A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.[122]

Table 35. RACs—Baseline Efficiencies for ER, ROB, and NC

Reverse cycle (yes/no)	Louvered sides (yes/no)	Capacity (Btu/hr)	Federal standard prior to June 1, 2014 ER baseline EER	Federal standard as of June 1, 2014 ROB/NC baseline CEER
No	Yes	< 6,000	9.7	11.0
		6,000-7,999	9.7	11.0
		8,000-13,999	9.8	10.9
		14,000-19,999	9.7	10.7
		20,000-27,999	8.5	9.4
		≥ 28,000	8.5	9.0
No	No	< 6,000	9.0	10.0
		6,000-7,999	9.0	10.0
		8,000-10,999	8.5	9.6
		11,000-13,999	8.5	9.5
		14,000-19,999	8.5	9.3
		≥ 20,000	8.5	9.4
Yes	Yes	< 20,000	9.0	9.8
		≥ 20,000	8.5	9.3
Yes	No	< 14,000	8.5	9.3
		≥ 14,000	8.0	8.7
Casement-only		All capacities	8.7	9.5
Casement-slider		All capacities	9.5	10.4

High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 5.0 Requirements for eligible room air conditioners effective October 30, 2023.[123] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

[122] Current DOE minimum efficiency standard for residential room air conditioners. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057.

[123] ENERGY STAR Room Air Conditioners Final Version 5.0 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20Room%20Air%20Conditioners%20Specification%20and%20Partner%20Commitments.pdf.

Table 36. RACs—Efficient Condition Requirements

Reverse cycle (Yes/No)	Louvered sides (Yes/No)	Capacity (Btu/hr)	Minimum CEER[124]
No	Yes	< 6,000	13.1
		6,000-7,999	13.7
		8,000-13,999	14.7
		14,000-19,999	14.4
		20,000-27,999	12.7
		≥ 28,000	12.2
No	No	< 6,000	12.8
		6,000-7,999	12.8
		8,000-10,999	13.0
		11,000-13,999	12.8
		14,000-19,999	12.6
		≥ 20,000	12.7
Yes	Yes	< 20,000	13.2
		≥ 20,000	12.6
Yes	No	< 14,000	12.6
		≥ 14,000	11.7
Casement-only		All capacities	12.8
Casement-slider		All capacities	14.0

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$Energy\ Savings\ [\Delta kWh] = Cap \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 24

[124] The updated ENERGY STAR specification discontinues the five percent energy credit for "connected functionality".

Where:

Cap	=	*Rated equipment cooling capacity of the installed (Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 37)*
$CEER_{Base}$	=	*Combined energy efficiency ratio of the baseline cooling equipment (Table 35)*
$CEER_{RAC}$	=	*Combined energy efficiency ratio of the installed RAC*

Table 37. RACs—Annual Operating Hours for Cooling[125]

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

Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right) \times CF_S$$

Equation 25

Where:

CF_S	=	*Summer peak coincidence factor (Table 38)*

Table 38. RACs—Coincidence Factor[126]

Season	CF
Summer[127]	0.87

125 Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator.

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

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

Early Retirement

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

The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and

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 39); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 3 years*
EUL	=	*Estimated useful life = 10 years*

Table 39. RACs—RUL of Replaced Unit[128]

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[129,130]	0.0
7	5.2		

[128] 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.

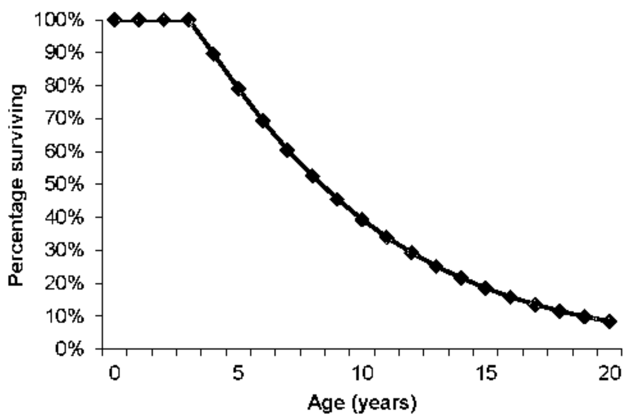
[129] RULs are capped at the seventy-fifth percentile of equipment age as determined based on DOE survival curves (see Figure 3). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

[130] 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.

Derivation of RULs

RACs have an estimated useful life of 10 years. This estimate is consistent with the age at which approximately 50 percent of the RACs installed in a given year will no longer be in service, as described by the survival function in Figure 3.

Figure 3. RACs—Survival Function[131]



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

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

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

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 26

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 27

Where:

EER_{ER}	=	*Energy efficiency ratio of the early retirement baseline cooling equipment (Table 35)*

Summer Demand Savings Algorithms

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

For the RUL time period:

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

Equation 28

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

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

Equation 29

Where:

CF_S	=	*Summer peak coincidence factor (Table 38)*

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

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

This value is consistent with the EUL reported in the DOE Technical Support Document for RACs.[132]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type (early retirement, replace-on-burnout, new construction)
- New unit manufacturer, model, and serial number
- ENERGY STAR certificate matching model
- Cooling capacity of the installed unit (Btu/hr)
- Combined energy efficiency ratio (CEER) of the new unit

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

- 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)
- 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.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 40. RACs—Revision History

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

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.
v10.0	10/2022	TRM v10.0 update. Update minimum CEER requirement for units with connected functionality. Updated coincidence factors, early retirement age eligibility, and documentation requirements.
v11.0	10/2023	TRM v11.0 update. Incorporated updated DOE final rule and ENERGY STAR specification v5.0. Updated early retirement age eligibility.
v12.0	10/2024	TRM v12.0 update. No revision.

2.2.4 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.[133,134]

[133] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[134] 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.[135] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 41, 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.[136] 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 41. PTHPs—ER Baseline Efficiency Levels for Standard Size PTACs[137]

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (no built-in resistance heat)	Baseline heating efficiency (COP) (replacing built-in resistance heat)
PTAC	< 7,000	11.0	–	1.0
	7,000-15,000	12.5 – (0.213 x Cap/1,000)		
	> 15,000	9.3		

135 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.

136 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.

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

Replace-on-Burnout

Table 42 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 42. PTHPs—ROB Minimum Efficiency Levels[138,139]

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)	Baseline heating efficiency (COP) (replacing built-in resistance heat)
PTHP	Standard size	< 7,000	11.9	3.3	1.0
		7,000-15,000	14.0 – (0.300 x Cap/1,000)	3.7 – (0.052 x Cap/1,000)	
		>15,000	9.5	2.9	
	Non-standard size	<7,000	9.3	2.7	
		7,000-15,000	10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)	
		>15,000	7.6	2.5	

138 IECC 2015 Table C403.2.3(3).
139 Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 42.

The high-efficiency retrofits must also meet the following criteria:[140]

- 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

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

Equation 30

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

Equation 31

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

Equation 32

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

Equation 33

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

Equation 34

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

Where:

$Cap_{C/H,pre}$	=	*For ER, rated equipment cooling/heating*[141] *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 41 through Table 42)*
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] (must exceed minimum requirements from Table 42)*[142]
$\eta_{baseline,H}$	=	*Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 41 through Table 42)*
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment [COP] (must exceed minimum requirements from Table 42)*[143]
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor (Table 43)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours] (Table 44)*

Table 43. PTHPs—Coincidence Factors[144]

Season	CF
Summer[145]	0.87
Winter[146]	0.83

[141] 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.

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

[143] Ibid.

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

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

[146] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and

Table 44. PTHPs—Cooling/Heating EFLHs[147]

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

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

Claimed Peak Demand Savings

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

Deemed Energy and Demand Savings Tables

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

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL is 15 years, as specified in as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[148]

Remaining Useful Life (RUL) for PTHP Systems

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

The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and

The remaining time in the EUL period (EUL – RUL).

adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

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

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

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 45); 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 45. PTHPs—RUL of Replaced PTAC[149,150]

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[151]	0.0

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 or county
- Equipment configuration category: standard/non-standard

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

[150] 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.

[151] RULs are capped at the seventy-fifth percentile of equipment age as determined based on DOE survival curves. Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 46. PTHPs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Added winter demand algorithm. Updated coincidence factors and documentation requirements
v9.0	10/2021	TRM v9.0 update. Clarified early retirement age eligibility. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Clarified electric resistance baseline. Updated coincidence factors and early retirement age eligibility.
v11.0	10/2023	TRM v11.0 update. Updated early retirement age eligibility.
v12.0	10/2024	TRM v12.0 update. No revision.

2.2.5 ENERGY STAR® Ground Source Heat Pumps Measure Overview

TRM Measure ID: R-HV-GH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) meeting the minimum requirements of ENERGY STAR geothermal heat pump key product criteria. Savings calculations are presented for systems with and without desuperheaters.

Eligibility Criteria

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

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

Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an air conditioner with an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard, effective January 1, 2023.[152]

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

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.7 SEER2. This value incorporates an adjustment to the baseline SEER2 value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[153] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 47. GSHPs—Baseline Efficiencies

Project type	Cooling mode[154]	Heating mode[155]
New construction	9.8 EER2 (14.3 SEER2)	2.2 COP (7.5 HSPF2)
ROB—air source heat pump baseline	9.8 EER2 (13.7 SEER2)	2.2 COP (7.5 HSPF2)
ROB—air conditioner with electric resistance furnace baseline		1 COP (3.412 HSPF2)

High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 3.2 requirements for eligible geothermal heat pumps effective January 1, 2012.[156] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 48. GSHPs—ENERGY STAR Requirements

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

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

[154] The Central HP EER2 baseline is reduced to 9.8 EER2 for systems rated at 15.2 SEER2 or higher. While GSHPs do not have a SEER2 rating, all full-load EER minimum efficiency requirements exceed that threshold. Therefore, the reduced EER2 baseline is extended to all GSHP installations.

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

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

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[157]

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

Equation 35

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

Equation 36

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on GSHPs in Texas.[158] Desuperheater savings were calculated for each climate zone by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high-efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to the replacement of air source heat pumps with GSHPs. These estimates were found to be within 5 percent of actual post-retrofit savings. Building models were developed using TRNSYS.[159]

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

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

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

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

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

These models were used to derive the energy and demand savings associated with installation of a desuperheater along with a GSHP, as shown in Table 51 and Table 52, respectively.

Energy Savings Algorithms

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

Equation 37

$$Cooling\ Energy\ Savings\ [kWh_C] = Cap_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{SEER2_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

Equation 38

Commented [DN6]: Updated to match coefficient definition.

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \frac{1\ kWh}{3{,}412\ Btu} \times EFLH_H \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right)$$

Equation 39

Where:

kWh_{DSH}	=	*Energy savings (kWh) associated with installation of a desuperheater (see Table 51); these savings should only be added if a desuperheater is installed*
$Cap_{C/H}$	=	*Rated equipment cooling/heating capacity of the installed GSHP (Btu/hr)*
$EFLH_{C/H}$	=	*Equivalent full load hours for cooling/heating (Table 49)*
$SEER2_{Base}$	=	*Energy efficiency ratio of the baseline cooling equipment (Table 47)*
EER_{GSHP}	=	*Energy efficiency ratio of the installed GSHP*
COP_{Base}	=	*Coefficient of performance of the baseline heating equipment converted from HSPF2 (Table 47)*
COP_{GSHP}	=	*Coefficient of performance of the installed GSHP*

Table 49. GSHPs—Equivalent Full Load Cooling/Heating Hours[160]

Climate zone	$EFLH_C$	$EFLH_H$
Zone 1: Amarillo	1,142	1,880
Zone 2: Dallas	1,926	1,343
Zone 3: Houston	2,209	1,127

[160] ENERGY STAR Central AC/HP Savings Calculator.

Climate zone	$EFLH_C$	$EFLH_H$
Zone 4: Corpus Christi	2,958	776
Zone 5: El Paso	1,524	1,559

Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER2_{Base}} - \frac{1}{EER_{GSHP}}\right) \times CF_S + kW_{DSH}$$

Commented [DN7]: Updated to match coefficient definition.

Equation 40

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_H \times \frac{1\ kWh}{3{,}412\ Btu} \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right) \times CF_W$$

Equation 41

Where:

$EER2_{Base}$	=	*Energy efficiency ratio of the baseline cooling equipment (see Table 47)*
$CF_{S/W}$	=	*Summer/winter peak coincidence factor (see Table 50)*
kW_{DSH}	=	*Summer demand savings (kW) associated with installation of a desuperheater (see Table 52); these savings should only be added if a desuperheater is installed*

Table 50. GSHPs—Coincidence Factors[161]

Season	CF
Summer[162]	0.87
Winter[163]	0.83

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

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

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

Deemed Energy Savings Tables

Table 51. GSHPs—Energy Savings for Desuperheaters per Cooling Tonnage

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

Deemed Summer Demand Savings Tables

Table 52. GSHPs—Summer Peak Demand Savings for Desuperheaters per Cooling Tonnage

Climate zone	kW/ton
Zone 1: Amarillo	0.440
Zone 2: Dallas	0.405
Zone 3: Houston	0.405
Zone 4: Corpus Christi	0.410
Zone 5: El Paso	0.405

Deemed Winter Demand Savings Tables

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

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

This value is consistent with the life expectancy of the heat pump components reported in multiple Department of Energy GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [164,165]

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:

- Climate zone or county
- Decision/action type (new construction, replace-on-burnout)
- Replaced unit heating type (heat pump, electric resistance furnace)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Manufacturer, model number, and serial number
- ENERGY STAR certificate matching installed model number
- Installed GSHP type (closed loop water-to-air, open loop water-to-air, closed loop water-to-water, open loop water-to-water, direct geoexchange)
- Energy efficiency ratio (EER) of the new unit
- Coefficient of performance (COP) of the new unit
- Product specification sheet
- Rated cooling and heating capacity of the new unit (Btu/hr)[166]
- Whether a desuperheater was also installed or present
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

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

[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] Rated capacities are not specified on the ENERGY STAR certificate and should be taken from the product specification sheet.

Relevant Standards and Reference Sources

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

Document Revision History

Table 53. GSHPs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards and alternative methodology.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updates to tracking requirements.
v8.0	10/2020	TRM v8.0 update. Updated algorithms to make units consistent.
v9.0	10/2021	TRM v9.0 update. Added clarifying language and updated algorithm units.
v10.0	10/2022	TRM v10.0 update. Updated coincidence factors and EUL.
v11.0	10/2023	TRM v11.0 update. Integrated federal standard change and SEER2 test procedure.
v12.0	10/2024	TRM v12.0 update. ~~No revision.~~ Updated algorithms to match coefficient definitions.

Commented [DN8]: Updated.

2.2.6 Large Capacity Split and Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: R-HV-LC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

- The deemed savings apply to central AC/HPs with a capacity of 65,000-240,000 Btu/hr (5.4-20 tons) and GSHPs with a capacity of 65,000-135,000 Btu/hr (5.4-11.3 tons).
- Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.
- Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[167,168]

Baseline Condition

New construction and replace-on-burnout baseline efficiency levels are provided in Table 54 and Table 55. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard, IECC 2015, and ASHRAE 90.1-2013.

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

Table 54. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for AC/HPs[169]

System type	Capacity (tons)	Baseline efficiencies	Source[170]
Air conditioners	> 5.4 to < 11.3	11.02 EER 14.612.8 IEER	DOE Standards/ IECC 2015
	11.3 to < 20	10.8 EER 14.0 IEER	
Heat pump (cooling)[171]	5.4 to < 11.3	11.0 EER 14.1 IEER	DOE Standards/ IECC 2015
	11.3 to < 20	10.6 EER 13.5 IEER	
Heat pump (heating)[172]	5.4 to < 11.3	3.4 COP	DOE Standards
	11.3 to < 20	3.3 COP	
	≥ 11.3 to ≤ 20	11.0 EER 12.4 IEER	
		10.8 EER 12.2 IEER	
Heat pump (cooling)[173]	5.4 to < 11.3	11.0 EER 12.0 IEER	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20	10.6 EER 11.6 IEER	
Heat pump (heating)[174]	5.4 to < 11.3	3.3 COP	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20	3.2 COP	

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

[170] 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.

[171] 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".

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

[173] 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".

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

Table 55. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for GSHPs[175]

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

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 54 and Table 55.

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

<u>Energy and Demand Savings Methodology</u>

Savings Algorithms and Input Variables

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

Equation 42

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

Equation 43

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

Equation 44

[175] Values from ASHRAE 90.1-2013.

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

Equation 45

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

Equation 46

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 47

$CF_{S/W}$	=	*Summer/winter peak coincidence factor (Table 56)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours (Table 57)*

Table 56. Large Capacity AC/HPs—Coincidence Factors[176]

Season	CF
Summer[177]	0.87
Winter[178]	0.83

Table 57. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours[179]

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

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

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

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a large-capacity air conditioner and 15 years for a large capacity heat pump based on the current DOE Final Rule standards for central heat pumps.[180] The EUL of a high-efficiency ground source heat pump unit is 24 years, consistent with the EUL reported in the DOE GSHP guide.[181]

These values are consistent with the life expectancy of the heat pump components reported in multiple DOE GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [182,183]

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:

- Climate zone or county
- 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

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

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

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

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

- Manufacturer, model, capacity, and serial number
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 58. 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.
v10.0	10/2022	TRM v10.0 update. Updated coincidence factors.
v11.0	10/2023	TRM v11.0 update. Updated GSHP EUL.
v12.0	10/2024	TRM v12.0 update. Updated baseline efficiency table.

2.2.7 Evaporative Cooling Measure Overview

TRM Measure ID: R-HV-EC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculations

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

The baseline condition is a new refrigerated air conditioner with a rated efficiency at 14 SEER, the federal minimum standard.[184] 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.

[184] 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.[185] The energy savings from the Xcel study are adjusted for climate using a cooling degree day (CDD) ratio derived from TMY 2020 weather data.[186] 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 48

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

$$Summer\ Peak\ Demand\ Savings\ |\Delta kW| = \frac{kWh_{Savings}}{EFLH_{Site}} \times CF_S$$

Equation 49

Where:

$EFLH_{Site}$	=	*Equivalent full-load hours of an evaporative cooling system for the project site location, El Paso, TX: 1,288*[187]

[185] 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.

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

[187] EFLH are calculated as the total annual kilowatt-hours divided by the max kilowatt value output by the BEopt model.

CF_S = *Summer coincidence factor*[188] *= 0.87*

Deemed Savings Tables

Table 59. 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.[189]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- 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

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 60. Evaporative Cooling—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. No revision
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated CDD reference.
v11.0	10/2023	TRM v11.0 update. No revision
v12.0	10/2024	TRM v12.0 update. No revision

2.2.8 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 in 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 61.

Table 61. Connected Thermostats—Baseline Efficiency of Existing ACs

Project type	Capacity (Btu/hr)	Cooling mode
Split air conditioners (manufactured as of 1/1/2023)	< 45,000	14.3 SEER2
	≥ 45,000	13.8 SEER2
Packaged air conditioners (manufactured as of 1/1/2023)	All	13.4 SEER2
Split/packaged air conditioners (manufactured 1/1/2015 through 12/31/2022)	All	12.8 SEER2
Split/packaged air conditioners (when age is unknown)[190]	All	12.3 SEER2
Split/packaged air conditioners (manufactured 1/23/2006 through 12/31/2014)	All	11.9 SEER2
Split/packaged air conditioners (manufactured before 1/23/2006)	All	9.1 SEER2

Table 62. Connected Thermostats—Baseline Efficiency of Existing HPs

Project type	Cooling mode	Heating mode
Split heat pumps (manufactured as of 1/1/2023)	14.3 SEER2	7.5 HSPF2
Packaged heat pumps (manufactured as of 1/1/2023)	13.4 SEER2	6.7 HSPF2
Split heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2	6.9 HSPF2
Packaged heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2	6.7 HSPF2
Split heat pumps (when age is unknown)[191]	12.3 SEER2	6.7 HSPF2
Packaged heat pumps (when ~~applying default~~ age is unknown)[192]	12.3 SEER2	6.6 HSPF2

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

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

[192] Ibid.

Project type	Cooling mode	Heating mode
Split/packaged heat pumps (manufactured 1/23/2006 through 12/31/2014)	11.9 SEER2	6.5 HSPF2
Split/packaged heat pumps (manufactured before 1/23/2006)	9.1 SEER2	5.7 HSPF2
Electric resistance furnace	–	3.412 HSPF2

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

High-Efficiency Condition

The high-efficiency condition is an HVAC unit being controlled by a connected thermostat compliant with the ENERGY STAR Final Version 1.0 requirements for eligible connected thermostats effective December 3, 2016.[193] A list of eligible thermostats is available on the ENERGY STAR website.[194] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Energy and Demand Savings Methodology

Energy savings are estimated according to the program requirements established by the ENERGY STAR program for thermostat service providers seeking certification. In addition to a series of other technical and programmatic requirements, providers must demonstrate that their thermostat services result in significant run-time reductions for the controlled cooling and heating equipment. Specifically, ENERGY STAR provides the runtime reduction criteria reproduced in Table 63.

ENERGY STAR runtime reductions are translated to energy savings using the methodologies defined in the Central and Mini-Split Air Conditioners and Heat Pumps measure.

Demand (kW) savings are not estimated for the Connected Thermostats measure.

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

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

Table 63. Connected Thermostats—Runtime Reduction Criteria for ENERGY STAR Certification

Metric	Statistical measure	Performance requirement
Annual percentage run time reduction, cooling	Lower 95 percent confidence limit of weighted national average	≥ 10 percent
	Weighted national average of 20th percentiles	≥ 5 percent
Annual percentage run time reduction, heating	Lower 95 percent confidence limit of weighted national average	≥ 8 percent
	Weighted national average of 20th percentiles	≥ 4 percent
Average resistance heat utilization for heat pump installations	National mean in 5°F outdoor temperature bins from 0 to 60°F	Reporting requirement

Savings Algorithms and Input Variables

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

Energy Savings Algorithms

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

Equation 50

$$Cooling\ Energy\ Savings\ [kWh_C] = \frac{Cap_C}{\eta_C} \times EFLH_C \times \frac{1\ kW}{1{,}000\ W} \times CRF$$

Equation 51

$$Heating\ Energy\ Savings\ [kWh_H] = \frac{Cap_H}{\eta_H} \times EFLH_H \times \frac{1\ kW}{1{,}000\ W} \times HRF \times DAF$$

Equation 52

Where:

$Cap_{C/H}$ = *HVAC equipment cooling/heating capacity. For thermostats installed on existing equipment, use the nominal tonnage converted to nominal capacity. For thermostats installed with a new HVAC system, use the AHRI rated capacity of the new equipment. For thermostats installed with a new or existing electric furnace, use the applicable nominal or rated cooling capacity as a proxy for heating capacity. [Btuh]; 1 ton = 12,000 Btuh*

η_C = *HVAC equipment cooling efficiency. For thermostats installed on existing equipment, default to the code SEER2 rating from Table 61 for ACs and Table 62 for HPs. For thermostats installed with a new HVAC system, use the AHRI SEER2 rating of the new equipment. [Btuh/W]*

η_H = *HVAC equipment heating efficiency. For thermostats installed on existing HP equipment, default to the code HSPF2 from Table 62. For thermostats installed with a new HP~~HVAC system~~, use the AHRI HSPF2 rating of the new equipment. For thermostats installed with a new or existing electric resistance furnace, use 3.412 HSPF. [Btuh/W]*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours (Table 64)*

CRF = *Cooling hours reduction factor = 10% (Table 63)*

HRF = *Heating hours reduction factor = 8% (Table 63)*

DAF = *Documentation adjustment factor; set to 0.75 for residences reporting electric resistance heat with no backup documentation or set to 1.0 in all other cases*

Table 64. Connected Thermostats—Equivalent Full Load Cooling/Heating Hours[195]

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

Deemed Energy Savings Tables

Deemed savings tables are only provided for connected thermostats installations where the cooling and heating equipment is unspecified. Savings are presented in kWh per thermostat, assuming a default of 3.7 tons.[196]

The following table describes various equipment replacement scenarios that may be encountered and specifies which baseline should be used in each case.

[195] ENERGY STAR Central AC/HP Savings Calculator.

[196] 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 65. Connected Thermostats—Baseline for Various Equipment Replacement Scenarios

Equipment replacement scenario	Baseline	
	Cooling	Heating
No HVAC equipment replacement	Existing	Existing
Non-condenserCoil replacements (e.g., coil or furnace ONLY)	Existing	Existing
Gas furnace replacements	Existing	No savings
Electric furnace replacements	Existing	Existing
Air conditioner condenser replacement with gas furnace	New	No savings
Air conditioner condenser replacement with electric heat	New	Existing[197]
Heat pump condenser replacement	New	New

For upstream and midstream programs where the existing HVAC system is unknown, assume a heating type weighting of 41.7% gas, 30.0% electric resistance, and 28.3% heat pump heat 41.8 percent gas, 49.3 percent electric resistance, and 9.0 percent heat pump heat.[198]

Table 66. Connected Thermostats—Energy Savings for Thermostats Installed on Unspecified Existing HVAC(kWh/thermostat)[199, 200, 201] (kWh/thermostat)

Climate zone		Total energy savings
Zone 1: Amarillo		1,2811,548
Zone 2: Dallas		1,3161,507
Zone 3: Houston		1,3181,479
Zone 4: Corpus Christi		1,4271,537
Zone 5: El Paso		1,2711,493

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.

197 In this scenario, utilize the existing cooling capacity as the existing heating capacity as a proxy due the fact that the existing heating capacity is not provided.

198 Residential Energy Consumption Survey (RECS) 20202015: Space heating in homes in the South and West Regions (HC6.8), February 27, 2017. https://www.eia.gov/consumption/residential/data/2015/ https://www.eia.gov/consumption/residential/data/2020/.

199 U.S. Census Bureau American Community Survey (CBACC), 2022. Table DP04. Texas. https://data.census.gov/table/ACSDP1Y2022.DP04?q=American%20Community%20survey&t=Housing%20Units&g=040XX00US48.

200 Assuming smart thermostat is installed in conjunction with an existing 3.7-ton HVAC unit.

201 CBACC used as primary source for percentage of gas and electric heating fuel type. RECS 2020 used to estimate percentages of central electric resistance and heat pump contributions to total electric heat.

Claimed Peak Demand Savings

Not applicable.

Example Deemed Savings Calculation

Example 1. A direct installed connected thermostat is installed on an existing 3.5-ton split air conditioner manufactured in 2015 in Climate Zone 2.

$$Cooling\ Energy\ Savings\ = \frac{3.5 \times 12{,}000 \times 1{,}926 \times 0.10}{12.8\ \times 1{,}000} = 632\ kWh$$

$$Heating\ Energy\ Savings\ = 0\ kWh$$

$$Total\ kWh\ Savings = 632 + 0 = 632\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

Example 2. A direct install connected thermostat is installed with a new 5-ton split heat pump rated at 56,000 cooling Btuh, 55,000 heating Btuh, 15.2 SEER2 and 8 HSPF2 in Climate Zone 3.

$$Cooling\ Energy\ Savings\ = \frac{56{,}000 \times 2{,}209 \times 0.10}{15.2\ \times 1{,}000} = 814\ kWh$$

$$Heating\ Energy\ Savings\ = \frac{55{,}000 \times 1{,}127 \times 0.08}{8\ \times 1{,}000} = 620\ kWh$$

$$Total\ kWh\ Savings = 814 + 620 = 1{,}434\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

Example 3. A midstream/upstream connected thermostat is installed in Climate Zone 4.

Total kWh Savings = ~~1,4201,537~~1,427 *kWh*

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

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.[202]

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 or county
- Thermostat quantity sold/installed
- Thermostat manufacturer and model number
- Copy of ENERGY STAR certificate matching model number

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

- HVAC system type (split AC, packaged AC, /split HP, packaged HP)
- Determine whether HVAC condenser was replaced in conjunction with the thermostat
- If installed with existing HVAC equipment:
  - HVAC capacity (Btuh): Nominal tons converted to capacity
  - Manufacture year
- If installed with new HVAC system:
  - HVAC capacity (Btuh): AHRI rated capacity
  - Part-load cooling efficiency (SEER2)
  - ~~Full-load cooling efficiency (EER2)~~
  - Heating efficiency (HSPF2) – HPs only
  - 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
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
  - Photograph of retired heating unit nameplate, utility inspection, recording nameplate information, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.

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

- If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy ~~and winter demand~~ savings.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 67. Connected Thermostats—Revision History

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 revision. Updated documentation requirement.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. Provided guidance about emergency heat settings and updated EUL reference. Added clarification to prevent double counting of savings with smart thermostat load management measure.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Incorporated algorithm approach. Incorporated new SEER2 test procedure.
v12.0	10/2024	TRM v12.0 update. Updated heating type weighting. Added electric resistance baseline and documentation requirement.

2.2.9 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[203] 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.

High-Efficiency Condition

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

[203] 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.

Energy and Demand Savings Methodology

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

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

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

Energy savings are not estimated through this specific measure.

Savings Algorithms and Input Variables

The demand algorithms and associated input variables are listed below:

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Baseline\ Period\ kW - Curtailment\ kW$$

Equation 53

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 68. Smart Thermostat Load Management—Deemed kW Savings per Device

Climate zone	kW/device
5	1.45

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Example Deemed Savings Calculation

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

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

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

$$kWh\ savings = 0\ kWh$$

Example 2. Suppose ten 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 69. Smart Thermostat Load Management—Example Total Program Year Savings Calculation

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

Measure Life and Lifetime Savings

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

Program Tracking Data and Evaluation Requirements

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

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

Utilities close to having AMI fully deployed in their territory can use the M&V approach (see Volume 4 section 2.6.1) for program participants with AMI meters and only use the deemed approach for participants without AMI meters.

Load management programs shall be tracked and reported separately from energy efficiency programs.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 70. Smart Thermostat Load Management—Revision History

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. Updates to calculated savings.
v8.0	10/2020	TRM v8.0 update. Updated description and tracking requirements.
v9.0	10/2021	TRM v9.0 update. Added clarification to prevent double counting of savings with smart thermostat load management measure.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Added guidance for utilities close to having AMI fully deployed. Added guidance on tracking and reporting of load management programs separate from energy efficiency programs.

2.2.10 Duct Sealing Measure Overview

TRM Measure ID: R-HV-DS

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

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

Eligibility Criteria

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

For the standard approach with leakage testing, duct leakage should be assessed following the Building Performance Institute (BPI) standards. Duct leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[204]

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

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

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

Baseline Condition

The savings calculation methods for this measure (when implemented with duct leakage testing) are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[205] For homes with an initial leakage rate greater than 35 percent of total fan flow, savings will be awarded with respect to this cap rather than the initial leakage. Data from nearly 28,000 single-family and mobile home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[206]

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

Low-income customers[207] are exempt from the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow.

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

High-Efficiency Condition

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

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

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205 Total Fan Flow = Cooling Capacity (tons) x 400 cfm/ton.

206 Based on data collected by Frontier Energy for investor-owned utilities in Texas.

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

Duct Leakage Testing (Standard Approach)

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. For this measure, leakage-to-outside must be directly measured. The project sponsor shall use the Combination Duct Blaster™ (or equivalent) and blower door method. Prior to beginning any installations, the project sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as RESNET certification, North American Technician Excellence (NATE) certification, or other certification by evaluator approved EPA-recognized ENERGY STAR Home Certification Organization (HCO). Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[208]

Categorizing Achieved Duct Leakage Reduction (Absent Leakage Testing)

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

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

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

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

[208] See ANSI/RESNET/ICC 380, Chapter 4 Procedure for Measuring Airtightness of Building or Dwelling Unit Enclosure and Chapter 5 Procedure for Measuring Airtightness of Duct Systems.

Table 71. Duct Sealing—Leakage Categorization Guide[209]

Category	Duct location	Duct insulation value	Leakage characteristics[210]
Low	> 90 percent conditioned	> R7	Some observable leaks
			Substantial leaks
		R4 - R7	Some observable leaks
			Substantial leaks
		< R4	Some observable leaks
			Substantial leaks
	50-90 percent conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
Average	> 90 percent conditioned	> R7	Catastrophic leaks
		R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	50-90 percent conditioned	> R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
		< R4	Substantial leaks
	< 50 percent conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
High	50-90 percent conditioned	R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	< 50 percent conditioned	> R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
			Catastrophic leaks
		< R4	Substantial leaks
			Catastrophic leaks

Energy and Demand Savings Methodology

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

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

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

Standard Approach (with Duct Leakage Testing)

The annual energy and summer and winter peak demand savings to be claimed according to the standard approach for this measure shall be calculated as a function of the reduction in duct leakage achieved, using the energy and demand savings coefficients from Table 72 through Table 74 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

Savings Algorithms and Input Variables

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

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

Deemed Energy Savings Tables

Table 72 presents the annual energy savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate annual energy savings for duct leakage reduction:

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

Equation 54

Where:

DL_{pre}	=	*Pre-improvement duct leakage at 25 Pa (cu. ft./min)*
DL_{post}	=	*Post-improvement duct leakage at 25 Pa (cu. ft./min)*
$V_{E,C}$	=	*Cooling Energy Savings Coefficient in Table 72*
$V_{E,H}$	=	*Heating Energy Savings Coefficient in Table 72*

Table 72. Duct Sealing—Energy Savings V_E per CFM_{25} Reduction

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

Deemed Summer Demand Savings Tables

Table 73 presents the summer peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed summer demand savings for duct leakage reduction:

$$Summer\ Pek\ Demand\ Savings\ [\Delta kW] = (DL_{pre} - DL_{post}) \times V_S$$

Equation 55

Where:

V_S = *Summer Demand Savings Coefficient (see Table 73)*

Table 73. Duct Sealing—Summer Demand Savings V_s per CFM_{25} Reduction

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

Deemed Winter Demand Savings Tables

Table 74 presents the winter peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed winter demand savings for duct leakage reduction:

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

Equation 56

Where:

V_W = *Winter Demand Savings Coefficient (see Table 74)*

Table 74. Duct Sealing—Winter Demand Savings V_W per CFM_{25} Reduction

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

Alternate Approach (No Duct Leakage Testing)

The following savings tables are provided for projects implemented without performing leakage testing, accounting for the application of pre-retrofit leakage caps to not hard-to-reach (HTR) projects. The annual energy and summer and winter peak demand savings to be claimed according to the alternate approach for this measure shall be taken from Table 72 through Table 74 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

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

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

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

Deemed Energy Savings Tables (Alternate Approach)

Table 75. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), HTR Alternate Approach

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

Table 76. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), HTR Alternate Approach

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

Table 77. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), HTR Alternate Approach

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

Table 78. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), HTR Alternate Approach

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

Table 79. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), HTR Alternate Approach

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

Deemed Summer Demand Savings Tables (Alternate Approach)

Table 80. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), HTR Alternate Approach

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

Table 81. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), HTR Alternate Approach

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

Table 82. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), HTR Alternate Approach

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

Table 83. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), HTR Alternate Approach

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

Table 84. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), HTR Alternate Approach

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

Deemed Winter Demand Savings Tables (Alternate Approach)

Table 85. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), HTR Alternate Approach

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

Table 86. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), HTR Alternate Approach

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

Table 87. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), HTR Alternate Approach

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

Table 88. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), HTR Alternate Approach

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

Table 89. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), HTR Alternate Approach

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

All Other Programs

Deemed Energy Savings Tables (Alternate Approach)

Table 90. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), Alternate Approach

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

Table 91. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), Alternate Approach

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

Table 92. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), Alternate Approach

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

Table 93. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), Alternate Approach

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

Table 94. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), Alternate Approach

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

Deemed Summer Demand Savings Tables (Alternate Approach)

Table 95. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), Alternate Approach

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

Table 96. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), Alternate Approach

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

Table 97. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), Alternate Approach

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

Table 98. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), Alternate Approach

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

Table 99. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), Alternate Approach

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

Deemed Winter Demand Savings Tables (Alternate Approach)

Table 100. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), Alternate Approach

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

Table 101. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), Alternate Approach

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

Table 102. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), Alternate Approach

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

Table 103. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), Alternate Approach

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

Table 104. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), Alternate Approach

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

Claimed Peak Demand Savings

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

Example Deemed Savings Calculation

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

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

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

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

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

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

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

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

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

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

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a duct sealing measure is 18 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-DuctSeal-BW.[211]

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

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Cooling type (central refrigerated, evaporative cooling, none)
- Heating type (central gas furnace, central electric resistance furnace, heat pump, none)
- Additional documentation is required to validate resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach)
- Cooling capacity of home HVAC units (tons)
- EESPs claiming savings according to duct leakage testing:
  - Pre-improvement duct leakage at 25 Pa (cu. ft./min)
  - Post-improvement duct leakage at 25 Pa (cu. ft./min)
  - Pre- and post-photos of leakage test readings
- EESPs claiming savings without performing leakage testing should provide:
  - Description of the leakage severity in the home (low, average, or high)
  - Description of location and condition of ducts:
    - Duct location (>90 percent conditioned, 50-90 percent conditioned, <50 percent conditioned)
    - Existing duct insulation value (>R7, R4-R7, <R4)
  - Leakage characteristics (some observable leaks, substantial leaks, catastrophic leaks)
  - Other relevant details that may assist with validating claimed leakage category (recommended)
  - Description and photos of interventions taken (both pre- and post-condition), such as newly sealed joints, supply vents, and other relevant leaks sealed
  - Incentive rate structure: incentive should be paid per home and should not vary by leakage category to avoid providing an incentive to overstate the existing leakage category.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 105. Duct Sealing—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor formatting changes, and language introduced to provide further direction for low-income customers and testing procedure. Contractors now required to track cooling capacity of HVAC equipment. Language added to reflect updates to federal standards for central heat pumps and central air conditioners.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Update of reference sources for air temperatures and densities, heating degree-days. Cooling demand savings required to be claimed.
v4.0	10/10/2016	TRM v4.0 update. Approach changed from algorithm-based to deemed savings coefficients estimated using building simulation models. Updated energy and demand savings. Added separate savings for homes with evaporative cooling. Updated measure description to eliminate eligibility for homes without a central AC, but with a ducted heating system.
v5.0	10/2017	TRM v5.0 update. Remove PY 2017 option to use energy and demand adjustment factors in combination with algorithm methodology from TRM v3.1.
v6.0	11/2018	TRM v6.0 update. Added alternative approach to bypass the need to complete leakage testing based on preceding guidance memo.

TRM version	Date	Description of change
v7.0	10/2019	TRM v8.0 update. Added clarifying language on incentive rate per home.
v8.0	10/2020	TRM v8.0 update. Updated eligibility and documentation requirements for electric resistance heat.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Corrected typo in leakage categorization guide.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

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 unless utility consumption data has demonstrated savings to expand to all residential customers. Utilities should work with the EM&V team to determine eligibility.

Cooling savings only 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.[212] Utilities' program manuals should be consulted for health and safety considerations related to the implementation of air sealing measures.

~~Only structures with electric refrigerated air conditioning systems are eligible.~~

Baseline Condition

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

Baseline assumptions used in the development of these deemed savings are based on a conversion from $ACH_{Natural}$. ASHRAE Handbook: Fundamentals specifies that more than 80 percent of sampled low-income housing had a pre-leakage rate at or below 1.75 $ACH_{Natural}$.[213] $ACH_{Natural}$ was converted to CFM_{50}/sq. ft. using Equation 57.

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

Equation 57

Where:

$ACH_{Natural,pre}$	=	*1.75 representing greater than 80 percent of sampled homes*
h	=	*Ceiling height (ft.) = 8.5 (default)*[214]
N	=	*N factor for single story normal shielding (Table 106) = 18.5*

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

[212] 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.*"

[213] 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12.

[214] 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.[215] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[216] 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 58, based on floor area and the number of bedrooms.[217] 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 106).

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

Equation 58

Where:

Min CFM_{50}	=	*Minimum final ventilation rate (CFM_{50})*
A_{Floor}	=	*Floor area (sq. ft.)*
OCC	=	*BR + 1, where BR is the number of bedrooms; if number of home occupants is known to exceed BR + 1, occupancy should be used instead*
N	=	*N factor (Table 106)*

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

Table 106. Air Infiltration—N Factors[218]

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[219] 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}).[220] 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}.

[218] 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.

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

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

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

Deemed Energy Savings Tables

Table 107 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.

$$Energy\ Savings\ [\Delta \text{kWh}] = \Delta CFM_{50} \times \left(V_{E,C} \times CAF + V_{E,H} \times HAF \times DAF\right) \cancel{\times DAF}$$

Equation 59

Where:

ΔCFM_{50}	=	*Air infiltration reduction in cubic feet per minute at 50 Pascal*
$V_{E,C}$	=	*Cooling energy savings coefficient (Table 107)*
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*
$V_{E,H}$	=	*Heating energy savings coefficient (Table 107)*
HAF	=	*Heating savings adjustment factor for homes with electric resistance space heaters; set to 1.0 for homes with central heating with supplemental space heating or set to 0.24 for homes with primary electric resistance space heating*
DAF	=	*Documentation adjustment factor; set to 0.75 for residences reporting electric resistance heat with no backup documentation or set to 1.0 in all other cases*

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 107 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 107 by a factor of 0.24.[221]

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

Table 107. Air Infiltration—Energy Savings V_E per CFM_{50} Reduction

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

Deemed Summer Demand Savings Tables

Table 108 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:

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \Delta CFM_{50} \times V_S \times CAF \cancel{\times DAF}$$

Equation 60

Where:

V_S = *Summer demand savings coefficient (Table 108)*

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 108 by a factor of 0.6.

Table 108. Air Infiltration—Peak Summer Demand Savings V_S per CFM_{50} Reduction

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

Deemed Winter Demand Savings Tables

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 109 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 109 by a factor of 0.24.

Table 109 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:

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \Delta CFM_{50} \times V_W \times HAF \times DAF$$

Equation 61

Where:

V_W = *Winter demand savings coefficient (Table 109)*

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 109 by a factor of 0.24.[222]

Table 109. Air Infiltration—Peak Winter Demand Savings V_W per CFM_{50} Reduction

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

Claimed Peak Demand Savings

Refer to Volume 1, Section 4.

Example Deemed Savings Calculation

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

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

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

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

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

[222] 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.

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

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

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

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

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-Wthr.[223]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- 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
    - ~~If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings~~
- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories

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

- 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

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

Document Revision History

Table 110. Air Infiltration—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. Revision of minimum ventilation requirements, pre-retrofit cap on infiltration levels, Climate Zone 5 savings values for homes with heat pumps, and tracking number of bedrooms and occupants in a house.
v3.1	11/05/2015	TRM v3.1 update. Provided clarification around effects of occupancy on minimum final ventilation.

TRM version	Date	Description of change
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 and updated documentation requirements. Updated eligibility to only LI/HTR. Added space heat adjustment factor and electric resistance documentation requirement.
v9.0	10/2021	TRM v9.0 update. Updated savings calculation example and EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Added electric resistance documentation adjustment factor.
v12.0	10/2024	TRM v12.0 update. Clarified application of electric resistance documentation adjustment factor. Updated eligibility to all residential customers, as applicable.

2.3.2 Ceiling Insulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building envelope

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

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

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

Area-Weighted U-Factor Calculation Method

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

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

Equation 62

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[224] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[225] 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 111.

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.

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

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

Table 111. 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 112 through Table 116, 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 112 through Table 118 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 112 through Table 118 by a factor of 0.24.[226]

Table 112. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Energy Savings (kWh/sq. ft.)

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

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.

Table 113. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Energy Savings (kWh/sq. ft.)

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

Table 114. Ceiling Insulation—Climate Zone 3: Houston, R-30 Energy Savings (kWh/sq. ft.)

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

Table 115. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Energy (kWh/sq. ft.)

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

Table 116. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Energy Savings (kWh/sq. ft.)

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

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

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

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

Equation 63

Where:

R30 Savings/ft²	=	*Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 112 through Table 116*
$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either Table 117 or Table 118*
$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)*
A	=	*Treated area (sq. ft.)*
DAF	=	*Documentation adjustment factor; set to 0.75 for residences reporting electric resistance heat with no backup documentation or set to 1.0 in all other cases*
		Note: this factor should only be applied to heating savings.

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 117. Ceiling Insulation—Energy Scale-Down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated air	Evaporative cooling	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
Zone 2: Dallas	6.66E-03	–	7.11E-04	2.00E-02	8.20E-03
Zone 3: Houston	6.22E-03	–	4.67E-04	1.38E-02	5.47E-03
Zone 4: Corpus Christi	4.92E-03	–	2.44E-04	9.04E-03	3.47E-03
Zone 5: El Paso	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 118. Ceiling Insulation—Energy Scale-Up Factors for 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
Zone 1: Amarillo	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
Zone 2: Dallas	4.45E-03	–	4.82E-04	1.33E-02	5.47E-03
Zone 3: Houston	4.00E-03	–	2.97E-04	9.19E-03	3.66E-03
Zone 4: Corpus Christi	3.24E-03	–	1.62E-04	5.99E-03	2.30E-03
Zone 5: El Paso	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 119 through Table 123 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 119 through Table 125 by a factor of 0.6.

Table 119. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Summer Peak Demand Savings (kW/sq. ft.)

Ceiling insulation base R-value	Refrigerated	Evaporative
< 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

Table 120. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Summer Peak 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

Table 121. Ceiling Insulation—Climate Zone 3: Houston, R-30 Summer Peak 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

Table 122. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Summer Peak 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

Table 123. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Summer Peak Demand Savings (kW/sq. ft)

Ceiling insulation base R-value	Refrigerated	Evaporative
< 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 124. Ceiling Insulation—Summer Peak Demand Scale-Down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)

Climate zone	Refrigerated air	Evaporative cooling
Zone 1: Amarillo	6.41E-06	1.97E-06
Zone 2: Dallas	7.30E-06	–
Zone 3: Houston	7.91E-06	–
Zone 4: Corpus Christi	5.20E-06	–
Zone 5: El Paso	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 125. Ceiling Insulation—Summer Peak Demand Scale-Up Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR)

Climate zone	Refrigerated air	Evaporative cooling
Zone 1: Amarillo	4.22E-06	1.89E-06
Zone 2: Dallas	4.92E-06	–
Zone 3: Houston	5.92E-06	–
Zone 4: Corpus Christi	3.47E-06	–
Zone 5: El Paso	4.22E-06	1.89E-06

Deemed Winter Demand Savings Tables

Table 126 through Table 130 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 126 through Table 132 by a factor of 0.24.[227]

Table 126. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Winter Peak 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

Table 127. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Winter Peak 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

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

Table 128. Ceiling Insulation—Climate Zone 3: Houston, R-30 Winter Peak 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

Table 129. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Winter Peak 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

Table 130. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Winter Peak 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.

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

Equation 64

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 119 through Table 123 or Table 126 through Table 130*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 124 and Table 125 (Summer) or Table 131 and Table 132 (Winter)*

Note: the heating documentation adjustment should only be applied to winter peak savings calculations.

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 131. Ceiling Insulation—Winter Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	4.29E-07	1.21E-05	6.30E-06
Zone 2: Dallas	3.97E-07	1.40E-05	9.55E-06
Zone 3: Houston	3.05E-07	1.10E-05	6.53E-06
Zone 4: Corpus Christi	3.19E-07	9.18E-06	4.32E-06
Zone 5: El Paso	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 132. Ceiling Insulation—Winter Peak Demand Scale-up Factors for Insulating to Greater than R-30(kW/sq. ft./ ΔR)

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.76E-07	7.85E-06	4.19E-06
Zone 2: Dallas	2.57E-07	8.33E-06	4.80E-06
Zone 3: Houston	2.19E-07	7.33E-06	4.46E-06
Zone 4: Corpus Christi	1.72E-07	5.79E-06	2.72E-06
Zone 5: El Paso	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.

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

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

$$Energy\ Savings = (0.22 + 2.13) \times 400 = 940\ kWh$$

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

$$Summer\ Peak\ Demand\ Savings = 2.38 \times 10^{-4} \times 400 = 0.10\ kW$$

$$Winter\ kWsavings\ per\ sq.ft = 5.75 \times 10^{-4} + 7.85 \times 10^{-6} \times (38 - 30) = 1.20 \times 10^{-3}\ kW/sq.ft.$$

$$Winter\ Peak\ Demand\ Savings = 1.20 \times 10^{-3} \times 400 = 0.48\ kW$$

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.

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

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

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

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

$$Summer\ Peak\ Demand\ Savings = 5.35 \times 10^{-4} \times 550 = 0.29\ kW$$

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

$$Winter\ Peak\ Demand\ Savings = 4.36 \times 10^{-4} \times 550 = 0.24\ kW$$

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),[228] the estimated useful life is 25 years for ceiling insulation.

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:

- Climate zone or county
- 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.
  - ~~If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings~~
- 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.

[228] 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_MeasureLifeStudyLightsandHVACGDS_1Jun2007.pdf.

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

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

Document Revision History

Table 133. 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.

TRM version	Date	Description of change
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.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Added electric resistance documentation adjustment factor.
v12.0	10/2024	TRM v12.0 update. Clarified application of electric resistance documentation adjustment factor.

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.[229] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[230] 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[231]. 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

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

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

231 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 135 through Table 139 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 135 through Table 141 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 135 through Table 141 by a factor of 0.24.[232]

Table 134. 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

[232] 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[233]

Table 135. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Energy Savings for Insulation Component (kWh/sq. ft)

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

Table 136. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Energy Savings for Insulation Component (kWh/sq. ft)

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

Table 137. Attic Encapsulation—Climate Zone 3: Houston, R-30 Energy Savings for Insulation Component (kWh/sq. ft)

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

233 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.

Table 138. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Energy Savings for Insulation Component (kWh/sq. ft)

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

Table 139. Attic Encapsulation—Climate Zone 5: El Paso, R-30 Energy Savings for Insulation Component (kWh/sq. ft)

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

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

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing 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.

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

Equation 65

Where:

R30 Savings/ft²	=	*Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 135 through Table 139*
$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either Table 140 or Table 141*

$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)*
A	=	*Treated area (sq. ft.)*
DAF	=	*Documentation adjustment factor; set to 0.75 for residences reporting electric resistance heat with no backup documentation or set to 1.0 in all other cases* *Note: This factor should only be applied to heating savings.*

If the roof deck and attic walls are insulated to a level less than R-30, the factors in Table 140 shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 140. Attic Encapsulation—Energy Scale-down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
Zone 2: Dallas	6.66E-03	–	7.11E-04	2.00E-02	8.20E-03
Zone 3: Houston	6.22E-03	–	4.67E-04	1.38E-02	5.47E-03
Zone 4: Corpus Christi	4.92E-03	–	2.44E-04	9.04E-03	3.47E-03
Zone 5: El Paso	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 141. Attic Encapsulation—Energy Scale-up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR)

Climate zone	Cooling savings		Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
Zone 2: Dallas	4.45E-03	–	4.82E-04	1.33E-02	5.47E-03
Zone 3: Houston	4.00E-03	–	2.97E-04	9.19E-03	3.66E-03
Zone 4: Corpus Christi	3.24E-03	–	1.62E-04	5.99E-03	2.30E-03
Zone 5: El Paso	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 142 through Table 146 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 142 through Table 148 by a factor of 0.6.

Table 142. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Refrigerated	Evaporative
< 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

Table 143. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< 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

Table 144. Attic Encapsulation—Climate Zone 3: Houston, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< 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

Table 145. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)

Ceiling insulation base R-value	Demand savings
< 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