insulation installed above a conditioned space
- Only for homes with a reported baseline R-value that is less than R-5:
    - Two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation.

      Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.

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. 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

Not applicable.

Document Revision History

Table 136. Residential Ceiling Insulation 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. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Provided savings tables for installation of insulation up to R-38. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air conditioning. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Clarified that no heating demand savings are to be claimed for homes with a gas furnace.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype simulation models and introduced new protocols for baseline and post-retrofit R-values, their associated savings estimations and documentation requirements.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Added clarifying language for U-factor methodology.
v8.0	10/2020	TRM v8.0 update. Updated savings tables. Added space heat adjustment factor and electric resistance documentation requirement.
v9.0	10/2021	TRM v9.0 update. Updated savings tables for < R-5 baseline category. ~~Clarified application of adjustment factors for space heating and cooling.~~

2.3.3 Attic Encapsulation Measure Overview

TRM Measure ID: R-BE-AE

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 bringing the attic into conditioned space by insulating and sealing the attic walls and roofs, eliminating leakage (to outside) and removing ceiling insulation, if present, to enhance airflow between the attic and the conditioned space directly below. Savings are presented according to Insulation Improvement and Infiltration Reduction components. Participants are expected to claim the sum of component savings.

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

The baseline condition is a vented, unfinished attic with some level of ceiling insulation. Ceiling insulation levels in existing construction can vary significantly, depending on the age of the home, type of insulation installed, and activity in the attic (such as using the attic for storage and HVAC equipment). 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 average ceiling insulation level prior to the retrofit for at participating homes is to be determined and documented by the contractor. Degradation due to age and density of the existing insulation should be taken into account.

Because existing ceiling insulation must be removed during measure implementation, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[228] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[229] 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[230]. 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-value according to the average insulation depth achieved across the area treated and the R per-inch of the insulation material installed.

Vents, obvious leaks, are to be sealed. Ceiling insulation between the attic and the conditioned space is removed.

Energy and Demand Savings Methodology

The energy and demand savings produced by the attic encapsulation measures have two components: 1) reduced heat transfer into the attic from the insulation improvement, and 2) reduced leakage of conditioned air to outside by closing off vents and sealing of leaks. Accordingly, deemed energy and demand savings are presented by their insulation and air infiltration components. Both insulation improvement component and infiltration reduction component savings should be claimed for all projects. Insulation improvement component savings shall be claimed using deemed savings derived for the ceiling insulation measure, as explained below. There are two paths for claiming infiltration reduction component savings depending on whether pre- and post-retrofit blower door testing is undertaken when implementing the attic encapsulation measure. If blower door testing is performed, savings for the infiltration reduction component can be estimated according to the Residential Air Infiltration measure (Measure 2.3.1). If blower door testing is not undertaken, savings for the Infiltration Reduction component shall be claimed as presented in the air infiltration reduction component savings presented in this measure (below).

In previous versions of the TRM, energy and demand savings for the attic encapsulation measure have been presented according to the results achieved by directly modeling the attic encapsulation measure according to the best interpretation of how the measure should be represented. The expectation is that this measure should, at a minimum, provide savings commensurate with those obtained from the installation of ceiling insulation. In general, the

[228] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[229] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[230] Department of Energy Insulation R-value recommendations for zone 2/3, https://www.energy.gov/energysaver/weatherize/insulation.

measure is expected to out-perform ceiling insulation. However, modeling results have not reflected this expectation due to complications accounting for reduced infiltration, resulting in lower deemed savings for the attic encapsulation measure than those estimated for ceiling insulation. To encourage implementation of the measure and begin to develop information about the outcomes, the savings presented in this measure for the insulation improvement component of the Attic Encapsulation Measure are equivalent to the ceiling insulation measure savings. After adding air infiltration reduction component savings to the insulation improvement component savings, attic encapsulation measure savings will exceed those of the ceiling insulation measure.

Insulation Component Savings

Savings Algorithms and Input Variables (Insulation Component)

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed by modeling the ceiling insulation measure using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. For details on the derivation of these savings, refer to the Residential Ceiling Insulation Measure (Measure 2.3.2).

Deemed Energy Savings Tables (Insulation Component)

Table 138 through Table 142 present the energy savings (kWh) associated with attic encapsulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are specified per square foot of conditioned space directly below the treated attic.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling energy savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling savings value from Table 138 through Table 144~~Table 144 Table 144~~ 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 138~~Table 138~~ through Table 144~~Table 144 Table 144~~ by a factor of 0.24.[231]

Table 137. Attic Encapsulation—Prototypical Home Characteristics

Shell characteristic	Value	Source
Base Attic Encapsulation	Vented Attic < R5 R5-< R8 R9-R14 R15-R22	Typical construction practice throughout the state
Change Attic Encapsulation with blower door test	Sealed attic with no ceiling insulation and R-30 roof deck insulation	R-30 retrofit insulation level consistent with DOE recommendations

[231] 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.

Shell characteristic	Value	Source
Change Attic Encapsulation without blower door test	Sealed attic with no ceiling insulation and R-30 roof deck insulation 18 percent leakage reduction	Insulation: R-30 retrofit insulation level consistent with DOE recommendations Leakage Reduction: mean reduction achieved via attic encapsulation according to ACCA Manual J, 8th Edition, Section 21-14[232]

Climate Zone 1: Panhandle Region

Table 138. Attic Encapsulation—Climate Zone 1: Panhandle Region—R-30 Deemed Annual Energy Savings for Insulation Component (kWh/sq. ft)

Ceiling insulation base R-value	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	0.41~~0.28~~	0.12~~0.08~~	0.12~~0.08~~	3.07~~2.16~~	1.31~~0.92~~
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

Climate Zone 2: North Region

Table 139. Attic Encapsulation—Climate Zone 2: North Region— R-30 Deemed Annual Energy Savings for Insulation Component (kWh/sq. ft)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	0.67~~0.46~~	0.07~~0.05~~	1.90~~1.34~~	0.79~~0.55~~
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

[232] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e. to a vented attic), which means that the reduction in infiltration Cfm may range from 3 to 30 percent, with an 18 percent mean, as noted above". See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

Climate Zone 3: South Region

Table 140. Attic Encapsulation—Climate Zone 3: South Region—R-30 Deemed Annual Energy Savings for Insulation Component (kWh/sq. ft)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5≤ R-8	0.680.46	0.050.03	1.300.92	0.530.37
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

Climate Zone 4: Valley Region

Table 141. Attic Encapsulation—Climate Zone 4: Valley Region—R-30 Deemed Annual Energy Savings for Insulation Component (kWh/sq. ft)

Ceiling insulation base R-value	Cooling savings	Heating savings		
		Gas	Electric resistance	Heat pump
< R-5≤ R-8	0.520.35	0.030.02	0.890.62	0.340.24
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

Climate Zone 5: West Region

Table 142. Attic Encapsulation—Climate Zone 5: West Region—R-30 Deemed Annual Energy Savings for Insulation Component (kWh/sq. ft)

Ceiling insulation base R-value	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
< R-5≤ R-8	0.630.43	0.210.15	0.070.05	1.961.40	0.810.57
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 either more than 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.

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

Equation 61

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 138 through Table 142*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 143~~Table 143~~ or Table 144*

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

A = *Treated area (ft²)*

If the roof deck and attic walls are insulated to a level less than R-30, the factors in Table 143~~Table 143~~ shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 143. Attic Encapsulation—Energy Scale-Down Factors: Insulating to Less Than R-30 (kWh/sq. ft./ΔR)

	Cooling savings		Heating savings		
Climate zone	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
1	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
2	6.66E-03	N/A	7.11E-04	2.00E-02	8.20E-03
3	6.22E-03	N/A	4.67E-04	1.38E-02	5.47E-03
4	4.92E-03	N/A	2.44E-04	9.04E-03	3.47E-03
5	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02

If the roof deck and attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 144. Attic Encapsulation—Energy Scale-up Factors: Insulating to greater than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
1	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
2	4.45E-03	N/A	4.82E-04	1.33E-02	5.47E-03
3	4.00E-03	N/A	2.97E-04	9.19E-03	3.66E-03
4	3.24E-03	N/A	1.62E-04	5.99E-03	2.30E-03
5	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 145 through Table 149 present the summer demand savings (kW/sq. ft.) associated with the Insulation Improvement component of the Attic Encapsulation Measure for the five Texas climate zones.

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 the appropriate cooling value in the refrigerated air column in Table 145 through Table 151 ~~Table 151~~ by a factor of 0.6.

Climate Zone 1: Panhandle Region

Table 145. Attic Encapsulation—Climate Zone 1: Panhandle Region—R-30 Deemed Summer Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Refrigerated air	Evaporative cooling
< R-5~~≤ R-8~~	8.00E-04~~4.50E-04~~	2.25E-04~~1.47E-04~~
R-5 to R-8	4.50E-04	1.47E-04
R-9 to R-14	2.33E-04	7.16E-05
R-15 to R-22	1.02E-04	2.87E-05

Climate Zone 2: North Region

Table 146. Attic Encapsulation—Climate Zone 2: North Region—R-30 Deemed Summer Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< R-5~~≤ R-8~~	9.00E-04~~5.17E-04~~
R-5 to R-8	5.17E-04
R-9 to R-14	2.67E-04
R-15 to R-22	1.15E-04

Climate Zone 3: South Region

Table 147. Attic Encapsulation—Climate Zone 3: South Region—R-30 Deemed Summer Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< R-5~~≤ R-8~~	6.25E-04~~5.51E-04~~
R-5 to R-8	5.51E-04
R-9 to R-14	2.87E-04
R-15 to R-22	1.22E-04

Climate Zone 4: Valley Region

Table 148. Attic Encapsulation—Climate Zone 4: Valley Region—R-30 Deemed Summer Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< R-5~~≤ R-8~~	4.75E-04~~3.40E-04~~
R-5 to R-8	3.40E-04
R-9 to R-14	1.79E-04
R-15 to R-22	7.95E-05

Climate Zone 5: West Region

Table 149. Attic Encapsulation—Climate Zone 5: West Region—R-30 Deemed Summer Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Refrigerated air	Evaporative cooling
< R-5~~≤ R-8~~	8.00E-04~~4.72E-04~~	2.23E-04~~1.53E-04~~
R-5 to R-8	4.72E-04	1.53E-04
R-9 to R-14	2.38E-04	6.25E-05
R-15 to R-22	1.03E-04	2.09E-05

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

If the roof deck and attic walls are insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

Table 150. Attic Encapsulation—Summer Peak Demand Scale-down Factors: Insulating to less than R-30 (kW/sq. ft./ΔR)

Climate zone	Refrigerated air	Evaporative cooling
1	6.41E-06	1.97E-06
2	7.30E-06	N/A
3	7.91E-06	N/A
4	5.20E-06	N/A
5	6.41E-06	1.97E-06

If the roof deck and attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

Table 151. Table. Attic Encapsulation—Summer Peak Demand Scale-up Factors:

Climate zone	Refrigerated air	Evaporative cooling
1	4.22E-06	1.89E-06
2	4.92E-06	N/A
3	5.92E-06	N/A
4	3.47E-06	N/A
5	4.22E-06	1.89E-06

Deemed Winter Demand Savings Tables

Table 152 through Table 156 present the winter demand savings associated with the Insulation Improvement component of the Attic Encapsulation Measure for the five Texas climate zones.

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 152~~Table 152~~ through Table 158~~Table 158~~ ~~Table 158~~ by a factor of 0.24.[233]

Climate Zone 1: Panhandle Region

Table 152. Attic Encapsulation—Climate Zone 1: Panhandle Region—R-30 Deemed Winter Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	4.25E-05~~2.51E-05~~	9.75E-04~~8.74E-04~~	8.00E-04~~4.53E-04~~
R-5 to R-8	2.51E-05	8.74E-04	4.53E-04
R-9 to R-14	1.37E-05	4.56E-04	2.38E-04
R-15 to R-22	4.72E-06	1.95E-04	1.01E-04

Climate Zone 2: North Region

Table 153. Attic Encapsulation—Climate Zone 2: North Region—R-30 Deemed Winter Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	3.50E-05~~2.79E-05~~	1.30E-03~~9.84E-04~~	8.25E-04~~6.60E-04~~
R-5 to R-8	2.79E-05	9.84E-04	6.60E-04
R-9 to R-14	1.45E-05	5.13E-04	3.51E-04
R-15 to R-22	6.42E-06	2.23E-04	1.52E-04

Climate Zone 3: South Region

Table 154. Attic Encapsulation—Climate Zone 3: South Region-R-30 Deemed Winter Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5~~≤ R-8~~	4.25E-05~~2.91E-05~~	1.15E-03~~7.71E-04~~	6.75E-04~~4.49E-04~~
R-5 to R-8	2.91E-05	7.71E-04	4.49E-04
R-9 to R-14	1.39E-05	4.01E-04	2.35E-04
R-15 to R-22	5.36E-06	1.74E-04	1.03E-04

[233] 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.

Climate Zone 4: Valley Region

Table 155. Attic Encapsulation—Climate Zone 4: Valley Region—R-30 Deemed Winter Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5≤ R-8	2.50E-052.18E-05	8.25E-046.31E-04	4.50E-043.03E-04
R-5 to R-8	2.18E-05	6.31E-04	3.03E-04
R-9 to R-14	1.13E-05	3.28E-04	1.57E-04
R-15 to R-22	5.71E-06	1.44E-04	6.95E-05

Climate Zone 5: West Region

Table 156. Attic Encapsulation—Climate Zone 5: West Region—R-30 Deemed Winter Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Gas	Electric resistance	Heat pump
< R-5≤ R-8	2.25E-051.14E-05	5.75E-043.72E-04	2.25E-041.57E-04
R-5 to R-8	1.14E-05	3.72E-04	1.57E-04
R-9 to R-14	5.38E-06	1.79E-04	7.54E-05
R-15 to R-22	2.26E-06	7.41E-05	3.11E-05

Scale-Down/Up Factors for Demand Reduction: 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 summer peak demand savings.

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

Equation 62

Where:

R30 Savings/ft^2	=	*Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from* Table 145 *through* Table 149 *or* Table 152 *through* Table 156.
$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either* Table 150 *and* Table 151 *(summer) or* Table 157 *and* Table 158 *(winter)*
$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)*
A	=	*Treated area (ft^2)*

If the roof deck and attic walls are insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings (per square foot of treated ceiling area).

Table 157. Attic Encapsulation—Winter Peak Demand Scale-down Factors: Insulating to less than R-30 (kW/sq. ft./ΔR)

Climate zone	Gas	Electric resistance	Heat pump
1	4.29E-07	1.21E-05	6.30E-06
2	3.97E-07	1.40E-05	9.55E-06
3	3.05E-07	1.10E-05	6.53E-06
4	3.19E-07	9.18E-06	4.32E-06
5	4.29E-07	1.21E-05	6.30E-06

If the roof deck/attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

Table 158. Attic Encapsulation—Winter Peak Demand Scale-up Factors: Insulating to greater than R-30 (kW/sq. ft./ ΔR)

Climate zone	Gas	Electric resistance	Heat pump
1	2.76E-07	7.85E-06	4.19E-06
2	2.57E-07	8.33E-06	4.80E-06
3	2.19E-07	7.33E-06	4.46E-06
4	1.72E-07	5.79E-06	2.72E-06
5	2.76E-07	7.85E-06	4.19E-06

Air Infiltration Reduction Component Savings

Energy and demand savings for the air infiltration reduction component of the attic encapsulation measure are calculated either using the results of pre- and post-retrofit blower door testing or an average percent infiltration reduction. Regardless of how air infiltration reduction component savings are calculated, they should be added to the insulation improvement component savings to arrive at the total energy and demand savings for implementing the Attic Encapsulation measure.

Homes without refrigerated cooling should not claim air infiltration reduction component savings for attic encapsulation.

With Blower Door Testing

Implementers choosing to perform pre- and post-measure blower door testing should claim the air infiltration reduction component deemed energy and demand savings for the Attic Encapsulation measure using the estimated CFM_{50} reduction from the blower door tests with the equations and coefficients in the Residential Infiltration measure (Measure 2.3.1).

Without Blower Door Testing

Implementers electing not to perform blower door testing when performing this measure shall claim air infiltration reduction component deemed energy and demand savings for the Attic Encapsulation measure using this section, which presents the annual energy (kWh) and summer and winter demand savings (kW) associated with attic encapsulation for the five Texas climate zones, taking into account a mean leakage reduction of 18 percent.[234] Savings are presented per home.

Savings Algorithms and Input Variables (Infiltration Reduction Component)

Calibrated simulation modeling was used to develop air infiltration reduction deemed savings, which are expressed in Measure 2.3.1 as linear functions of the leakage reduction achieved (in CFM_{50}).[235] For details on the derivation of the air infiltration measure savings, refer to the Residential Air Infiltration measure (Measure 2.3.1).

ACCA Manual J provides an average leakage reduction attributable to attic encapsulation projects of 18 percent.[236] Accordingly, deemed savings attributable to the air infiltration reduction component of an attic encapsulation project implemented without pre- and post-implementation blower door testing are estimated by applying an 18 percent leakage reduction to the infiltration rates embedded in the deemed savings prototype model homes used in the derivation of residential envelope measure deemed savings for the Texas TRM. This 18 percent

---

[234] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (~~i.e.~~ i.e., to a vented attic), which means that the reduction in infiltration CFM may range from 3 to 30 percent, with an 18 percent mean, as noted above". See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

[235] Model testing indicates a ~~straight line~~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.

[236] Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.