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

Baseline Condition

The baseline condition is defined as a residence with no existing radiant barrier installed on roof decking.

High-Efficiency Condition

The high efficiency condition is defined as a radiant barrier installed on roof decking. The radiant barrier must be compliant with the standards set by RIMA-I, including proper attic ventilation. A list of verified products is available on the RIMA-I website.[239]

Table 205. Radiant Barriers—RIMA-I Product Testing Requirements[240]

Physical property	Test method or standard	Requirement
Surface emittance	ASTM C 1371	0.1 or less
Water vapor transmission	ASTM E 96 Procedure A desiccant method	0.02 for vapor retarder; 0.5 or greater for perforated products
Surface burning		
Flame spread	ASTM E 84	25 or less
Smoke density	ASTM E 84	450 or less
Corrosivity	ASTM D 3310	Corrosion on less than two percent of the affected surface
Tear resistance	ASTM D 2261	N/A
Adhesive performance		
Bleeding	Section 10.1 of ASTM C 1313	Bleeding of delamination of less than two percent of the surface area
Pliability	Section 10.2 of ASTM C 1313	No cracking or delamination
Mold and mildew	ASTM C 1338	No growth when visually examined under 5x magnification
Tensile strength	ASTM D 2261	Report tearing strength in machine direction and cross direction

[239] RIMA International verified products. https://rimainternational.org/verify/.
[240] RIMA International Product Testing Requirements. https://rimainternational.org/technical/testing/.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This measure references deemed savings from the Arkansas Technical Reference Manual (TRM) v9.0 where calibrated simulation modeling was used to develop these deemed savings.[241] Specifically, these deemed savings estimates were developed using BEopt, running EnergyPlus as the underlying simulation engine. Since radiant barrier savings are sensitive to weather, savings were modeled using typical meteorological year (TMY) 3 weather data.

Arkansas savings were mapped to Texas climate zones by comparing cooling and heating degree days developed using TMY data. Since TMY3 data is no longer accessible through the National Solar Radiation Database (NSRDB) Viewer, degree days were compared using TMY 2020 weather data.[242]

Degree day ratios were derived by dividing Texas cooling and heating degree days by the closest degree day match among Arkansas climate zones. These ratios were multiplied against corresponding Arkansas TRM deemed savings yielding savings values adjusted for Texas climate. The resulting ratios are specified in Table 206.

Table 206. Radiant Barriers—Cooling and Heating Adjustment Factors (AF)[243]

Climate zone	Cooling AF	Heating AF
Zone 1: Amarillo	0.95	1.02
Zone 2: Dallas	1.06	0.88
Zone 3: Houston	1.12	0.56
Zone 4: Corpus Christi	1.44	0.27
Zone 5: El Paso	0.99	0.99

Deemed Energy Demand Savings Tables

Table 207 through Table 211 present the energy savings (kWh) in the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

[241] Arkansas Public Service Commission. AR TRM v9.0. http://www.apscservices.info/EEInfo/TRMV9.0.pdf.

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

[243] These adjustment factors were multiplied against respective cooling and heating savings from the Arkansas TRM v9.0 Radiant Barriers measure. The cooling factor for Amarillo was applied against Arkansas Climate Zone 8 (Fort Smith), and the heating factor for Amarillo was applied against Arkansas Climate Zone 9 (Fayetteville). Factors for all remaining TX climate zones were applied against savings for Arkansas Climate Zone 6 (El Dorado).

For customers who participate in HTR or 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 207 through Table 211 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 207 through Table 211 by a factor of 0.24.[244]

Savings are specified per square foot of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier is installed. The square footage should not reflect the total area of installed radiant barrier.

Table 207. Radiant Barriers—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Cooling savings	Heating savings		
	Refrigerated air	Gas	Electric resistance	Heat pump
≤ R-19	0.2234	0.0072	0.2099	0.1106
> R-19	0.1350	0.0031	0.0962	0.0573

Table 208. Radiant Barriers—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Cooling savings	Heating savings		
	Refrigerated air	Gas	Electric resistance	Heat pump
≤ R-19	0.2887	0.0044	0.1449	0.0334
> R-19	0.1777	0.0026	0.0676	0.0132

Table 209. Radiant Barriers—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Cooling savings	Heating savings		
	Refrigerated air	Gas	Electric resistance	Heat pump
≤ R-19	0.3046	0.0028	0.0916	0.0211
> R-19	0.1874	0.0017	0.0427	0.0083

[244] This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42, 000 BTU for central electric furnaces and two 1,500 W 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 210. Radiant Barriers—Climate Zone 4: Corpus Christi, Energy Savings (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Cooling savings	Heating savings		
	Refrigerated air	Gas	Electric resistance	Heat pump
≤ R-19	0.3937	0.0013	0.0443	0.0102
> R-19	0.2423	0.0008	0.0207	0.0040

Table 211. Radiant Barriers—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Cooling savings	Heating savings		
	Refrigerated	Gas	Electric resistance	Heat pump
≤ R-19	0.2691	0.0050	0.1636	0.0377
> R-19	0.1656	0.0030	0.0764	0.0149

Deemed Summer Demand Savings Tables

Table 212 presents the summer demand savings (kW) in the five Texas climate zones per square foot of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier in installed.

For customers who participate in HTR or 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 212 by a factor of 0.6.

Table 212. Radiant Barriers—Summer Peak Demand Savings for Residences with Refrigerated Air (kWh/sq. ft.)

Radiant barrier with existing ceiling insulation base R-value	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
≤ R-19	0.00014	0.00015	0.00016	0.00020	0.00014
> R-19	0.00008	0.00010	0.00010	0.00013	0.00009

Deemed Winter Demand Savings Tables

Winter demand savings are not specified for this measure at this time. They will be added when savings are updated to reflect Texas consumption data.

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

Radiant barriers and other reflective insulation systems have similar lifetime expectations to other attic insulation measures.[245] The estimated useful life (EUL) of radiant barriers is 25 years for radiant barriers based on the GDS Associates Measure Life Report value for ceiling insulation.

This value matches lifetime assumptions for radiant barriers from both Oak Ridge National Laboratory (ORNL)[246] and National Renewable Energy Laboratory (NREL).[247]

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 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
- Baseline R-value of existing ceiling insulation (≤ R-19, > R-19)
- Square footage of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier is installed
- Manufacturer and product name/model number

References and Efficiency Standards

Petitions and Rulings

Not applicable.

---

[245] US Department of Energy (DOE) Insulation Fact Sheet. https://web.ornl.gov/sci/buildings/docs/factSheets/Insulation-FactSheet-2008.pdf.

[246] "Radiant Barrier: Effect of Radiant Barriers on Heating and Cooling Bils", ORNL. https://web.ornl.gov/sci/buildings/tools/radiant/rb2/.

[247] National Residential Efficiency Measures Database, NREL. https://remdb.nrel.gov/measures.php?gId=13&ctId=51.

Relevant Standards and Reference Sources

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

Document Revision History

Table 213. Radiant Barriers—Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. Clarified savings normalization by area. Added electric resistance documentation adjustment factor.

2.3.8 Cool Roofs Measure Overview

TRM Measure ID: R-BE-CR

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

Reflective roofing materials reduce the overall heat load on a home by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during the cooling season, but reduces free heat during the heating season, so the measure saves energy in the summer but uses more energy in winter. As such, cool roofs are most beneficial in warmer climates and may not be recommended for homes where the primary heat source is electric resistance. The measure is for retrofit of existing homes.

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 an existing home with a standard medium- or dark-colored roof.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[248] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[249] 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

The ENERGY STAR roofing products certification program was discontinued effective June 1, 2022.[250] Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification below.[251]

In lieu of the former ENERGY STAR list of qualified products, roofing products must now have a performance rating that is validated by the Cool Roof Rating Council (CRRC)[252,253] and be listed on the CRRC Rated Roof Products Directory.[254] This is consistent with the former ENERGY STAR test criteria, which allows for products already participating in the CRRC Product Rating Program to submit solar reflectance and thermal emittance product information derived from CRRC certification.

The ENERGY STAR program classifies roofs with a slope greater than 2/12 as having a steep slope and roofs with a slope less than or equal to 2/12 as low slope roofs. ENERGY STAR performance specifications for cool roof products for use on roofs with steep slopes and low slopes are provided in Table 214.

Table 214. Cool Roofs—ENERGY STAR Specification[255]

Roof slope	Characteristic	Performance specification
Low slope ≤ 2/12	Initial solar reflectance	≥ 0.65
	3-year solar reflectance	≥ 0.50
High slope > 2/12	Initial solar reflectance	≥ 0.25
	3-year solar reflectance	≥ 0.15

[248] Electric Resistance Heating. https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[249] Portable Heaters. https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[250] ENERGY STAR Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.
[251] ENERGY STAR Program Requirements for Roof Products v2.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.
[252] CRRC guidance for roof rating alternative to discontinued ENERGY STAR® program. https://coolroofs.org/documents/CRRC-ENERGY-STAR-Sunset-Info-Sheet-2022-03-07.pdf.
[253] CRRC Roof Rating Program. https://coolroofs.org/programs/roof-rating-program.
[254] CRRC Rated Roof Products Directory. https://coolroofs.org/directory/roof.
[255] ENERGY STAR Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

If a cool roof is installed concurrently with changes to attic insulation levels, savings should be claimed for the reflective roof according to the post-retrofit (ceiling or roof deck) insulation levels. Savings for changes in insulation levels should be claimed separately according to the ceiling insulation or attic encapsulation measures, assuming the retrofit performed meets the requirements of those measures.

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 were modified as follows. Roof slopes were modified to reflect representative levels for the low slope and steep slope roofs. A 1/12 slope was selected for modeling low slope roofs (defined as having slope <= 2/12), and a 4/12 slope was selected for modeling steep slope roofs (slope > 2/12). Based on the performance criteria and review of the rated 3-year reflectance of rated products listed in the CRRC database, four reflectance levels were selected for modeling: 0.2, 0.4, 0.6, and 0.8, representing 20 to 80 percent reflectance.

Because of the interplay between the performance of insulation and attic/roof deck temperatures, which are directly affected by the installation of a cool roof, savings were estimated for a range of different attic insulation scenarios: a range of ceiling insulation levels from no insulation (R-0) to R-30, and two roof deck insulation levels, R-19 and R-38, were modeled. Savings for a roof deck insulation level of R-30 are provided by interpolating between the R-19 and R-38 scenarios.

These modifications are shown in Table 215.

The model runs calculated energy use for the prototypical home prior to encapsulating the attic. Change-case models were run to calculate energy use with the floor insulation measure in place with either R-30 or R-38 insulation.

Table 215. Cool Roofs—Prototypical Home Characteristics

Shell characteristic	Value	Source
Base case roof material	Medium asphalt shingle, reflectance = 0.15	Prototype home default
Change case roof material	Medium asphalt shingle, reflectance = 0.2 reflectance = 0.4 reflectance = 0.6 Reflectance = 0.8	Lower reflectance levels only relevant for steep slope roofs. Modeled reflectance levels reflect midpoints of ranges: 0.15 ≤ R < 0.3 Reflectance 0.3 ≤ R < 0.5 Reflectance 0.5 ≤ R < 0.7 Reflectance > 0.7
Roof slope: low-slope roof	1/12	Not modified between base and change cases
Roof slope: steep slope roof	4/12	Not modified between base and change cases

Shell characteristic	Value	Source
Ceiling (attic floor) insulation levels	< R-5 R-5 to R-8 R-9 to R-14 R-15 to R-22 R-30	Not modified between base and change cases
Roof Deck (underside) Insulation Levels	R-19 R-38	Not modified between base and change cases

Deemed Energy Savings Tables

Savings are presented first for homes with ceiling insulation and subsequently for those with roof deck insulation. 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 216 through Table 220 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 216 through Table 220 by a factor of 0.24.[256]

Homes with Ceiling Insulation

Table 216 through Table 220 present the energy savings (kWh) for installation of a reflective roof on homes with varying levels of ceiling (attic floor) insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

Table 216. Cool Roofs—Climate Zone 1: Amarillo,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Steep slope						
< R-5	0.15 – 0.29	0.03	0.01	0.00	-0.05	-0.02
< R-5	0.3 – 0.49	0.15	0.06	-0.02	-0.26	-0.09
< R-5	0.5 – 0.69	0.27	0.10	-0.03	-0.47	-0.18
< R-5	≥ 0.7	0.40	0.15	-0.06	-0.71	-0.26
R-5 to R-8	0.15 – 0.29	0.02	0.01	0.00	-0.04	-0.01
R-5 to R-8	0.3 – 0.49	0.12	0.04	-0.02	-0.20	-0.07
R-5 to R-8	0.5 – 0.69	0.21	0.08	-0.03	-0.36	-0.14

[256] This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500 W 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.

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
R-5 to R-8	≥ 0.7	0.31	0.12	-0.05	-0.54	-0.20
R-9 to R-14	0.15 – 0.29	0.02	0.01	0.00	-0.03	-0.01
R-9 to R-14	0.3 – 0.49	0.08	0.03	-0.01	-0.13	-0.05
R-9 to R-14	0.5 – 0.69	0.15	0.06	-0.03	-0.25	-0.09
R-9 to R-14	≥ 0.7	0.22	0.08	-0.04	-0.37	-0.14
R-15 to R-22	0.15 - 0.29	0.01	0.00	0.00	-0.02	-0.01
R-15 to R-22	0.3 – 0.49	0.06	0.02	-0.01	-0.09	-0.04
R-15 to R-22	0.5 – 0.69	0.10	0.04	-0.02	-0.17	-0.06
R-15 to R-22	≥ 0.7	0.15	0.06	-0.03	-0.25	-0.10
R-30	0.15 – 0.29	0.01	0.00	0.00	-0.01	0.00
R-30	0.3 – 0.49	0.04	0.01	-0.01	-0.06	-0.02
R-30	0.5 – 0.69	0.07	0.02	-0.02	-0.11	-0.04
R-30	≥ 0.7	0.10	0.04	-0.03	-0.16	-0.06
Low slope						
< R-5	0.5 – 0.69	0.30	0.11	-0.04	-0.52	-0.20
< R-5	≥ 0.7	0.43	0.16	-0.06	-0.77	-0.29
R-5 to R-8	0.5 – 0.69	0.23	0.09	-0.03	-0.40	-0.15
R-5 to R-8	≥ 0.7	0.34	0.13	-0.05	-0.59	-0.22
R-9 to R-14	0.5 – 0.69	0.16	0.06	-0.03	-0.27	-0.10
R-9 to R-14	≥ 0.7	0.23	0.09	-0.04	-0.41	-0.15
R-15 to R-22	0.5 – 0.69	0.11	0.04	-0.02	-0.19	-0.07
R-15 to R-22	≥ 0.7	0.17	0.07	-0.03	-0.28	-0.11
R-30	0.5 – 0.69	0.08	0.03	-0.02	-0.13	-0.05
R-30	≥ 0.7	0.12	0.05	-0.03	-0.19	-0.07

Table 217. Cool Roofs—Climate Zone 2: Dallas,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Steep slope					
< R-5	0.15 – 0.29	0.05	0.00	-0.04	-0.01
< R-5	0.3 – 0.49	0.23	-0.01	-0.17	-0.07
< R-5	0.5 – 0.69	0.43	-0.01	-0.32	-0.12

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
< R-5	≥ 0.7	0.64	-0.02	-0.48	-0.18
R-5 to R-8	0.15 – 0.29	0.04	0.00	-0.03	-0.01
R-5 to R-8	0.3 – 0.49	0.18	-0.01	-0.13	-0.05
R-5 to R-8	0.5 – 0.69	0.34	-0.01	-0.24	-0.09
R-5 to R-8	≥ 0.7	0.50	-0.02	-0.36	-0.14
R-9 to R-14	0.15 – 0.29	0.03	0.00	-0.02	-0.01
R-9 to R-14	0.3 – 0.49	0.13	-0.01	-0.09	-0.03
R-9 to R-14	0.5 – 0.69	0.24	-0.01	-0.16	-0.06
R-9 to R-14	≥ 0.7	0.35	-0.02	-0.25	-0.09
R-15 to R-22	0.15 – 0.29	0.02	0.00	-0.01	0.00
R-15 to R-22	0.3 – 0.49	0.09	0.00	-0.06	-0.02
R-15 to R-22	0.5 – 0.69	0.17	-0.01	-0.11	-0.04
R-15 to R-22	≥ 0.7	0.25	-0.01	-0.17	-0.06
R-30	0.15 – 0.29	0.01	0.00	-0.01	0.00
R-30	0.3 – 0.49	0.06	0.00	-0.04	-0.02
R-30	0.5 – 0.69	0.12	-0.01	-0.07	-0.03
R-30	≥ 0.7	0.18	-0.01	-0.11	-0.04
Low slope					
< R-5	0.5 – 0.69	0.47	-0.01	-0.35	-0.13
< R-5	≥ 0.7	0.70	-0.02	-0.53	-0.20
R-5 to R-8	0.5 – 0.69	0.37	-0.01	-0.27	-0.10
R-5 to R-8	≥ 0.7	0.55	-0.02	-0.40	-0.15
R-9 to R-14	0.5 – 0.69	0.26	-0.01	-0.19	-0.07
R-9 to R-14	≥ 0.7	0.39	-0.02	-0.28	-0.10
R-15 to R-22	0.5 – 0.69	0.19	-0.01	-0.13	-0.05
R-15 to R-22	≥ 0.7	0.28	-0.01	-0.19	-0.07
R-30	0.5 – 0.69	0.14	-0.01	-0.08	-0.03
R-30	≥ 0.7	0.20	-0.01	-0.13	-0.05

Table 218. Cool Roofs—Climate Zone 3: Houston,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Steep slope					
< R-5	0.15 – 0.29	0.05	0.00	-0.02	-0.01
< R-5	0.3 – 0.49	0.26	0.00	-0.13	-0.05
< R-5	0.5 – 0.69	0.48	-0.01	-0.24	-0.09
< R-5	≥ 0.7	0.71	-0.01	-0.37	-0.13
R-5 to R-8	0.15 – 0.29	0.04	0.00	-0.02	-0.01
R-5 to R-8	0.3 – 0.49	0.20	0.00	-0.10	-0.04
R-5 to R-8	0.5 – 0.69	0.37	-0.01	-0.18	-0.07
R-5 to R-8	≥ 0.7	0.55	-0.01	-0.28	-0.10
R-9 to R-14	0.15 – 0.29	0.03	0.00	-0.01	-0.01
R-9 to R-14	0.3 – 0.49	0.14	0.00	-0.07	-0.03
R-9 to R-14	0.5 – 0.69	0.26	-0.01	-0.13	-0.05
R-9 to R-14	≥ 0.7	0.39	-0.01	-0.19	-0.07
R-15 to R-22	0.15 – 0.29	0.02	0.00	-0.01	0.00
R-15 to R-22	0.3 – 0.49	0.10	0.00	-0.05	-0.02
R-15 to R-22	0.5 – 0.69	0.18	-0.01	-0.09	-0.03
R-15 to R-22	≥ 0.7	0.27	-0.01	-0.13	-0.05
R-30	0.15 – 0.29	0.01	0.00	-0.01	0.00
R-30	0.3 – 0.49	0.06	0.00	-0.03	-0.01
R-30	0.5 – 0.69	0.12	-0.01	-0.06	-0.02
R-30	≥ 0.7	0.18	-0.01	-0.08	-0.03
Low slope					
< R-5	0.5 – 0.69	0.54	-0.01	-0.27	-0.10
< R-5	≥ 0.7	0.79	-0.01	-0.41	-0.15
R-5 to R-8	0.5 – 0.69	0.42	-0.01	-0.21	-0.08
R-5 to R-8	≥ 0.7	0.62	-0.01	-0.31	-0.12
R-9 to R-14	0.5 – 0.69	0.30	-0.01	-0.14	-0.05
R-9 to R-14	≥ 0.7	0.44	-0.01	-0.21	-0.08

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
R-15 to R-22	0.5 – 0.69	0.21	-0.01	-0.10	-0.04
R-15 to R-22	≥ 0.7	0.31	-0.01	-0.15	-0.06
R-30	0.5 – 0.69	0.14	-0.01	-0.07	-0.03
R-30	≥ 0.7	0.22	-0.01	-0.10	-0.04

Table 219. Cool Roofs—Climate Zone 4: Corpus Christi, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating Savings		
			Gas	Electric resistance	Heat pump
Steep slope					
< R-5	0.15 – 0.29	0.04	0.00	-0.01	0.00
< R-5	0.3 – 0.49	0.19	0.00	-0.08	-0.03
< R-5	0.5 – 0.69	0.34	0.00	-0.15	-0.06
< R-5	≥ 0.7	0.50	-0.01	-0.23	-0.08
R-5 to R-8	0.15 – 0.29	0.03	0.00	-0.01	0.00
R-5 to R-8	0.3 – 0.49	0.14	0.00	-0.06	-0.02
R-5 to R-8	0.5 – 0.69	0.26	0.00	-0.11	-0.04
R-5 to R-8	≥ 0.7	0.38	-0.01	-0.17	-0.06
R-9 to R-14	0.15 – 0.29	0.02	0.00	-0.01	0.00
R-9 to R-14	0.3 – 0.49	0.10	0.00	-0.04	-0.02
R-9 to R-14	0.5 – 0.69	0.17	0.00	-0.08	-0.03
R-9 to R-14	≥ 0.7	0.26	0.00	-0.11	-0.04
R-15 to R-22	0.15 - 0.29	0.01	0.00	-0.01	0.00
R-15 to R-22	0.3 – 0.49	0.06	0.00	-0.03	-0.01
R-15 to R-22	0.5 – 0.69	0.12	0.00	-0.05	-0.02
R-15 to R-22	≥ 0.7	0.17	0.00	-0.08	-0.03
R-30	0.15 – 0.29	0.01	0.00	0.00	0.00
R-30	0.3 – 0.49	0.04	0.00	-0.02	-0.01
R-30	0.5 – 0.69	0.07	0.00	-0.03	-0.01
R-30	≥ 0.7	0.11	0.00	-0.05	-0.02

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating Savings		
			Gas	Electric resistance	Heat pump
Low slope					
< R-5	0.5 – 0.69	0.37	0.00	-0.17	-0.07
< R-5	≥ 0.7	0.54	-0.01	-0.25	-0.09
R-5 to R-8	0.5 – 0.69	0.28	0.00	-0.13	-0.05
R-5 to R-8	≥ 0.7	0.41	-0.01	-0.19	-0.07
R-9 to R-14	0.5 – 0.69	0.19	0.00	-0.09	-0.03
R-9 to R-14	≥ 0.7	0.28	0.00	-0.13	-0.05
R-15 to R-22	0.5 – 0.69	0.13	0.00	-0.06	-0.02
R-15 to R-22	≥ 0.7	0.19	0.00	-0.08	-0.03
R-30	0.5 – 0.69	0.09	0.00	-0.04	-0.01
R-30	≥ 0.7	0.13	0.00	-0.06	-0.02

Table 220. Cool Roofs—Climate Zone 5: El Paso,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Steep slope						
< R-5	0.15 – 0.29	0.05	0.02	0.00	-0.05	-0.02
< R-5	0.3 – 0.49	0.27	0.10	-0.01	-0.26	-0.09
< R-5	0.5 – 0.69	0.50	0.19	-0.02	-0.49	-0.19
< R-5	≥ 0.7	0.74	0.29	-0.04	-0.77	-0.29
R-5 to R-8	0.15 – 0.29	0.04	0.02	0.00	-0.04	-0.01
R-5 to R-8	0.3 – 0.49	0.21	0.08	-0.01	-0.20	-0.07
R-5 to R-8	0.5 – 0.69	0.39	0.15	-0.02	-0.38	-0.14
R-5 to R-8	≥ 0.7	0.58	0.23	-0.03	-0.59	-0.22
R-9 to R-14	0.15 – 0.29	0.03	0.01	0.00	-0.03	-0.01
R-9 to R-14	0.3 – 0.49	0.15	0.06	-0.01	-0.14	-0.05
R-9 to R-14	0.5 – 0.69	0.27	0.11	-0.01	-0.27	-0.10
R-9 to R-14	≥ 0.7	0.41	0.16	-0.02	-0.41	-0.15
R-15 to R-22	0.15 – 0.29	0.02	0.01	0.00	-0.02	-0.01
R-15 to R-22	0.3 – 0.49	0.10	0.04	-0.01	-0.10	-0.04
R-15 to R-22	0.5 – 0.69	0.19	0.08	-0.01	-0.18	-0.07

Ceiling insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
R-15 to R-22	≥ 0.7	0.29	0.12	-0.02	-0.28	-0.10
R-30	0.15 – 0.29	0.01	0.01	0.00	-0.01	-0.01
R-30	0.3 – 0.49	0.07	0.03	0.00	-0.06	-0.02
R-30	0.5 – 0.69	0.13	0.05	-0.01	-0.12	-0.04
R-30	≥ 0.7	0.20	0.08	-0.01	-0.18	-0.07
Low slope						
< R-5	0.5 – 0.69	0.57	0.22	-0.02	-0.56	-0.21
< R-5	≥ 0.7	0.84	0.32	-0.04	-0.88	-0.33
R-5 to R-8	0.5 – 0.69	0.45	0.18	-0.02	-0.44	-0.16
R-5 to R-8	≥ 0.7	0.66	0.26	-0.03	-0.68	-0.25
R-9 to R-14	0.5 – 0.69	0.32	0.13	-0.02	-0.31	-0.12
R-9 to R-14	≥ 0.7	0.47	0.19	-0.03	-0.47	-0.18
R-15 to R-22	0.5 – 0.69	0.23	0.09	-0.01	-0.21	-0.08
R-15 to R-22	≥ 0.7	0.34	0.14	-0.02	-0.32	-0.12
R-30	0.5 – 0.69	0.17	0.07	-0.01	-0.14	-0.06
R-30	≥ 0.7	0.25	0.10	-0.02	-0.22	-0.08

Homes with Roof Deck Insulation

Table 221 through Table 225 present the energy savings (kWh) for the installation of a reflective roof on homes with varying levels of roof deck insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

Table 221. Cool Roofs—Climate Zone 1: Amarillo,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Steep slope						
R-19	0.15 – 0.29	0.00	0.00	0.00	0.00	0.00
R-19	0.3 – 0.49	0.06	0.02	-0.01	-0.13	-0.05
R-19	0.5 – 0.69	0.13	0.04	-0.01	-0.28	-0.11
R-19	≥ 0.7	0.20	0.07	-0.02	-0.42	-0.16
R-30	0.15 – 0.29	0.01	0.00	0.00	-0.01	-0.01

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
R-30	0.3 – 0.49	0.05	0.02	-0.01	-0.12	-0.04
R-30	0.5 – 0.69	0.11	0.03	-0.01	-0.23	-0.09
R-30	≥ 0.7	0.16	0.05	-0.02	-0.35	-0.14
R-38	0.15 – 0.29	0.01	0.00	0.00	-0.02	-0.01
R-38	0.3 – 0.49	0.05	0.02	-0.01	-0.11	-0.04
R-38	0.5 – 0.69	0.09	0.03	-0.01	-0.20	-0.08
R-38	≥ 0.7	0.13	0.04	-0.02	-0.30	-0.12
Low slope						
R-19	0.5 – 0.69	0.13	0.04	-0.01	-0.27	-0.11
R-19	≥ 0.7	0.20	0.07	-0.02	-0.42	-0.16
R-30	0.5 – 0.69	0.11	0.03	-0.01	-0.23	-0.09
R-30	≥ 0.7	0.16	0.05	-0.02	-0.34	-0.13
R-38	0.5 – 0.69	0.09	0.03	-0.01	-0.20	-0.08
R-38	≥ 0.7	0.13	0.04	-0.02	-0.29	-0.11

Table 222. Cool Roofs—Climate Zone 2: Dallas,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Steep slope					
R-19	0.15 – 0.29	0.00	0.00	0.00	0.00
R-19	0.3 – 0.49	0.10	0.00	-0.09	-0.03
R-19	0.5 – 0.69	0.21	-0.01	-0.18	-0.07
R-19	≥ 0.7	0.32	-0.01	-0.28	-0.11
R-30	0.15 – 0.29	0.01	0.00	-0.01	-0.01
R-30	0.3 – 0.49	0.09	0.00	-0.08	-0.03
R-30	0.5 – 0.69	0.17	-0.01	-0.15	-0.06
R-30	≥ 0.7	0.26	-0.01	-0.23	-0.09
R-38	0.15 – 0.29	0.02	0.00	-0.01	-0.01
R-38	0.3 – 0.49	0.08	0.00	-0.07	-0.03
R-38	0.5 – 0.69	0.14	-0.01	-0.13	-0.05
R-38	≥ 0.7	0.21	-0.01	-0.19	-0.07

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Low slope					
R-19	0.5 – 0.69	0.21	-0.01	-0.18	-0.07
R-19	≥ 0.7	0.32	-0.01	-0.28	-0.11
R-30	0.5 – 0.69	0.17	-0.01	-0.15	-0.06
R-30	≥ 0.7	0.26	-0.01	-0.23	-0.09
R-38	0.5 – 0.69	0.14	-0.01	-0.13	-0.05
R-38	≥ 0.7	0.21	-0.01	-0.19	-0.07

Table 223. Cool Roofs—Climate Zone 3: Houston,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Steep slope					
R-19	0.15 – 0.29	0.00	0.00	0.00	0.00
R-19	0.3 – 0.49	0.11	0.00	-0.07	-0.03
R-19	0.5 – 0.69	0.22	-0.01	-0.14	-0.05
R-19	≥ 0.7	0.34	-0.01	-0.22	-0.08
R-30	0.15 – 0.29	0.01	0.00	-0.01	0.00
R-30	0.3 – 0.49	0.09	0.00	-0.06	-0.02
R-30	0.5 – 0.69	0.19	0.00	-0.12	-0.04
R-30	≥ 0.7	0.28	-0.01	-0.18	-0.07
R-38	0.15 – 0.29	0.02	0.00	-0.01	0.00
R-38	0.3 – 0.49	0.08	0.00	-0.06	-0.02
R-38	0.5 – 0.69	0.16	0.00	-0.10	-0.04
R-38	≥ 0.7	0.23	-0.01	-0.15	-0.06
Low slope					
R-19	0.5 – 0.69	0.22	-0.01	-0.14	-0.06
R-19	≥ 0.7	0.35	-0.01	-0.22	-0.08
R-30	0.5 – 0.69	0.19	0.00	-0.12	-0.05
R-30	≥ 0.7	0.28	-0.01	-0.18	-0.07
R-38	0.5 – 0.69	0.16	0.00	-0.10	-0.04
R-38	≥ 0.7	0.23	-0.01	-0.15	-0.06

Table 224. Cool Roofs—Climate Zone 4: Corpus Christi,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings (refrigerated)	Heating savings		
			Gas	Electric resistance	Heat pump
Steep slope					
R-19	0.15 – 0.29	0.00	0.00	0.00	0.00
R-19	0.3 – 0.49	0.09	0.00	-0.04	-0.02
R-19	0.5 – 0.69	0.17	0.00	-0.09	-0.03
R-19	≥ 0.7	0.26	0.00	-0.13	-0.05
R-30	0.15 – 0.29	0.01	0.00	-0.01	0.00
R-30	0.3 – 0.49	0.08	0.00	-0.03	-0.01
R-30	0.5 – 0.69	0.14	0.00	-0.07	-0.02
R-30	≥ 0.7	0.21	0.00	-0.11	-0.04
R-38	0.15 – 0.29	0.01	0.00	-0.01	0.00
R-38	0.3 – 0.49	0.07	0.00	-0.03	-0.01
R-38	0.5 – 0.69	0.12	0.00	-0.06	-0.02
R-38	≥ 0.7	0.18	0.00	-0.09	-0.03
Low slope					
R-19	0.5 – 0.69	0.23	-0.01	-0.29	-0.11
R-19	≥ 0.7	0.36	-0.02	-0.46	-0.18
R-30	0.5 – 0.69	0.17	0.00	-0.16	-0.06
R-30	≥ 0.7	0.26	-0.01	-0.25	-0.09
R-38	0.5 – 0.69	0.12	0.00	-0.06	-0.02
R-38	≥ 0.7	0.18	0.00	-0.09	-0.03

Table 225. Cool Roofs—Climate Zone 5: El Paso,
Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Steep slope						
R-19	0.15 – 0.29	0.00	0.00	0.00	0.00	0.00
R-19	0.3 – 0.49	0.11	0.04	-0.01	-0.14	-0.05
R-19	0.5 – 0.69	0.22	0.08	-0.01	-0.28	-0.11
R-19	≥ 0.7	0.35	0.12	-0.02	-0.45	-0.17
R-30	0.15 – 0.29	0.01	0.01	0.00	-0.01	-0.01

Roof deck insulation R-value	Installed roof material 3-year reflectance	Cooling savings		Heating savings		
		Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
R-30	0.3 – 0.49	0.10	0.03	0.00	-0.12	-0.04
R-30	0.5 – 0.69	0.19	0.06	-0.01	-0.23	-0.09
R-30	≥ 0.7	0.28	0.10	-0.01	-0.37	-0.14
R-38	0.15 – 0.29	0.02	0.01	0.00	-0.02	-0.01
R-38	0.3 – 0.49	0.09	0.03	0.00	-0.11	-0.04
R-38	0.5 – 0.69	0.16	0.05	-0.01	-0.20	-0.08
R-38	≥ 0.7	0.23	0.08	-0.01	-0.31	-0.12
Low slope						
R-19	0.5 – 0.69	0.23	0.08	-0.01	-0.29	-0.11
R-19	≥ 0.7	0.36	0.12	-0.02	-0.46	-0.18
R-30	0.5 – 0.69	0.19	0.06	-0.01	-0.24	-0.09
R-30	≥ 0.7	0.29	0.10	-0.01	-0.38	-0.15
R-38	0.5 – 0.69	0.16	0.05	-0.01	-0.21	-0.08
R-38	≥ 0.7	0.24	0.08	-0.01	-0.32	-0.12

Deemed Summer Demand Savings Tables

Savings are presented first for homes with ceiling insulation, and subsequently for those with roof deck insulation. 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 226 through Table 230 by a factor of 0.6.

Homes with Ceiling Insulation

Table 226 through Table 230 present the summer demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of ceiling insulation (attic floor) for the five Texas climate zones. Savings are per square foot of treated roof area.

Table 226. Cool Roofs—Climate Zone 1: Amarillo,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
< R-5	0.15 – 0.29	–	–	2.34 x 10-5	1.06 x 10-5
< R-5	0.3 – 0.49	–	–	1.21 x 10-4	6.05 x 10-5
< R-5	0.5 – 0.69	2.50 x 10-4	1.18 x 10-4	2.35 x 10-4	1.06 x 10-4
< R-5	≥ 0.7	3.97 x 10-4	1.94 x 10-4	3.94 x 10-4	1.85 x 10-4
R-5 to R-8	0.15 – 0.29	–	–	1.48 x 10-5	6.69 x 10-6

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-5 to R-8	0.3 – 0.49	–	–	8.09 x 10-5	4.47 x 10-5
R-5 to R-8	0.5 – 0.69	1.78 x 10-4	9.21 x 10-5	1.63 x 10-4	7.51 x 10-5
R-5 to R-8	≥ 0.7	2.85 x 10-4	1.55 x 10-4	2.86 x 10-4	1.40 x 10-4
R-9 to R-14	0.15 – 0.29	–	–	6.05 x 10-6	7.93 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	5.64 x 10-5	2.18 x 10-5
R-9 to R-14	0.5 – 0.69	1.17 x 10-4	5.99 x 10-5	1.08 x 10-4	4.52 x 10-5
R-9 to R-14	≥ 0.7	1.92 x 10-4	9.10 x 10-5	1.90 x 10-4	9.38 x 10-5
R-15 to R-22	0.15 – 0.29	–	–	2.30 x 10-6	-8.73 x 10-7
R-15 to R-22	0.3 – 0.49	–	–	3.55 x 10-5	1.53 x 10-5
R-15 to R-22	0.5 – 0.69	7.90 x 10-5	3.73 x 10-5	7.34 x 10-5	2.74 x 10-5
R-15 to R-22	≥ 0.7	1.31 x 10-4	6.28 x 10-5	1.37 x 10-4	7.50 x 10-5
R-30	0.15 – 0.29	–	–	-8.06 x 10-7	3.42 x 10-6
R-30	0.3 – 0.49	–	–	2.36 x 10-5	1.83 x 10-5
R-30	0.5 – 0.69	5.39 x 10-5	1.76 x 10-5	4.99 x 10-5	2.70 x 10-5
R-30	≥ 0.7	9.25 x 10-5	4.31 x 10-5	9.56 x 10-5	5.99 x 10-5

Table 227. Cool Roofs—Climate Zone 2: Dallas,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
< R-5	0.15 – 0.29	–	3.46 x 10-5
< R-5	0.3 – 0.49	–	1.79 x 10-4
< R-5	0.5 – 0.69	3.63 x 10-4	3.41 x 10-4
< R-5	≥ 0.7	5.36 x 10-4	5.15 x 10-4
R-5 to R-8	0.15 – 0.29	–	2.63 x 10-5
R-5 to R-8	0.3 – 0.49	–	1.36 x 10-4
R-5 to R-8	0.5 – 0.69	2.83 x 10-4	2.64 x 10-4
R-5 to R-8	≥ 0.7	4.10 x 10-4	4.06 x 10-4
R-9 to R-14	0.15 – 0.29	–	1.78 x 10-5
R-9 to R-14	0.3 – 0.49	–	1.02 x 10-4
R-9 to R-14	0.5 – 0.69	1.99 x 10-4	1.73 x 10-4
R-9 to R-14	≥ 0.7	2.85 x 10-4	2.85 x 10-4
R-15 to R-22	0.15 – 0.29	–	9.26 x 10-6
R-15 to R-22	0.3 – 0.49	–	7.69 x 10-5

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
R-15 to R-22	0.5 – 0.69	1.47 x 10-4	1.23 x 10-4
R-15 to R-22	≥ 0.7	2.04 x 10-4	2.15 x 10-4
R-30	0.15 – 0.29	–	1.34 x 10-5
R-30	0.3 – 0.49	–	5.58 x 10-5
R-30	0.5 – 0.69	1.01 x 10-4	8.64 x 10-5
R-30	≥ 0.7	1.52 x 10-4	1.58 x 10-4

Table 228. Cool Roofs—Climate Zone 3: Houston,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
< R-5	0.15 – 0.29	–	3.27 x 10-5
< R-5	0.3 – 0.49	–	1.74 x 10-4
< R-5	0.5 – 0.69	3.62 x 10-4	3.56 x 10-4
< R-5	≥ 0.7	5.86 x 10-4	5.48 x 10-4
R-5 to R-8	0.15 – 0.29	–	2.38 x 10-5
R-5 to R-8	0.3 – 0.49	–	1.33 x 10-4
R-5 to R-8	0.5 – 0.69	2.76 x 10-4	2.72 x 10-4
R-5 to R-8	≥ 0.7	4.64 x 10-4	4.28 x 10-4
R-9 to R-14	0.15 – 0.29	–	1.55 x 10-5
R-9 to R-14	0.3 – 0.49	–	1.07 x 10-4
R-9 to R-14	0.5 – 0.69	2.12 x 10-4	2.03 x 10-4
R-9 to R-14	≥ 0.7	3.30 x 10-4	3.11 x 10-4
R-15 to R-22	0.15 – 0.29	–	1.75 x 10-5
R-15 to R-22	0.3 – 0.49	–	7.56 x 10-5
R-15 to R-22	0.5 – 0.69	1.53 x 10-4	1.44 x 10-4
R-15 to R-22	≥ 0.7	2.37 x 10-4	2.26 x 10-4
R-30	0.15 – 0.29	–	9.44 x 10-6
R-30	0.3 – 0.49	–	5.11 x 10-5
R-30	0.5 – 0.69	1.09 x 10-4	9.65 x 10-5
R-30	≥ 0.7	1.75 x 10-4	1.64 x 10-4

Table 229. Cool Roofs—Climate Zone 4: Corpus Christi,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-Year reflectance	Low slope	Steep slope
< R-5	0.15 – 0.29	–	1.82 x 10-5
< R-5	0.3 – 0.49	–	9.19 x 10-5
< R-5	0.5 – 0.69	1.67 x 10-4	1.66 x 10-4
< R-5	≥ 0.7	2.75 x 10-4	2.69 x 10-4
R-5 to R-8	0.15 – 0.29	–	1.46 x 10-5
R-5 to R-8	0.3 – 0.49	–	6.97 x 10-5
R-5 to R-8	0.5 – 0.69	1.22 x 10-4	1.23 x 10-4
R-5 to R-8	≥ 0.7	2.02 x 10-4	2.01 x 10-4
R-9 to R-14	0.15 – 0.29	–	6.80 x 10-6
R-9 to R-14	0.3 – 0.49	–	4.15 x 10-5
R-9 to R-14	0.5 – 0.69	7.62 x 10-5	7.37 x 10-5
R-9 to R-14	≥ 0.7	1.26 x 10-4	1.28 x 10-4
R-15 to R-22	0.15 – 0.29	–	4.71 x 10-6
R-15 to R-22	0.3 – 0.49	–	2.55 x 10-5
R-15 to R-22	0.5 – 0.69	4.24 x 10-5	4.39 x 10-5
R-15 to R-22	≥ 0.7	7.33 x 10-5	7.94 x 10-5
R-30	0.15 – 0.29	–	2.50 x 10-6
R-30	0.3 – 0.49	–	1.01 x 10-5
R-30	0.5 – 0.69	2.41 x 10-5	2.04 x 10-5
R-30	≥ 0.7	4.01 x 10-5	4.77 x 10-5

Table 230. Cool Roofs—Climate Zone 5: El Paso,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
< R-5	0.15 – 0.29	–	–	3.58 x 10-5	1.28 x 10-5
< R-5	0.3 – 0.49	–	–	1.72 x 10-4	7.49 x 10-5
< R-5	0.5 – 0.69	3.95 x 10-4	1.54 x 10-4	3.44 x 10-4	1.65 x 10-4
< R-5	≥ 0.7	6.15 x 10-4	2.42 x 10-4	5.19 x 10-4	2.20 x 10-4
R-5 to R-8	0.15 – 0.29	–	–	2.72 x 10-5	8.96 x 10-6
R-5 to R-8	0.3 – 0.49	–	–	1.27 x 10-4	6.00 x 10-5
R-5 to R-8	0.5 – 0.69	3.06 x 10-4	1.34 x 10-4	2.59 x 10-4	1.38 x 10-4

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-5 to R-8	≥ 0.7	4.77 x 10-4	2.05 x 10-4	3.97 x 10-4	1.78 x 10-4
R-9 to R-14	0.15 – 0.29	–	–	1.25 x 10-5	9.26 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	8.24 x 10-5	5.30 x 10-5
R-9 to R-14	0.5 – 0.69	2.07 x 10-4	1.00 x 10-4	1.73 x 10-4	8.86 x 10-5
R-9 to R-14	≥ 0.7	3.27 x 10-4	1.44 x 10-4	2.60 x 10-4	1.22 x 10-4
R-15 to R-22	0.15 – 0.29	–	–	6.16 x 10-6	3.73 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	6.18 x 10-5	4.40 x 10-5
R-15 to R-22	0.5 – 0.69	1.50 x 10-4	7.63 x 10-5	1.24 x 10-4	6.49 x 10-5
R-15 to R-22	≥ 0.7	2.42 x 10-4	1.11 x 10-4	1.88 x 10-4	8.86 x 10-5
R-30	0.15 – 0.29	–	–	6.64 x 10-6	5.65 x 10-7
R-30	0.3 – 0.49	–	–	4.77 x 10-5	2.87 x 10-5
R-30	0.5 – 0.69	1.01 x 10-4	5.91 x 10-5	8.81 x 10-5	5.07 x 10-5
R-30	≥ 0.7	1.80 x 10-4	8.50 x 10-5	1.32 x 10-4	6.75 x 10-5

Homes with Roof Deck Insulation

Table 231 through Table 235 present the summer demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of roof deck for the five Texas climate zones. Savings are per square foot of treated roof area.

Table 231. Cool Roofs—Climate Zone 1: Amarillo,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-19	0.15 – 0.29	–	–	–	–
R-19	0.3 – 0.49	–	–	2.67 x 10-5	7.62 x 10-6
R-19	0.5 – 0.69	5.56 x 10-5	1.84 x 10-5	5.35 x 10-5	1.55 x 10-5
R-19	≥ 0.7	9.88 x 10-5	7.61 x 10-6	8.81 x 10-5	1.52 x 10-5
R-30	0.15 – 0.29	–	–	3.37 x 10-6	3.42 x 10-6
R-30	0.3 – 0.49	–	–	1.97 x 10-5	7.38 x 10-6
R-30	0.5 – 0.69	3.21 x 10-5	9.13 x 10-6	3.06 x 10-5	1.25 x 10-5
R-30	≥ 0.7	6.91 x 10-5	8.48 x 10-6	5.94 x 10-5	1.60 x 10-5
R-38	0.15 – 0.29	–	–	5.82 x 10-6	5.90 x 10-6

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-38	0.3 – 0.49	–	–	1.46 x 10-5	7.20 x 10-6
R-38	0.5 – 0.69	1.50 x 10-5	2.38 x 10-6	1.40 x 10-5	1.04 x 10-5
R-38	≥ 0.7	4.75 x 10-5	9.12 x 10-6	3.85 x 10-5	1.66 x 10-5

Table 232. Cool Roofs—Climate Zone 2: Dallas,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
		Refrigerated	Refrigerated
R-19	0.15 – 0.29	–	5.45 x 10-5
R-19	0.3 – 0.49	–	9.02 x 10-5
R-19	0.5 – 0.69	7.41 x 10-5	1.21 x 10-4
R-19	≥ 0.7	1.16 x 10-4	5.18 x 10-6
R-30	0.15 – 0.29	–	2.22 x 10-5
R-30	0.3 – 0.49	–	5.01 x 10-5
R-30	0.5 – 0.69	4.37 x 10-5	7.67 x 10-5
R-30	≥ 0.7	7.41 x 10-5	3.37 x 10-5
R-38	0.15 – 0.29	–	-1.31 x 10-6
R-38	0.3 – 0.49	–	2.10 x 10-5
R-38	0.5 – 0.69	2.16 x 10-5	4.44 x 10-5
R-38	≥ 0.7	4.36 x 10-5	5.45 x 10-5

Table 233. Cool Roofs—Climate Zone 3: Houston,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
		Refrigerated	Refrigerated
R-19	0.15 – 0.29	–	–
R-19	0.3 – 0.49	–	–
R-19	0.5 – 0.69	9.43 x 10-5	9.42 x 10-5
R-19	≥ 0.7	1.32 x 10-4	1.21 x 10-4
R-30	0.15 – 0.29	–	-1.46 x 10-6
R-30	0.3 – 0.49	–	2.60 x 10-5
R-30	0.5 – 0.69	7.13 x 10-5	6.50 x 10-5

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
		Refrigerated	Refrigerated
R-30	≥ 0.7	8.56 x 10-5	8.46 x 10-5
R-38	0.15 – 0.29	–	-2.53 x 10-6
R-38	0.3 – 0.49	–	1.37 x 10-5
R-38	0.5 – 0.69	5.46 x 10-5	4.37 x 10-5
R-38	≥ 0.7	5.19 x 10-5	5.82 x 10-5

Table 234. Cool Roofs—Climate Zone 4: Corpus Christi,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope	Steep slope
		Refrigerated	Refrigerated
R-19	0.15 – 0.29	–	–
R-19	0.3 – 0.49	–	3.38 x 10-5
R-19	0.5 – 0.69	4.44 x 10-5	5.01 x 10-5
R-19	≥ 0.7	7.43 x 10-5	7.37 x 10-5
R-30	0.15 – 0.29	–	3.36 x 10-6
R-30	0.3 – 0.49	–	2.68 x 10-5
R-30	0.5 – 0.69	2.09 x 10-5	3.56 x 10-5
R-30	≥ 0.7	5.33 x 10-5	5.29 x 10-5
R-38	0.15 – 0.29	–	5.81 x 10-6
R-38	0.3 – 0.49	–	2.17 x 10-5
R-38	0.5 – 0.69	3.83 x 10-6	2.51 x 10-5
R-38	≥ 0.7	3.80 x 10-5	3.78 x 10-5

Table 235. Cool Roofs—Climate Zone 5: El Paso,
Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-19	0.15 – 0.29	–	–	–	–
R-19	0.3 – 0.49	–	–	3.64 x 10-5	2.24 x 10-5
R-19	0.5 – 0.69	8.11 x 10-5	2.76 x 10-5	8.95 x 10-5	4.42 x 10-5
R-19	≥ 0.7	1.33 x 10-4	2.30 x 10-5	1.35 x 10-4	4.44 x 10-5
R-30	0.15 – 0.29	–	–	6.66 x 10-6	1.11 x 10-6
R-30	0.3 – 0.49	–	–	3.01 x 10-5	5.29 x 10-6
R-30	0.5 – 0.69	5.61 x 10-5	1.09 x 10-5	6.63 x 10-5	1.83 x 10-5

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope		Steep slope	
		Refrigerated	Evaporative	Refrigerated	Evaporative
R-30	≥ 0.7	1.13 x 10-4	1.29 x 10-5	1.05 x 10-4	2.23 x 10-5
R-38	0.15 – 0.29	–	–	1.15 x 10-5	1.91 x 10-6
R-38	0.3 – 0.49	–	–	2.55 x 10-5	-7.15 x 10-6
R-38	0.5 – 0.69	3.79 x 10-5	-1.22 x 10-6	4.95 x 10-5	-5.19 x 10-7
R-38	≥ 0.7	9.92 x 10-5	5.60 x 10-6	8.40 x 10-5	6.29 x 10-6

Deemed Winter Demand Savings Tables

Savings are presented first for homes with ceiling insulation, and subsequently for those with roof deck insulation. 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 236 through Table 240 by a factor of 0.24.[257]

Homes with Ceiling Insulation

Table 236 through Table 240 present the winter demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of ceiling insulation (attic floor) for the five Texas climate zones. Savings are per square foot of treated roof area.

Table 236. Cool Roofs—Climate Zone 1: Amarillo,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
< R-5	0.15 – 0.29	–	–	–	-5.60 x 10-7	-1.18 x 10-5	-5.68 x 10-6
< R-5	0.3 – 0.49	–	–	–	-3.08 x 10-6	-5.83 x 10-5	-2.67 x 10-5
< R-5	0.5 – 0.69	-3.03 x 10-6	-1.14 x 10-4	-5.47 x 10-5	-6.38 x 10-6	-1.06 x 10-4	-4.91 x 10-5
< R-5	≥ 0.7	-1.46 x 10-5	-1.66 x 10-4	-8.19 x 10-5	-2.21 x 10-5	-1.54 x 10-4	-7.28 x 10-5
R-5 to R-8	0.15 – 0.29	–	–	–	-1.01 x 10-6	-9.53 x 10-6	-4.74 x 10-6
R-5 to R-8	0.3 – 0.49	–	–	–	-4.25 x 10-6	-4.66 x 10-5	-2.12 x 10-5
R-5 to R-8	0.5 – 0.69	1.52 x 10-6	-9.25 x 10-5	-4.52 x 10-5	-5.04 x 10-6	-8.62 x 10-5	-4.15 x 10-5
R-5 to R-8	≥ 0.7	-9.01 x 10-6	-1.34 x 10-4	-6.68 x 10-5	-2.13 x 10-5	-1.24 x 10-4	-5.82 x 10-5
R-9 to R-14	0.15 – 0.29	–	–	–	-8.59 x 10-7	-7.63 x 10-6	-3.69 x 10-6

[257] 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.

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-9 to R-14	0.3 – 0.49	–	–	–	-3.68 x 10-6	-3.63 x 10-5	-1.55 x 10-5
R-9 to R-14	0.5 – 0.69	-1.04 x 10-7	-7.28 x 10-5	-3.43 x 10-5	-1.49 x 10-5	-6.73 x 10-5	-3.07 x 10-5
R-9 to R-14	≥ 0.7	-6.86 x 10-6	-1.05 x 10-4	-4.98 x 10-5	-2.11 x 10-5	-9.83 x 10-5	-4.57 x 10-5
R-15 to R-22	0.15 – 0.29	–	–	–	-8.96 x 10-7	-5.40 x 10-6	-2.51 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	–	-3.85 x 10-6	-2.60 x 10-5	-1.08 x 10-5
R-15 to R-22	0.5 – 0.69	-1.72 x 10-6	-5.26 x 10-5	-2.47 x 10-5	-1.19 x 10-5	-4.80 x 10-5	-2.15 x 10-5
R-15 to R-22	≥ 0.7	-9.72 x 10-7	-7.65 x 10-5	-3.64 x 10-5	-1.44 x 10-5	-7.05 x 10-5	-3.23 x 10-5
R-30	0.15 – 0.29	-	-	-	-8.09 x 10-7	-3.58 x 10-6	-1.64 x 10-6
R-30	0.3 – 0.49	-	-	-	-1.08 x 10-5	-1.73 x 10-5	-7.31 x 10-6
R-30	0.5 – 0.69	-5.10 x 10-6	-3.52 x 10-5	-1.58 x 10-5	-1.54 x 10-5	-3.12 x 10-5	-1.36 x 10-5
R-30	≥ 0.7	-3.71 x 10-6	-5.35 x 10-5	-2.58 x 10-5	-2.10 x 10-5	-4.64 x 10-5	-2.11 x 10-5

Table 237. Cool Roofs—Climate Zone 2: Dallas,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
< R-5	0.15 – 0.29	–	–	–	2.40 x 10-6	-1.29 x 10-5	-6.63 x 10-6
< R-5	0.3 – 0.49	–	–	–	-2.62 x 10-8	-6.19 x 10-5	-3.24 x 10-5
< R-5	0.5 – 0.69	-2.83 x 10-6	-1.48 x 10-4	-7.24 x 10-5	-1.44 x 10-6	-1.19 x 10-4	-6.06 x 10-5
< R-5	≥ 0.7	-6.02 x 10-6	-2.17 x 10-4	-1.07 x 10-4	-4.75 x 10-6	-1.81 x 10-4	-9.06 x 10-5
R-5 to R-8	0.15 – 0.29	–	–	–	4.57 x 10-6	-1.03 x 10-5	-5.30 x 10-6
R-5 to R-8	0.3 – 0.49	–	–	–	1.59 x 10-6	-4.70 x 10-5	-2.68 x 10-5
R-5 to R-8	0.5 – 0.69	-3.36 x 10-6	-1.19 x 10-4	-5.69 x 10-5	1.19 x 10-6	-9.33 x 10-5	-4.88 x 10-5
R-5 to R-8	≥ 0.7	-3.79 x 10-6	-1.74 x 10-4	-8.66 x 10-5	-4.46 x 10-6	-1.43 x 10-4	-7.18 x 10-5
R-9 to R-14	0.15 – 0.29	–	–	–	-7.26 x 10-7	-8.09 x 10-6	-3.86 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	–	-2.92 x 10-6	-4.23 x 10-5	-2.03 x 10-5
R-9 to R-14	0.5 – 0.69	-1.29 x 10-5	-9.30 x 10-5	-4.31 x 10-5	-3.26 x 10-6	-7.90 x 10-5	-3.76 x 10-5
R-9 to R-14	≥ 0.7	-1.27 x 10-5	-1.41 x 10-4	-6.53 x 10-5	-7.53 x 10-6	-1.19 x 10-4	-5.52 x 10-5
R-15 to R-22	0.15 – 0.29	–	–	–	3.23 x 10-7	-5.84 x 10-6	-2.76 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	–	-1.95 x 10-6	-3.04 x 10-5	-1.43 x 10-5
R-15 to R-22	0.5 – 0.69	-1.48 x 10-5	-6.81 x 10-5	-3.23 x 10-5	-2.74 x 10-6	-5.69 x 10-5	-2.66 x 10-5
R-15 to R-22	≥ 0.7	-1.61 x 10-5	-1.02 x 10-4	-4.67 x 10-5	-3.88 x 10-7	-8.65 x 10-5	-4.05 x 10-5

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-30	0.15 – 0.29	–	–	–	-3.74 x 10-7	2.81 x 10-6	8.71 x 10-6
R-30	0.3 – 0.49	–	–	–	-1.78 x 10-6	-1.39 x 10-5	9.39 x 10-7
R-30	0.5 – 0.69	-3.37 x 10-6	-4.77 x 10-5	-2.23 x 10-5	-2.20 x 10-6	-3.16 x 10-5	-7.00 x 10-6
R-30	≥ 0.7	-1.67 x 10-5	-7.04 x 10-5	-3.03 x 10-5	-4.41 x 10-6	-5.14 x 10-5	-1.57 x 10-5

Table 238. Cool Roofs—Climate Zone 3: Houston,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
< R-5	0.15 - 0.29	–	–	–	-7.91 x 10-7	-1.54 x 10-5	-7.77 x 10-6
< R-5	0.3 – 0.49	–	–	–	-3.12 x 10-6	-7.71 x 10-5	-3.90 x 10-5
< R-5	0.5 – 0.69	-3.28 x 10-6	-1.56 x 10-4	-7.95 x 10-5	-6.08 x 10-6	-1.40 x 10-4	-7.09 x 10-5
< R-5	≥ 0.7	-4.78 x 10-6	-2.23 x 10-4	-1.11 x 10-4	-7.97 x 10-6	-2.04 x 10-4	-1.05 x 10-4
R-5 to R-8	0.15 - 0.29	–	–	–	-7.39 x 10-7	-1.25 x 10-5	-6.46 x 10-6
R-5 to R-8	0.3 – 0.49	–	–	–	-2.67 x 10-6	-6.28 x 10-5	-3.05 x 10-5
R-5 to R-8	0.5 – 0.69	-4.26 x 10-6	-1.28 x 10-4	-6.54 x 10-5	-5.79 x 10-6	-1.14 x 10-4	-5.59 x 10-5
R-5 to R-8	≥ 0.7	-4.68 x 10-6	-1.84 x 10-4	-9.11 x 10-5	-9.38 x 10-6	-1.68 x 10-4	-8.50 x 10-5
R-9 to R-14	0.15 - 0.29	–	–	–	-6.93 x 10-7	-9.35 x 10-6	-4.68 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	–	-3.38 x 10-6	-4.69 x 10-5	-2.31 x 10-5
R-9 to R-14	0.5 – 0.69	-5.14 x 10-6	-9.71 x 10-5	-4.78 x 10-5	-6.46 x 10-6	-8.68 x 10-5	-4.28 x 10-5
R-9 to R-14	≥ 0.7	-4.83 x 10-6	-1.41 x 10-4	-6.90 x 10-5	-1.00 x 10-5	-1.27 x 10-4	-6.19 x 10-5
R-15 to R-22	0.15 - 0.29	–	–	–	-7.06 x 10-7	-6.48 x 10-6	-3.22 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	–	-3.70 x 10-6	-3.32 x 10-5	-1.62 x 10-5
R-15 to R-22	0.5 – 0.69	-5.52 x 10-6	-6.85 x 10-5	-3.34 x 10-5	-6.80 x 10-6	-6.15 x 10-5	-3.00 x 10-5
R-15 to R-22	≥ 0.7	-8.06 x 10-6	-1.00 x 10-4	-4.89 x 10-5	-9.55 x 10-6	-9.10 x 10-5	-4.44 x 10-5
R-30	0.15 - 0.29	–	–	–	-6.32 x 10-7	-4.54 x 10-6	-2.25 x 10-6
R-30	0.3 – 0.49	–	–	–	-3.32 x 10-6	-2.23 x 10-5	-1.07 x 10-5
R-30	0.5 – 0.69	-5.55 x 10-6	-4.83 x 10-5	-2.35 x 10-5	-6.05 x 10-6	-4.13 x 10-5	-2.00 x 10-5
R-30	≥ 0.7	-6.77 x 10-6	-7.30 x 10-5	-3.95 x 10-5	-8.39 x 10-6	-6.06 x 10-5	-2.93 x 10-5

Table 239. Cool Roofs—Climate Zone 4: Corpus Christi,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
< R-5	0.15 - 0.29	–	–	–	-4.72 x 10-7	-1.47 x 10-5	-6.94 x 10-6
< R-5	0.3 – 0.49	–	–	–	-2.45 x 10-6	-7.36 x 10-5	-3.49 x 10-5
< R-5	0.5 – 0.69	-5.41 x 10-6	-1.51 x 10-4	-7.33 x 10-5	-4.77 x 10-6	-1.34 x 10-4	-6.20 x 10-5
< R-5	≥ 0.7	-7.53 x 10-6	-2.19 x 10-4	-1.02 x 10-4	-7.11 x 10-6	-1.99 x 10-4	-9.32 x 10-5
R-5 to R-8	0.15 - 0.29	–	–	–	-4.02 x 10-7	-1.19 x 10-5	-5.71 x 10-6
R-5 to R-8	0.3 – 0.49	–	–	–	-2.13 x 10-6	-5.99 x 10-5	-2.89 x 10-5
R-5 to R-8	0.5 – 0.69	-3.72 x 10-6	-1.20 x 10-4	-5.60 x 10-5	-3.17 x 10-6	-1.08 x 10-4	-5.08 x 10-5
R-5 to R-8	≥ 0.7	-7.11 x 10-6	-1.79 x 10-4	-8.65 x 10-5	-4.84 x 10-6	-1.61 x 10-4	-7.59 x 10-5
R-9 to R-14	0.15 - 0.29	–	–	–	-6.35 x 10-7	-8.94 x 10-6	-4.36 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	–	-1.95 x 10-6	-4.53 x 10-5	-2.21 x 10-5
R-9 to R-14	0.5 – 0.69	-3.55 x 10-6	-9.21 x 10-5	-4.40 x 10-5	-2.94 x 10-6	-8.27 x 10-5	-3.89 x 10-5
R-9 to R-14	≥ 0.7	-4.77 x 10-6	-1.35 x 10-4	-6.41 x 10-5	-3.95 x 10-6	-1.23 x 10-4	-5.95 x 10-5
R-15 to R-22	0.15 - 0.29	–	–	–	-1.73 x 10-6	-6.16 x 10-6	-2.94 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	–	-2.67 x 10-6	-3.25 x 10-5	-1.62 x 10-5
R-15 to R-22	0.5 – 0.69	-3.83 x 10-6	-6.74 x 10-5	-3.45 x 10-5	-3.08 x 10-6	-5.91 x 10-5	-2.83 x 10-5
R-15 to R-22	≥ 0.7	-4.47 x 10-6	-9.81 x 10-5	-4.84 x 10-5	-4.19 x 10-6	-8.82 x 10-5	-4.34 x 10-5
R-30	0.15 - 0.29	–	–	–	-1.34 x 10-7	-4.03 x 10-6	-1.87 x 10-6
R-30	0.3 – 0.49	–	–	–	-9.58 x 10-7	-2.14 x 10-5	-1.03 x 10-5
R-30	0.5 – 0.69	-3.13 x 10-6	-4.69 x 10-5	-2.41 x 10-5	-2.42 x 10-6	-4.01 x 10-5	-2.00 x 10-5
R-30	≥ 0.7	-3.46 x 10-6	-6.78 x 10-5	-3.32 x 10-5	-2.98 x 10-6	-5.89 x 10-5	-2.88 x 10-5

Table 240. Cool Roofs—Climate Zone 5: El Paso,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
< R-5	0.15 - 0.29	–	–	–	-6.68 x 10-7	-2.51 x 10-5	-1.01 x 10-5
< R-5	0.3 – 0.49	–	–	–	-7.29 x 10-6	-1.33 x 10-4	-5.50 x 10-5
< R-5	0.5 – 0.69	-1.53 x 10-5	-2.93 x 10-4	-1.17 x 10-4	-1.34 x 10-5	-2.50 x 10-4	-1.02 x 10-4
< R-5	≥ 0.7	-1.73 x 10-5	-4.44 x 10-4	-1.79 x 10-4	-1.93 x 10-5	-3.82 x 10-4	-1.57 x 10-4
R-5 to R-8	0.15 - 0.29	–	–	–	-2.41 x 10-7	-1.98 x 10-5	-7.98 x 10-6

Ceiling insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-5 to R-8	0.3 – 0.49	–	–	–	-4.83 x 10-6	-1.03 x 10-4	-4.14 x 10-5
R-5 to R-8	0.5 – 0.69	-1.33 x 10-5	-2.36 x 10-4	-9.44 x 10-5	-1.22 x 10-5	-1.99 x 10-4	-7.97 x 10-5
R-5 to R-8	≥ 0.7	-1.47 x 10-5	-3.64 x 10-4	-1.48 x 10-4	-1.73 x 10-5	-3.11 x 10-4	-1.28 x 10-4
R-9 to R-14	0.15 - 0.29	–	–	–	-5.77 x 10-7	-1.35 x 10-5	-5.48 x 10-6
R-9 to R-14	0.3 – 0.49	–	–	–	-4.07 x 10-6	-7.56 x 10-5	-3.15 x 10-5
R-9 to R-14	0.5 – 0.69	-9.52 x 10-6	-1.70 x 10-4	-6.83 x 10-5	-9.66 x 10-6	-1.44 x 10-4	-5.76 x 10-5
R-9 to R-14	≥ 0.7	-1.06 x 10-5	-2.73 x 10-4	-1.12 x 10-4	-1.38 x 10-5	-2.33 x 10-4	-9.66 x 10-5
R-15 to R-22	0.15 - 0.29	–	–	–	-4.29 x 10-7	-9.41 x 10-6	-4.20 x 10-6
R-15 to R-22	0.3 – 0.49	–	–	–	-3.14 x 10-6	-4.91 x 10-5	-2.00 x 10-5
R-15 to R-22	0.5 – 0.69	-7.55 x 10-6	-1.14 x 10-4	-4.66 x 10-5	-7.70 x 10-6	-9.71 x 10-5	-4.02 x 10-5
R-15 to R-22	≥ 0.7	-8.94 x 10-6	-1.85 x 10-4	-7.43 x 10-5	-1.05 x 10-5	-1.55 x 10-4	-6.29 x 10-5
R-30	0.15 - 0.29	–	–	–	-2.85 x 10-7	-6.26 x 10-6	-2.54 x 10-6
R-30	0.3 – 0.49	–	–	–	-2.32 x 10-6	-3.11 x 10-5	-1.25 x 10-5
R-30	0.5 – 0.69	-5.52 x 10-6	-7.44 x 10-5	-2.95 x 10-5	-6.01 x 10-6	-5.97 x 10-5	-2.46 x 10-5
R-30	≥ 0.7	-7.73 x 10-6	-1.20 x 10-4	-4.89 x 10-5	-7.78 x 10-6	-9.69 x 10-5	-3.98 x 10-5

Homes with Roof Deck Insulation

Table 241 through Table 245 present the winter demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of roof deck for the five Texas climate zones. Savings are per square foot of treated roof area.

Table 241. Cool Roofs—Climate Zone 1: Amarillo,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	0.15 - 0.29	–	–	–	–	–	–
R-19	0.3 – 0.49	–	–	–	6.62 x 10-7	-3.75 x 10-5	-1.86 x 10-5
R-19	0.5 – 0.69	1.68 x 10-6	-6.28 x 10-5	-2.35 x 10-5	5.59 x 10-6	-7.49 x 10-5	-3.71 x 10-5
R-19	≥ 0.7	-1.78 x 10-6	-9.77 x 10-5	-4.08 x 10-5	7.13 x 10-6	-1.12 x 10-4	-5.19 x 10-5
R-30	0.15 - 0.29	–	–	–	-1.08 x 10-7	-3.00 x 10-6	-1.52 x 10-6
R-30	0.3 – 0.49	–	–	–	2.49 x 10-6	-3.23 x 10-5	-1.75 x 10-5
R-30	0.5 – 0.69	-5.08 x 10-7	-5.14 x 10-5	-2.26 x 10-5	3.99 x 10-6	-6.01 x 10-5	-3.15 x 10-5

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-30	≥ 0.7	-1.76 x 10-6	-7.76 x 10-5	-3.59 x 10-5	4.24 x 10-6	-8.76 x 10-5	-4.38 x 10-5
R-38	0.15 - 0.29	–	–	–	-1.87 x 10-7	-5.19 x 10-6	-2.62 x 10-6
R-38	0.3 – 0.49	–	–	–	3.82 x 10-6	-2.85 x 10-5	-1.67 x 10-5
R-38	0.5 – 0.69	-2.10 x 10-6	-4.31 x 10-5	-2.20 x 10-5	2.82 x 10-6	-4.93 x 10-5	-2.74 x 10-5
R-38	≥ 0.7	-1.74 x 10-6	-6.29 x 10-5	-3.23 x 10-5	2.13 x 10-6	-6.99 x 10-5	-3.79 x 10-5

Table 242. Cool Roofs—Climate Zone 2: Dallas,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	0.15 - 0.29	–	–	–	–	–	–
R-19	0.3 – 0.49	–	–	–	-1.68 x 10-6	-4.21 x 10-5	-2.13 x 10-5
R-19	0.5 – 0.69	3.73 x 10-6	-8.26 x 10-5	-3.29 x 10-5	3.93 x 10-6	-8.72 x 10-5	-4.49 x 10-5
R-19	≥ 0.7	2.09 x 10-6	-1.33 x 10-4	-5.96 x 10-5	2.27 x 10-6	-1.30 x 10-4	-5.31 x 10-5
R-30	0.15 - 0.29	–	–	–	-7.35 x 10-8	-3.36 x 10-6	-1.70 x 10-6
R-30	0.3 – 0.49	–	–	–	-1.19 x 10-6	-3.52 x 10-5	-1.73 x 10-5
R-30	0.5 – 0.69	6.09 x 10-7	-6.66 x 10-5	-3.33 x 10-5	8.00 x 10-8	-6.99 x 10-5	-3.56 x 10-5
R-30	≥ 0.7	-1.22 x 10-6	-1.03 x 10-4	-5.11 x 10-5	-1.19 x 10-6	-1.03 x 10-4	-4.63 x 10-5
R-38	0.15 - 0.29	–	–	–	-1.27 x 10-7	-5.81 x 10-6	-2.93 x 10-6
R-38	0.3 – 0.49	–	–	–	-8.41 x 10-7	-3.02 x 10-5	-1.44 x 10-5
R-38	0.5 – 0.69	-1.66 x 10-6	-5.49 x 10-5	-3.36 x 10-5	-2.72 x 10-6	-5.73 x 10-5	-2.88 x 10-5
R-38	≥ 0.7	-3.63 x 10-6	-8.17 x 10-5	-4.49 x 10-5	-3.70 x 10-6	-8.42 x 10-5	-4.14 x 10-5

Table 243. Cool Roofs—Climate Zone 3: Houston,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	0.15 - 0.29	–	–	–	–	–	–
R-19	0.3 – 0.49	–	–	–	5.21 x 10-8	-4.60 x 10-5	-2.10 x 10-5
R-19	0.5 – 0.69	-4.82 x 10-7	-9.84 x 10-5	-5.19 x 10-5	-1.73 x 10-7	-9.69 x 10-5	-4.88 x 10-5
R-19	≥ 0.7	1.47 x 10-6	-1.47 x 10-4	-7.52 x 10-5	2.13 x 10-6	-1.52 x 10-4	-8.03 x 10-5
R-30	0.15 - 0.29	–	–	–	2.41 x 10-8	-3.94 x 10-6	-2.10 x 10-6

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-30	0.3 – 0.49	–	–	–	1.86 x 10-7	-4.00 x 10-5	-1.93 x 10-5
R-30	0.5 – 0.69	-1.49 x 10-6	-8.32 x 10-5	-4.30 x 10-5	-4.20 x 10-7	-7.79 x 10-5	-4.01 x 10-5
R-30	≥ 0.7	-1.30 x 10-6	-1.17 x 10-4	-6.28 x 10-5	-7.36 x 10-7	-1.19 x 10-4	-6.33 x 10-5
R-38	0.15 - 0.29	–	–	–	4.96 x 10-8	-6.80 x 10-6	-3.63 x 10-6
R-38	0.3 – 0.49	–	–	–	4.75 x 10-7	-3.56 x 10-5	-1.81 x 10-5
R-38	0.5 – 0.69	-2.23 x 10-6	-7.22 x 10-5	-3.66 x 10-5	-5.99 x 10-7	-6.41 x 10-5	-3.37 x 10-5
R-38	≥ 0.7	-3.32 x 10-6	-9.52 x 10-5	-5.37 x 10-5	-2.82 x 10-6	-9.58 x 10-5	-5.09 x 10-5

Table 244. Cool Roofs—Climate Zone 4: Corpus Christi,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	0.15 - 0.29	–	–	–	–	–	–
R-19	0.3 – 0.49	–	–	–	-1.53 x 10-6	-4.45 x 10-5	-2.26 x 10-5
R-19	0.5 – 0.69	-2.27 x 10-6	-9.14 x 10-5	-3.90 x 10-5	-2.29 x 10-6	-9.18 x 10-5	-4.65 x 10-5
R-19	≥ 0.7	-2.65 x 10-6	-1.39 x 10-4	-6.06 x 10-5	-4.16 x 10-6	-1.37 x 10-4	-6.18 x 10-5
R-30	0.15 - 0.29	–	–	–	-1.08 x 10-7	-3.76 x 10-6	-1.77 x 10-6
R-30	0.3 – 0.49	–	–	–	-1.19 x 10-6	-3.68 x 10-5	-1.74 x 10-5
R-30	0.5 – 0.69	-2.72 x 10-6	-7.35 x 10-5	-3.29 x 10-5	-2.34 x 10-6	-7.31 x 10-5	-3.62 x 10-5
R-30	≥ 0.7	-3.34 x 10-6	-1.09 x 10-4	-4.88 x 10-5	-3.60 x 10-6	-1.09 x 10-4	-5.07 x 10-5
R-38	0.15 - 0.29	–	–	–	-1.87 x 10-7	-6.50 x 10-6	-3.06 x 10-6
R-38	0.3 – 0.49	–	–	–	-9.37 x 10-7	-3.12 x 10-5	-1.36 x 10-5
R-38	0.5 – 0.69	-3.05 x 10-6	-6.05 x 10-5	-2.85 x 10-5	-2.37 x 10-6	-5.95 x 10-5	-2.87 x 10-5
R-38	≥ 0.7	-3.85 x 10-6	-8.74 x 10-5	-4.03 x 10-5	-3.19 x 10-6	-8.78 x 10-5	-4.27 x 10-5

Table 245. Cool Roofs—Climate Zone 5: El Paso,
Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	0.15 - 0.29	–	–	–	–	–	–
R-19	0.3 – 0.49	–	–	–	2.07 x 10-6	-5.87 x 10-5	-2.38 x 10-5
R-19	0.5 – 0.69	7.97 x 10-7	-1.30 x 10-4	-5.39 x 10-5	1.10 x 10-6	-1.31 x 10-4	-5.30 x 10-5

Roof deck insulation R-value	Installed roof material 3-year reflectance	Low slope			Steep slope		
		Gas	Electric resistance	Heat pump	Gas	Electric resistance	Heat pump
R-19	≥ 0.7	-1.19 x 10-6	-2.13 x 10-4	-8.83 x 10-5	-8.95 x 10-7	-2.10 x 10-4	-8.53 x 10-5
R-30	0.15 - 0.29	–	–	–	-1.04 x 10-7	-4.45 x 10-6	-1.81 x 10-6
R-30	0.3 – 0.49	–	–	–	4.81 x 10-7	-4.81 x 10-5	-1.95 x 10-5
R-30	0.5 – 0.69	3.74 x 10-8	-1.01 x 10-4	-4.16 x 10-5	-7.12 x 10-7	-1.01 x 10-4	-4.15 x 10-5
R-30	≥ 0.7	-1.64 x 10-6	-1.61 x 10-4	-6.73 x 10-5	-2.51 x 10-6	-1.60 x 10-4	-6.58 x 10-5
R-38	0.15 - 0.29	–	–	–	-1.79 x 10-7	-7.68 x 10-6	-3.13 x 10-6
R-38	0.3 – 0.49	–	–	–	-6.75 x 10-7	-4.04 x 10-5	-1.63 x 10-5
R-38	0.5 – 0.69	-5.15 x 10-7	-7.93 x 10-5	-3.26 x 10-5	-2.03 x 10-6	-7.94 x 10-5	-3.31 x 10-5
R-38	≥ 0.7	-1.97 x 10-6	-1.24 x 10-4	-5.20 x 10-5	-3.68 x 10-6	-1.24 x 10-4	-5.16 x 10-5

Example Deemed Savings Calculation

Example 1. A contractor installs 1500 square feet of white asphalt shingle roofing with a 3-year rated reflectance of 0.55 on a home in Climate Zone 3 with a roof slope of 4/12, refrigerated air, and a gas furnace, which has existing ceiling insulation estimated at R-12.

$$Energy\ Savings = (0.26 - 0.01) \times 1500 = 375\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 2.03x10^{-4} \times 1500 = 0.30\ kW$$

$$Winter\ Peak\ Demand\ Savings = -6.46x10^{-6} \times 1500 = -0.01\ kW$$

Example 2. A contractor applies a reflective coating to a 1200 square foot home with a heat pump and a low-slope roof in Climate Zone 2, with R-19 roof deck insulation. The coating has a 3-year rated reflectance of 0.75.

$$Energy\ Savings = (0.32 - 0.11) \times 1200 = 252\ kWh$$

$$Summer\ Peak\ Demand\ Savings = N/A$$

$$Winter\ Peak\ Demand\ Savings = -5.96x10^{-5} \times 1200 = -0.07\ kW$$

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 BS-LtRoof.[258]

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
- Insulation R-value (as is, post measure installation of ceiling/roof insulation)
- 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.
- 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
    - Because heating savings are negative, no adjustment factor will be applied to projects with missing documentation
- Square footage of reflective roofing material installed
- Slope of the roof (low or high slope)
- Three-year solar reflectance as rated by Cool Roof Rating Certification of the reflective material installed
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

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

References and Efficiency Standards

Petitions and Rulings

- Docket No. 47755-1. 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 Revisions To Residential And Nonresidential Deemed Savings Incorporated In Texas Technical Reference Manual Version 5.0 Program Year 2018 And Deemed Savings Derived For A New Measure. 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 246. Cool Roofs—Revision History

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 origin.
v7.0	11/2019	TRM v7.0 update. Added savings for R-30 insulation.
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. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Addressed sunsetting of ENERGY STAR Roof program.
v11.0	10/2023	TRM v11.0 update. No revision.

2.3.9 Solar Screens Measure Overview

TRM Measure ID: R-BE-SS

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 presented for the installation of solar screens on west- and/or south-facing windows or glass doors. Deemed savings are calculated per square foot of treated window or door opening.

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. The heating savings penalty applies to homes that are centrally heated with either a furnace (gas or electric resistance) or a heat pump. 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.

Solar screens must be installed on windows or glass doors that face west or south and receive significant direct sun exposure. Solar screens must block at least 65 percent of the solar heat gain to qualify for deemed savings.

Baseline Condition

The baseline is a single pane, clear glass, unshaded, west-, or south-facing window with a solar heat gain coefficient of 0.68. The baseline window area is assumed to be 7.5 percent of the total wall area.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[259] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[260] 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

Solar screen material installed on south- or west-facing windows must reduce solar heat gain by at least 65 percent. Solar screens are not recommended for homes with electric resistance heat.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. A single modification was made to the prototype models for the various climate zone-HVAC type combinations to create the base case models for estimating savings for the solar screens measure. Windows facing all directions are assumed to be single-pane windows with U-values of 1.16 BTU/h-sq. ft.-R and solar heat gain coefficients (SHGC) of 0.76.

For the change case models, an 80 percent reduction was applied to the solar heat gain coefficient for the south- and west-facing windows.

Summer and winter peak demand savings are estimated by taking the difference in demand for the 20 hours identified from the TMY3 datasets in which the summer and winter peaks are most likely to occur, as described in TRM Volume 1 Section 4 - Peak Demand Definitions.

The model assumes the average solar screen installed blocks 80 percent of the solar heat gain attributed to the south and west-facing windows based on performance data from solar screens analyzed at sun angles of 30, 45, and 75 degrees to the window. [261]

While it is recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, they are often not removed seasonally. This may be due to solar screens serving as an insect screen in addition to blocking the sun or simply that they're installed in difficult-to-reach areas such as second-floor windows. The savings estimates presented herein assume that the installed solar screens remain in place year-round.

---

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

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

[261] Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80 percent of solar heat gain.

Thermal Performance Improvement

Manual J and other studies researched indicate a thermal improvement to a window with a solar screen due to reduced air infiltration. The National Certified Testing Laboratories provided a report stating a 15 percent reduction in the thermal transmittance of a single pane, ¼" clear glass window with a solar screen added to the exterior.

Another study that was conducted for NFRC indicated between a 22 percent and 4 percent improvement to the U-value of a window with a solar screen. A single pane, clear window has a 22 percent improvement with the addition of a solar screen, whereas a double pane, spectrally selective low-E window may only have a 4 percent improvement. The deemed savings models assume an average 10 percent improvement in thermal performance with the addition of a solar screen.

Window Frame

The window frame accounts for 10-30 percent[262] of the window area, and since it is opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15 percent frame area was incorporated into the performance of the window.

Example Calculation

Example 1. A home in Climate Zone 4 with a central air conditioning unit and an electric resistance furnace installs 75 square feet of solar screens.

$$Energy\ Savings = \big(6.09 + (-3.21)\big) \times 75 = 216\,kWh$$

$$Summer\ Peak\ Demand\ Savings = 3.17 \times 10^{-3} \times 75 = 0.24\,kW$$

$$Winter\ Peak\ Demand\ Savings = -2.32 \times 10^{-3} \times 75 = -0.17\,kW$$

Deemed Energy Savings Tables

Table 247 presents the deemed energy savings value per square foot of solar screen installed. 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 appropriate cooling value in Table 247 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 247 by a factor of 0.24.[263]

---

[262] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.

[263] 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 247. Solar Screens—Energy Savings (kWh) per Square Foot of Solar Screen

Climate zone	Cooling savings (kWh/sq. ft.)		Heating savings (kWh/sq. ft.)		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	3.67	1.34	-0.62	-12.81	-4.54
Zone 2: Dallas	5.38	-	-0.29	-7.14	-2.56
Zone 3: Houston	5.33	-	-0.16	-4.69	-1.69
Zone 4: Corpus Christi	6.09	-	-0.09	-3.21	-1.16
Zone 5: El Paso	5.62	1.99	-0.44	-10.48	-3.81

Deemed Summer Demand Savings Tables

Table 248 presents the deemed summer peak demand savings value per square foot of solar screen installed.

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 value in Table 248 by a factor of 0.6.

Table 248. Solar Screens—Summer Peak Demand Savings (kW) per Square Foot of Solar Screen

Climate zone	Refrigerated	Evaporative
Zone 1: Amarillo	2.89E-03	1.35E-03
Zone 2: Dallas	3.42E-03	-
Zone 3: Houston	3.29E-03	-
Zone 4: Corpus Christi	3.17E-03	-
Zone 5: El Paso	3.12E-03	1.07E-03

Deemed Winter Demand Savings Tables

Table 249 presents the deemed winter peak demand savings value per square foot of solar screen installed.

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 249 by a factor of 0.24.[264]

[264] 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 249. Solar Screens—Winter Peak Demand Savings (kW) per Square Foot of Solar Screen

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	-1.16E-04	-1.73E-03	-9.45E-04
Zone 2: Dallas	-5.20E-05	-1.32E-03	-7.96E-04
Zone 3: Houston	-1.07E-04	-2.65E-03	-1.71E-03
Zone 4: Corpus Christi	-7.68E-05	-2.32E-03	-1.08E-03
Zone 5: El Paso	-1.45E-04	-3.34E-03	-1.30E-03

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 10 years as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-WinFilm.[265]

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 (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
    - Because heating savings are negative, no adjustment factor will be applied to projects with missing documentation
- Square footage of windows or door openings treated
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

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

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 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.

Relevant Standards and Reference Sources

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

Document Revision History

Table 250. Solar Screens—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. Savings awarded for south-facing windows, in addition to east- and west-facing windows.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. 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. 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.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.
v5.0	10/2017	TRM v5.0 update. Added explicit reference to mini-split technology. Added provision for low-income and hard-to-reach customers cooled by room air conditioners to claim savings.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updated documentation requirements.
v8.0	10/2020	TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

2.3.10 ENERGY STAR® Windows Measure Overview

TRM Measure ID: R-BE-EW

Market Sector: Residential

Applicable Building Types: Single-family, multifamily, manufactured

Measure Category: Building envelope

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

Replacing existing single- or double-pane windows with ENERGY STAR-compliant windows can help reduce heat transfer through window glazing, minimize air infiltration around window frames, reduce sun ultraviolet damage to household furniture, and lower household energy bills by an average of 12 percent nationwide.[266]

Window savings are calculated on a per-square-foot-of-window basis, inclusive of frame and sash.

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

There are two base cases: single-pane and double-pane windows. In both cases, a metal frame is specified. Estimated U-Values and SHGCs for baseline windows are presented in Table 251. A weighted single- and double-pane baseline is also provided, assuming a standard distribution

[266] ENERGY STAR Windows, Doors, & Skylights. https://www.energystar.gov/products/res_windows_doors_skylights.

of 46 percent single-pane and 54 percent double-pane based on 2020 RECS survey data.[267] This baseline may be used exclusively if applied consistently for all projects.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[268] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[269] 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.

Table 251. Windows—Baseline Window Specification

Number of panes	U-factor Btu/(h·sq. ft.·°F)	Solar heat gain coefficient (SHGC)
1	1.16	0.76
2	0.76	0.67

High-Efficiency Condition

Performance criteria are based on ratings certified by the National Fenestration Rating Council (NFRC) and vary by location.

The table below displays the ENERGY STAR Final Version 7.0 Requirements for eligible windows, doors, and skylights effective October 23, 2023.[270] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 252. Windows—ENERGY STAR Requirements[271]

US region, ENERGY STAR	U-factor Btu/(h·sq. ft.·°F)	Solar heat gain coefficient (SHGC)
North-Central	≤ 0.25	≤ 0.40
South-Central	≤ 0.28	≤ 0.23
Southern	≤ 0.32	≤ 0.23

[267] 2020 Residential Energy Consumption Survey (RECS). Structural and geographic characteristics in the South and West regions (HC2.8). Analysis based on West South-Central census region. https://www.eia.gov/consumption/residential/data/2020/.

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

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

[270] ENERGY STAR Residential Windows, Doors, and Skylights Final Version 6.0 Program Requirements. https://www.energystar.gov/sites/default/files/ES_Residential_WDS_V7_Final%20Specification%202022.pdf.

[271] ENERGY STAR Windows, Doors, and Skylights Climate Zone Finder. Note that these zones differ from the TRM climate zones. https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/climate_zone/search.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Base case homes were fitted with single-pane and double-pane windows. Efficiency case homes were equipped with windows meeting the appropriate ENERGY STAR window specification for the location in which the window was to be installed. The climate zones in the ENERGY STAR windows specification were mapped to the Texas TRM climate zones as shown in Table 253.

Table 253. Windows—TRM and ENERGY STAR Climate Zones

Climate zone	US region, ENERGY STAR
Zone 1: Amarillo	North-Central
Zone 2: Dallas	South-Central
Zone 3: Houston	Southern
Zone 4: Corpus Christi	Southern
Zone 5: El Paso	South-Central

Deemed Energy Savings Tables

Table 254 through Table 256 present the energy savings (kWh) 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 appropriate cooling values in Table 254 and Table 256 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 deemed heating values by a factor of 0.24.[272]

[272] 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 254. Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline

Climate zone	Cooling savings		Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.83	0.98	0.29	6.70	3.16
Zone 2: Dallas	5.42	–	0.10	3.09	1.45
Zone 3: Houston	5.32	–	0.02	0.77	0.41
Zone 4: Corpus Christi	5.97	–	0.02	0.82	0.34
Zone 5: El Paso	5.67	1.90	0.00	0.99	0.69

Table 255. Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline

Climate zone	Cooling savings		Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.03	0.72	0.18	4.15	2.00
Zone 2: Dallas	4.11	–	0.04	1.47	0.76
Zone 3: Houston	3.96	–	-0.01	-0.21	0.01
Zone 4: Corpus Christi	4.45	–	0.00	-0.01	0.02
Zone 5: El Paso	4.24	1.46	-0.03	-0.18	0.16

Table 256. Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline

Climate zone	Cooling savings		Heating savings		
	Refrigerated	Evaporative	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.40	0.84	0.23	5.33	2.54
Zone 2: Dallas	4.71	–	0.07	2.22	1.08
Zone 3: Houston	4.59	–	–	0.24	0.19
Zone 4: Corpus Christi	5.15	–	0.01	0.37	0.17
Zone 5: El Paso	4.90	1.66	-0.02	0.36	0.40

Deemed Summer Demand Savings Tables

Table 257 through Table 259 presents the summer demand savings (kW) 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 appropriate deemed cooling values by a factor of 0.6.

Table 257. Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline

Climate zone	Refrigerated	Evaporative
Zone 1: Amarillo	3.09E-03	1.16E-03
Zone 2: Dallas	3.89E-03	–
Zone 3: Houston	3.51E-03	–
Zone 4: Corpus Christi	2.99E-03	–
Zone 5: El Paso	3.86E-03	1.05E-03

Table 258. Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline

Climate zone	Refrigerated	Evaporative
Zone 1: Amarillo	2.08E-03	8.36E-04
Zone 2: Dallas	2.80E-03	–
Zone 3: Houston	2.40E-03	–
Zone 4: Corpus Christi	2.15E-03	–
Zone 5: El Paso	2.76E-03	8.09E-04

Table 259. Windows—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline

Climate zone	Refrigerated	Evaporative
Zone 1: Amarillo	2.55E-03	9.86E-04
Zone 2: Dallas	3.30E-03	–
Zone 3: Houston	2.91E-03	–
Zone 4: Corpus Christi	2.54E-03	–
Zone 5: El Paso	3.27E-03	9.20E-04

Deemed Winter Demand Savings Table 260 through Table 262 presents the winter demand savings (kW) 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 deemed heating values by a factor of 0.24.[273]

[273] 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 260. Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	2.01E-04	4.98E-03	2.43E-03
Zone 2: Dallas	1.77E-04	4.73E-03	2.74E-03
Zone 3: Houston	6.89E-05	1.78E-03	3.11E-04
Zone 4: Corpus Christi	4.78E-05	1.65E-03	6.68E-04
Zone 5: El Paso	2.83E-05	1.10E-03	5.00E-04

Table 261. Windows—Winter Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	1.32E-04	3.30E-03	1.64E-03
Zone 2: Dallas	1.12E-04	3.16E-03	1.89E-03
Zone 3: Houston	2.33E-05	6.68E-04	3.58E-06
Zone 4: Corpus Christi	1.53E-05	5.62E-04	2.34E-04
Zone 5: El Paso	1.31E-05	5.84E-04	2.76E-04

Table 262. Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	1.64E-04	4.08E-03	2.00E-03
Zone 2: Dallas	4.42E-04	3.88E-03	2.28E-03
Zone 3: Houston	4.44E-05	1.18E-03	1.46E-04
Zone 4: Corpus Christi	3.03E-05	1.06E-03	4.34E-04
Zone 5: El Paso	2.01E-05	8.22E-04	3.79E-04

Example Deemed Savings Calculation

Example 1. A home in Climate Zone 1 with evaporative cooling and an electric resistance furnace replaces 125 square feet of single-pane windows with ENERGY STAR windows.

$$Energy\ Savings = (0.98\ +\ 6.70)\ \times\ 125 = 960\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 1.16x10^{-3}\ \times\ 125 = 0.15\ kW$$

$$Winter\ Peak\ Demand\ Savings = 4.98x10^{-3}\ \times\ 125 = 0.62\ kW$$

Example 2. A home in Climate Zone 5 with a central air conditioning unit and a gas furnace replaces 250 square feet of windows with unknown number of panes with ENERGY STAR windows.

$$Energy\ Demand\ Savings = \left(4.90 + \ (-0.02)\right)\ \times\ 250 = 1{,}220\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 3.27\ \times\ 10^{-3}\ \times\ 250 = 0.82\ kW$$

$$Winter\ Peak\ Demand\ Savings = 2.01\ \times\ 10^{-5}\ \times\ 250 = 0.01\ kW$$

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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for ENERGY STAR windows[274].

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
- 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
- Baseline window number of panes (single, double, weighted)
    - The weighted baseline may be used if applied universally for all projects in a given program during the entire program year.
- U-factor and SHGC of each new window
- Area of new ENERGY STAR windows
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

[274] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 48. 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.

Relevant Standards and Reference Sources

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

Document Revision History

Table 263. Windows—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.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. 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. Climate Zone 2 savings values awarded for Climate Zone 5 homes.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Consolidated table formats.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.
v5.0	10/2017	TRM v5.0 update. Added explicit reference to mini-split technology
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updated documentation requirements.
v8.0	10/2020	TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. Added option for a weighted single-pane and double-pane baseline.
v11.0	10/2023	TRM v11.0 update. Updated ENERGY STAR specification. Added electric resistance documentation adjustment factor.

2.3.11 ENERGY STAR® Low-E Storm Windows Measure Overview

TRM Measure ID: R-BE-SW

Market Sector: Residential

Applicable Building Types: Single-family, multifamily, manufactured

Measure Category: Building envelope

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 and third-party field testing

Measure Description

ENERGY STAR low-e storm windows are a glazing attachment added to single- or double-pane windows. Storm windows are an affordable option for homes where full window replacement may be difficult. Low-emissivity (low-e) metal oxide coating decreases the summer heat gain and winter heat loss of an existing window by reducing thermal transmission. Thermal transmission is reduced as follows:

- The low-e coating acts as a selective heat mirror that reflects infrared light back outside during the summer and back onto the home during the winter.
- The marine-quality glazing and caulked or compression-sealed interface reduces air leakage and infiltration.
- The dead air space, or air barrier, created between the existing window and new storm window frame further reduces thermal transmission during both summer and winter.

The low-e coating is extremely durable and has negligible impact on visible light transmission.

Eligibility Criteria

A low-e storm window may be installed on the interior or exterior of the existing window assembly. Installation is a simple process that is often completed by residential homeowners without the assistance of professional contractors. Due to the simple installation process, low-e storm windows are sometimes installed seasonally. However, savings estimates assume windows are installed for the entire year. Therefore, windows should be permanently mounted and operable.

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes. 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 an existing single- or double-pane window assembly according to manufacturer specifications. A weighted single- and double-pane baseline is also provided, assuming a standard distribution of 46 percent single-pane and 54 percent double-pane based on 2020 RECS survey data.[275] This baseline may be used exclusively if applied consistently for all projects.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[276] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[277] 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

Performance criteria are based on ratings certified by the National Fenestration Rating Council (NFRC) and vary by location.

The table below displays the ENERGY STAR Final Version 1.0 Requirements for eligible exterior and interior storm windows effective September 5, 2018.[278] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

[275] 2020 Residential Energy Consumption Survey (RECS). Structural and geographic characteristics in the South and West regions (HC2.8). Analysis based on West South-Central census region. https://www.eia.gov/consumption/residential/data/2020/.

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

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

[278] ENERGY STAR Program Requirements Product Specification for Exterior and Interior Storm Windows, v1.0. https://www.energystar.gov/sites/default/files/Storm%20Window%20Product%20Specification_Final_0.pdf.

Table 264. Low-E Storm Windows—ENERGY STAR Requirements

US region, ENERGY STAR	Emissivity	Solar transmission
North-Central	≤ 0.22	Any
South-Central	≤ 0.22	≤ 0.55
Southern	≤ 0.22	≤ 0.55

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using Lawrence Berkeley National Laboratory's RESFEN building simulation models for residential fenestration.[279] The properties of low-e storm windows used in the RESFEN building models are presented in Table 265. This measure assumes equal weighting between the three low-e storm window glass options.

Table 265. Low-E Storm Windows—Window Assembly Properties[280]

Window type	Glass options	U-factor	SHGC	Air leakage
Storm window over existing single-pane	Low-e	0.35	0.47	1.25
	Low-e with solar control	0.35	0.32	1.25
Storm window over existing double-pane	Low-e	0.26	0.43	1.25
	Low-e with solar control	0.27	0.29	1.25

Assumed building characteristics are based on a 1,700 square-foot single-story and 2,800 square-foot two-story residence. The modeled residence has a 15 percent window-to-floor-area ratio. Assumed building characteristics are presented in Table 266.

Table 266. Low-E Storm Windows—Modeled Building Characteristics

Characteristic	Model assumption
Area	Single-story: 1,700 sq. ft. Two-story: 2,800 sq. ft.
Existing window performance[281,282]	Single pane: 0.88 U-factor, 0.61 SHGC, 2 cfm/sq. ft. air infiltration Double pane: 0.51 U-factor, 0.57 SHGC, 2 cfm/sq. ft. air infiltration
Existing window area	15 percent of floor area

[279] RESFEN window tool. LBNL. https://windows.lbl.gov/software/resfen.
[280] Averaged values from the selected products in Attachments Energy Rating Council (AERC). https://aercenergyrating.org/product-search/residential-product-search/.
[281] Culp, TD and KA Cort. "Database of Low-e Storm Window Energy Performance across US Climate Zones." US DOE, September 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf.
[282] Air infiltration assumption from: "AERC 1.2: Physical Test Methods for Measuring Energy Performance Properties of Fenestration Attachments." AERC, 2018. www.aercnet.org.

Characteristic	Model assumption
Existing window frame	Wood double-hung
Foundation	Slab on-grade
Insulation	Newer construction: IECC 2006 based on climate zone Older construction: See RESFEN 6 documentation
HVAC efficiency	Newer construction: 13 SEER, 7.7 HSPF, 0.8 AFUE for IECC Climate Zones 1-3 and 0.9 AFUE for IECC Climate Zones 4-8 Older construction: 10 SEER, 6.8 HSPF, 0.78 AFUE

Deemed Energy Savings Tables

Table 267 through Table 269 present the energy savings (kWh) 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 HTR or LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 267 and Table 269 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 deemed heating values by a factor of 0.24.[283]

Savings are an average of newer and older construction baselines for retrofit applications.

Table 267. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline

Climate zone	Cooling savings	Heating savings		
	Refrigerated	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	1.49	–	15.66	5.34
Zone 2: Dallas	2.52	–	6.65	2.09
Zone 3: Houston	2.49	–	4.55	1.48
Zone 4: Corpus Christi	3.22	–	2.82	0.80
Zone 5: El Paso	2.35	–	6.00	2.06

Table 268. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline

Climate zone	Cooling savings	Heating savings		
	Refrigerated	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	1.56	–	6.23	2.35
Zone 2: Dallas	2.50	–	2.46	0.88
Zone 3: Houston	2.62	–	1.84	0.67

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

Climate zone	Cooling savings	Heating savings		
	Refrigerated	Gas	Electric resistance	Heat pump
Zone 4: Corpus Christi	3.21	–	1.05	0.32
Zone 5: El Paso	2.37	–	1.90	0.79

Table 269. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline

Climate zone	Cooling savings	Heating savings		
	Refrigerated	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	1.53	–	10.58	3.73
Zone 2: Dallas	2.51	–	4.39	1.44
Zone 3: Houston	2.56	–	3.09	1.04
Zone 4: Corpus Christi	3.21	–	1.87	0.54
Zone 5: El Paso	2.36	–	3.79	1.38

Deemed Summer Demand Savings Tables

Table 270 through Table 272 present the summer demand savings (kW) 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 appropriate deemed cooling values by a factor of 0.6.

Table 270. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline

Climate zone	Refrigerated air
Zone 1: Amarillo	0.0016
Zone 2: Dallas	0.0018
Zone 3: Houston	0.0016
Zone 4: Corpus Christi	0.0016
Zone 5: El Paso	0.0016

Table 271. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline

Climate zone	Refrigerated air
Zone 1: Amarillo	0.0016
Zone 2: Dallas	0.0017
Zone 3: Houston	0.0016
Zone 4: Corpus Christi	0.0016
Zone 5: El Paso	0.0015

Table 272. Low-E Storm Window—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline

Climate zone	Refrigerated air
Zone 1: Amarillo	0.0016
Zone 2: Dallas	0.0017
Zone 3: Houston	0.0016
Zone 4: Corpus Christi	0.0016
Zone 5: El Paso	0.0015

Deemed Winter Demand Savings Tables

Table 273 through Table 275 present the winter demand savings (kW) 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 deemed heating values by a factor of 0.24.[284]

Table 273. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	–	0.0116	0.0041
Zone 2: Dallas	–	0.0102	0.0039
Zone 3: Houston	–	0.0105	0.0011
Zone 4: Corpus Christi	–	0.0057	0.0016
Zone 5: El Paso	–	0.0067	0.0015

Table 274. Low-E Storm Windows—Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	–	0.0050	0.0019
Zone 2: Dallas	–	0.0053	0.0022
Zone 3: Houston	–	0.0039	0.0002
Zone 4: Corpus Christi	–	0.0019	0.0037
Zone 5: El Paso	–	0.0035	0.0014

[284] This factor was derived based on expected capacity reduction assuming 1,200 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 275. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline

Climate zone	Gas	Electric resistance	Heat pump
Zone 1: Amarillo	–	0.0080	0.0029
Zone 2: Dallas	–	0.0076	0.0030
Zone 3: Houston	–	0.0069	0.0006
Zone 4: Corpus Christi	–	0.0037	0.0027
Zone 5: El Paso	–	0.0050	0.0014

Claimed Peak Demand Savings

No load shape could be extracted from the building simulation for this measure. Due to the equivalent load shape with the existing ENERGY STAR Windows measure, demand savings were estimated by applying the ratio of energy to demand savings from the windows measure to the modeled storm windows energy 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) for low-e storm windows is 20 years according to the US Department of Energy.[285]

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
- 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); 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

[285] Culp, TD and KA Cort. "Database of Low-e Storm Window Energy Performance across US Climate Zones." US DOE, September 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf.

- Baseline window number of panes (single, double, weighted)
    - The weighted baseline may be used if applied universally for all projects in a given program during the entire program year.
- Emissivity and solar transmission of each new window
- Area of new ENERGY STAR storm windows
- 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 276. Low-E Storm Windows—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. Added option for a weighted single-pane and double-pane baseline.
v11.0	10/2023	TRM v11.0 update. Added electric resistance documentation adjustment factor.

2.4 RESIDENTIAL: WATER HEATING

2.4.1 Water Heater Installations—Electric Tankless and Fuel Substitution Measure Overview

TRM Measure ID: R-WH-WH

Market Sector: Residential

Measure Category: Water heating

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: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves installing a new electric tankless[286] or gas-fueled water heater (storage or tankless) in place of an electric storage water heater.

Eligibility Criteria

This measure involves installing a gas storage, gas (instantaneous tankless), or electric tankless water heater in place of an electric storage water heater that meets all the additional requirements described below. Currently, there are no conventional, electrically fueled storage units that sufficiently exceed the new federal standard to merit inclusion as an efficient condition in these deemed savings.

Savings may be awarded for installations in newly constructed homes where customer and utility representatives provide written indication that an electric storage water heater would otherwise have been installed, along with relevant design documentation showing an electric storage water heater.

[286] Currently, most electric tankless water heaters are rated at or near the federal standard and may yield negative or no energy savings using the current baseline. However, this measure maintains eligibility for any electric tankless water heaters that may be rated above current minimum efficiency requirements.

Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency Uniform Energy Factor (UEF) determined by tank size and first hour rating (FHR), a proxy for draw pattern. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 277).[287]

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline.

Table 277. DHW Replacements—Federal Standard for Residential Electric Storage Water Heaters

Rated storage volume	Draw pattern	First hour rating (FHR)[288,289]	Uniform energy factor (UEF)[290]
≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	$0.8808 - (0.0008 \times V_r)$
	Low usage	18 ≤ FHR < 51	$0.9254 - (0.0003 \times V_r)$
	Medium usage	51 ≤ FHR < 75	$0.9307 - (0.0002 \times V_r)$
	High usage	75 ≤ FHR	$0.9349 - (0.0001 \times V_r)$
> 55 gal and ≤ 120 gal	Very small usage	0 ≤ FHR < 18	$1.9236 - (0.0011 \times V_r)$
	Low usage	18 ≤ FHR < 51	$2.0440 - (0.0011 \times V_r)$
	Medium usage	51 ≤ FHR < 75	$2.1171 - (0.0011 \times V_r)$
	High usage	75 ≤ FHR	$2.2418 - (0.0011 \times V_r)$

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification effective April 18, 2023, with qualified products meeting the minimum requirements from

Table 278[291]. However, the ENERGY STAR v5.0 specification does not cover electric tankless water heaters or gas storage products with an FHR less than 51. In these cases, the high efficiency condition corresponds to the respective federal standards for residential water heaters.[292]

---

[287] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

[288] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[289] Assume FHR equal to that of installed water heater.

[290] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

[291] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.

[292] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

Table 278 has consolidated both sources in one location for ease of reference.

For water heater replacement and fuel substitution, the new unit must meet the following federal minimum energy factor shown in

Table 278. Water heaters must be installed in accordance with local code requirements.

FHR does not apply to tankless water heaters, which are rated in terms of max gallons per minute (GPM). For gas storage water heaters, reported draw pattern should be consistent with the ENERGY STAR certificate.[293]

Table 278. DHW Replacements—Efficiency Standards[294]

DHW type	Rated storage volume	Draw pattern	FHR	UEF[295]
Electric tankless[296]	< 2 gal	Very small usage	N/A	0.91
		Low usage		0.91
		Medium usage		0.91
		High usage		0.92
Gas tankless	< 2 gal and > 50,000 Btuh	Very small usage	N/A	0.95
		Low usage		
		Medium usage		
		High usage		
Gas storage	≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	0.3456 – (0.0020 x V_r)
		Low usage	18 ≤ FHR < 51	0.5982 – (0.0019 x V_r)
		Medium usage	51 ≤ FHR < 75	0.81
		High usage	75 ≤ FHR	0.86
	> 55 gal and ≤ 100 gal	Very small usage	0 ≤ FHR < 18	0.86
		Low usage	18 ≤ FHR < 51	
		Medium usage	51 ≤ FHR < 75	
		High usage	75 ≤ FHR	

[293] As of August 2023, all gas tankless products on the ENERGY STAR qualified product listing were rated as high usage. https://www.energystar.gov/productfinder/product/certified-water-heaters/results.

[294] 10 CFR Part 430.32 Energy and water conservation standards. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

[295] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

[296] There is no ENERGY STAR tankless water heater category because all products perform at or near the federal standard. These units are still eligible to claim savings against the *electric storage water heater* baseline if draw pattern and UEF can be verified using manufacturer specification sheets or other documentation.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

Electric Tankless Water Heater

Energy Savings Algorithm

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,avg}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

Equation 67

Where:

ρ = *Water density [lbs/gal] = 8.33*

C_p = *Specific heat of water [Btu/lb·°F] = 1*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 279). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[297]

Table 279. DHW Replacements—Water Heater Consumption (Gal/Year)[298]

Climate zone	Number of bedrooms			
	1	2	3	4
Zone 1: Amarillo	15,476	20,171	24,866	29,561
Zone 2: Dallas	14,778	19,244	23,710	28,177
Zone 3: Houston	14,492	18,864	23,236	27,608
Zone 4: Corpus Christi	14,213	18,494	22,775	27,056
Zone 5: El Paso	14,905	19,412	23,920	28,427

[297] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[298] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

$T_{setpoint}$ = *Water heater setpoint temperature [°F][299] = 120*

$T_{supply,avg}$ = *Average annual supply water temperature [°F] (see Table 280)*

UEF_{pre} = *Baseline uniform energy factor (see Table 278)[300]*

UEF_{post} = *Uniform energy factor of new water heater (see Table 278)*

3,412 = *Constant to convert from Btu to kWh*

Table 280. DHW Replacements—Water Mains Temperature (°F)[301]

Climate zone	$T_{supply,avg}$	$T_{supply,seasonal}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

Equation 68

Where:

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 281)*

$T_{supply,seasonal}$ = *Seasonal supply water temperature [°F] (see Table 280)*

[299] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

[300] Note that for efficient water heater installations in newly-constructed homes, the baseline energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

[301] Based on typical meteorological year (TMY) 3 dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Table 281. DHW Replacements—Coincidence Factors[302]

Climate zone	Summer	Winter
Zone 1: Amarillo	0.042	0.067
Zone 2: Dallas	0.039	0.068
Zone 3: Houston	0.041	0.070
Zone 4: Corpus Christi	0.041	0.065
Zone 5: El Paso	0.036	0.067

Gas Storage or Tankless Water Heater (Fuel Substitution)

Energy and demand savings awarded for replacing an electric water heater with a gas storage or gas tankless water heater are equal to the consumption of the unit replaced.

Energy Savings Algorithm for Units Less than 55 Gallons

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}}\right)}{3{,}412}$$

Equation 69

Demand Savings Algorithm for Units Less than 55 Gallons

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = CF_S \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

Equation 70

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = CF_W \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,winter}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

Equation 71

[302] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

Example Deemed Savings Calculation

Example 1. An existing 40-gallon electric water heater in a two-bedroom home in Dallas is replaced with a new, electric tankless water heater with a high usage draw pattern and a uniform energy factor of 0.92. Important: note that energy savings can be negative if the UEF rating does not exceed the equivalent electric storage water heater baseline.

$$\Delta kWh = \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 71.8) \times \left(\frac{1}{0.9309} - \frac{1}{0.92}\right)\right]}{3{,}412} = -29\ kWh$$

$$\Delta kW_S = 0.042 \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 84) \times \left(\frac{1}{0.930} - \frac{1}{0.92}\right)\right]}{365 \times 3{,}412} = -0.002\ kW$$

$$\Delta kW_W = 0.068 \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 60.6) \times \left(\frac{1}{0.9227} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = -0.007\ kW$$

Example 2. An old 30-gallon electric water heater in a one-bedroom house in El Paso is replaced with a new gas storage water heater with a first-hour rating of 51 gal/hr and a uniform energy factor of 0.81.

$$\Delta kWh = \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 70.4) \times \left(\frac{1}{0.9247}\right)\right]}{3{,}412} = 1{,}952\ kWh$$

$$\Delta kW_S = 0.036 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 81.5) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.15\ kW$$

$$\Delta kW_W = 0.067 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 60.4) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.43\ kW$$

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 20 years for a tankless water heater (gas or electric), as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Instant-Res.[303]

The EUL is 11 years for a high-efficiency gas water heater, as specified for EUL ID WtrHt-Res-Gas.

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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Water heater quantity
- Manufacturer and model number of new water heater
- ENERGY STAR certificate matching model number (if applicable)
- Baseline volume (gallons), FHR, and UEF
- New water heater volume (gallons, zero if tankless), FHR, and UEF
- 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.

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

Document Revision History

Table 282. DHW Replacements—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated measure to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. Updated to reflect that new construction permitted to claim savings subject to documentation requirements and that gas-fueled tankless water heaters are eligible for installation.
v3.0	04/10/2015	TRM v3.0 update. Amended fuel substitution savings to reflect the full consumption of the electric unit being replaced. Revised demand savings for installing an electric tankless unit to reflect daily usage patterns.
v3.1	11/05/2015	TRM v3.1 update. Clarified the baseline for water heaters greater than 55 gallons.
v4.0	10/10/2016	TRM v4.0 update. Updated HPWH baseline usage for gas storage water heaters larger than 55 gallons.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	11/2019	TRM v7.0 update. Implemented new baseline and high-efficiency standards.
v8.0	10/2020	TRM v8.0 update. Clarified HPWH baseline for tanks sizes over 55 gal. Updated algorithms to refer to UEF.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Verified compliance with ENERGY STAR specification v4.0. Updated documentation requirements.
v11.0	10/2023	TRM v11.0 update. Removed requirement to install HPWH for DHW > 55 gallons. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.

2.4.2 ENERGY STAR® Heat Pump Water Heaters Measure Overview

TRM Measure ID: R-WH-HW

Market Sector: Residential

Measure Category: Water heating

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 algorithms and estimates

Measure Description

This measure involves the installation of an ENERGY STAR-compliant heat pump water heater (HPWH). Note that this measure does not account for the interactive air conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.

Eligibility Criteria

This measure applies to residential, electric, and storage-type heat pump water heaters. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

First hour rating (FHR) is a proxy for draw pattern. There are no certified ENERGY STAR water heaters in the very small usage category, and that draw pattern is not covered in the current ENERGY STAR specification. Approximately 94 percent of certified units are in the medium and high usage categories. However, HPWHs with low usage draw patterns are eligible as long as they comply with minimum ENERGY STAR FHR requirements.

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency uniform energy factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.[304]

[304] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8.

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.[305] The TRM will add an early retirement baseline after the effective date for the new standard.

Table 283. HPWHs—Federal Standard for Residential Water Heaters

Rated storage volume	Draw pattern	FHR [306] [307]	UEF [308]
≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	0.8808 − (0.0008 × V_r)
	Low usage	18 ≤ FHR < 51	0.9254 − (0.0003 × V_r)
	Medium usage	51 ≤ FHR < 75	0.9307 − (0.0002 × V_r)
	High usage	75 ≤ FHR	0.9349 − (0.0001 × V_r)
> 55 gal and ≤ 120 gal	Very small usage	0 ≤ FHR < 18	1.9236 − (0.0011 × V_r)
	Low usage	18 ≤ FHR < 51	2.0440 − (0.0011 × V_r)
	Medium usage	51 ≤ FHR < 75	2.1171 − (0.0011 × V_r)
	High usage	75 ≤ FHR	2.2418 − (0.0011 × V_r)

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 284.[309]

Table 284. HPWHs—ENERGY STAR Specification

Criteria		ENERGY STAR Requirements
UEFr	Integrated HPWH	UEF ≥ 3.30
	Integrated HPWH, 120 volt/15 amp circuit	UEF ≥ 2.20
	Split-system HPWH	UEF ≥ 2.20

[305] Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063.

[306] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[307] Assume FHR equal to that of installed water heater.

[308] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

[309] ENERGY STAR HPWH Key Product Criteria. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.[310] ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+

Criteria	ENERGY STAR Requirements
First-hour rating	FHR ≥ 45 gallons per hour
Warranty	Warranty ≥ 6 years on sealed system
Safety	UL 174 and UL 1995 or UL 60335-2-40
Lower compressor cut-off temperature (reporting requirement only)	Report ambient temperature below which the compressor cuts off and electric-resistance-only operation begins

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.[310]

HPWHs depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces in where temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.[311] Modern HPWHs operate with little to no change in performance with considerably less air volume. Updated recommendations reduce the air volume requirement to 700 cubic feet.[312] These conditions are not enforced as an eligibility requirement but should be considered when installing an HPWH.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

HPWH savings are calculated on a per-unit basis. Deemed savings are calculated utilizing the standard algorithms outlined below for water heating. Consumption in gallons per year us estimated using data from Building America Performance Analysis Procedures for Existing Homes.[313] Temperature data are based on TMY3 dataset.[314]

States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

[310] ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

[311] Heat Pump Water Heaters. Department of Energy, May 2012. http://energy.gov/energysaver/articles/heat-pump-water-heaters

[312] Heat Pump Water Heaters – Code Compliance Brief, U.S. Department of Energy Building Technologies Office. https://basc.pnnl.gov/code-compliance/heat-pump-water-heaters-code-compliance-brief.

[313] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf..

[314] TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

For upstream/midstream program delivery, a default of three bedrooms may be used to calculate the annual hot water use in gallons per year (GPY). The default number of bedrooms was estimated by taking the weighted average calculated from 2020 RECS Survey Data.

Energy Savings Algorithm

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

Equation 72

Where:

ρ = *Water density [lbs/gal] = 8.33*

C_p = *Specific heat of water [Btu/lb·°F] = 1*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 285). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[315]

Table 285. HPWHs—Water Heater Consumption (Gal/Year) [316]

Climate zone	Number of bedrooms			
	1	2	3	4
Zone 1: Amarillo	15,476	20,171	24,866	29,561
Zone 2: Dallas	14,778	19,244	23,710	28,177
Zone 3: Houston	14,492	18,864	23,236	27,608
Zone 4: Corpus Christi	14,213	18,494	22,775	27,056
Zone 5: El Paso	14,905	19,412	23,920	28,427

$T_{setpoint}$ = *Water heater setpoint temperature [°F]*[317] *= 120*

$T_{supply,annual}$ = *Average annual supply water temperature [°F] (see Table 286)*

[315] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[316] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[317] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

UEF_{pre} = *Baseline uniform energy factor (calculate per Table 283)*[318]

UEF_{post} = *Uniform energy factor of new water heater*

3,412 = *Constant to convert from Btu to kWh*

Table 286. HPWHs—Water Mains Temperature (°F)[319]

Climate zone	$T_{supply,annual}$	$T_{supply,seasonal}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

Equation 73

Where:

$T_{supply,seasonal}$ = *Seasonal supply water temperature [°F] (see Table 286)*

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 287)*

Table 287. HPWHs—Coincidence Factors[320]

Climate zone	Summer	Winter
Zone 1: Amarillo	0.042	0.067
Zone 2: Dallas	0.039	0.068
Zone 3: Houston	0.041	0.070
Zone 4: Corpus Christi	0.041	0.065

[318] Note that for efficient water heater installations in new construction homes, the baseline uniform energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

[319] Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

[320] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

Zone 5: El Paso	0.036	0.067

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) for this measure is 13 years.[321]

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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Manufacturer and model number of new HPWH
- ENERGY STAR certificate matching model number (if applicable)
- HPWH quantity
- HPWH type (integrated HPWH, integrated HPWH 120v/15A circuit, split-system HPWH)
- Baseline volume (gallons), FHR, and UEF

[321] 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, "Heat Pump Water Heaters and American Homes: A Good Fit?" p 9-74. https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf.

- New HPWH volume (gallons), FHR, and UEF
- 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 288. HPWHs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. No revision.
v3.0	04/10/2015	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. Consolidated table formats.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. Implementation of new baseline and update to the efficiency of qualifying HPWHs.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Added new construction eligibility
v9.0	10/2021	TRM v9.0 update. Clarified baseline condition. Confirmed ENERGY STAR-qualified product listing still does not contain a significant number of products with low or very small usage patterns.
v10.0	10/2022	TRM v10.0 update. Verified compliance with ENERGY STAR Version 4.0 Requirements. Updated savings methodology to algorithm approach. Updated documentation requirements.
v11.0	10/2023	TRM v11.0 update. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.

2.4.3 ENERGY STAR® Solar Water Heaters Measure Overview

TRM Measure ID: R-WH-SW

Market Sector: Residential

Measure Category: Water heating

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: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves installing a new solar water heater in place of an electric storage water heater. Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

Eligibility Criteria

These deemed savings are for solar water heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes and in new construction homes. However, savings are calculated under the assumption of replace-on-burnout.

Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency uniform energy factor (UEF) determined by tank size and first hour rating (FHR), a proxy for draw pattern. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 279).[322]

This baseline applies to replace-on-burnout, and new construction applications. No additional savings are awarded for early retirement. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.[323] The TRM will add an early retirement baseline after the effective date for the new standard.

[322] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

[323] Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063.

Table 289. Solar DHW—Federal Standard for Residential Electric Storage Water Heaters

Rated storage volume	Draw pattern	FHR[324,325]	UEF[326]
≥ 20 gal and ≤ 55 gal	Very small usage	0 ≤ FHR < 18	0.8808 − (0.0008 × V_r)
	Low usage	18 ≤ FHR < 51	0.9254 − (0.0003 × V_r)
	Medium usage	51 ≤ FHR < 75	0.9307 − (0.0002 × V_r)
	High usage	75 ≤ FHR	0.9349 − (0.0001 × V_r)
> 55 gal and ≤ 120 gal	Very small usage	0 ≤ FHR < 18	1.9236 − (0.0011 × V_r)
	Low usage	18 ≤ FHR < 51	2.0440 − (0.0011 × V_r)
	Medium usage	51 ≤ FHR < 75	2.1171 − (0.0011 × V_r)
	High usage	75 ≤ FHR	2.2418 − (0.0011 × V_r)

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must have a solar uniform energy factor (SUEF) greater than or equal to 3.0, and warranties of ≥ 10 years on collectors, ≥ 6 years on sealed systems, ≥ 2 years on controls, and ≥ 1 year on piping and parts.[327] A complete list of certified ENERGY STAR solar water heaters can be accessed via the ENERGY STAR program website.[328]

Solar water heaters must be certified according to the current SRCC OG-300 standard based on tank size and final SUEF.[329]

[324] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.
[325] Assume FHR equal to that of installed water heater.
[326] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.
[327] ENERGY STAR Requirements (effective January 5th, 2022, released March 29, 2022). https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.
[328] ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=bb099b76-3da7-49bf-a746-fbde4d076d0d&scrollTo=422&search_text=&type_filter=Solar+with+Electric+Backup&fuel_filter=&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&currentZipCode=78701&page_number=0&lastpage=0. 0
[329] ENERGY STAR certification for residential water heaters. https://solar-rating.org/programs/estar/.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Solar water heating savings values are on a per-unit basis. Variables used to compute deemed savings include tank volume and installed unit SUEF as rated in the SRCC "Summary of SRCC Certified Solar Collector and Water Heating System Ratings." The SUEF is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed as a means to compare solar water heating systems with conventional water heating systems rated with an UEF and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both UEF and SUEF are based on the same environmental and hot water use conditions used in the DOE Test Procedures for Water Heaters. The only significant difference is that the DOE test does not specify solar radiation. So SRCC uses a 1500 Btu/sq. ft./day solar radiation profile—a value typical of Sunbelt states (note - the annual average solar radiation for Dallas is 1533 Btu/sq. ft./day. Information on the SRCC can be found at http://www.solar-rating.org/.

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

Energy Savings Algorithm

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SUEF_{post}}\right)}{3{,}412}$$

Equation 74

Where:

ρ	=	*Water density [lbs/gal] = 8.33*
C_p	=	*Specific heat of water [Btu/lb·°F] = 1*
GPY	=	*Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 290). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[330]
$T_{setpoint}$	=	*Water heater setpoint temperature [°F]*[331] *= 120*

[330] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[331] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

$T_{supply,annual}$	=	*Average annual supply water temperature [°F] (see Table 291)*
UEF_{pre}	=	*Baseline uniform energy factor (calculate per Table 289)*[332]
$SUEF_{post}$	=	*Solar uniform energy factor of new water heater*
3,412	=	*Constant to convert from Btu to kWh*

Table 290. Solar DHW—Water Heater Consumption (Gal/Year) [333]

Climate zone	Number of bedrooms			
	1	2	3	4
Zone 1: Amarillo	15,476	20,171	24,866	29,561
Zone 2: Dallas	14,778	19,244	23,710	28,177
Zone 3: Houston	14,492	18,864	23,236	27,608
Zone 4: Corpus Christi	14,213	18,494	22,775	27,056
Zone 5: El Paso	14,905	19,412	23,920	28,427

Table 291. Solar DHW—Water Mains Temperature (°F)[334]

Climate zone	$T_{supply,annual}$	$T_{supply,seasonal}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SUEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

Equation 75

[332] Note that for efficient water heater installations in new construction homes, the baseline uniform energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

[333] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[334] Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Where:

$T_{supply,seasonal}$ = *Seasonal supply water temperature [°F] (see Table 291)*

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 292)*

Table 292. Solar DHW—Coincidence Factors[335]

Climate zone	Summer	Winter
Zone 1: Amarillo	0.042	0.067
Zone 2: Dallas	0.039	0.068
Zone 3: Houston	0.041	0.070
Zone 4: Corpus Christi	0.041	0.065
Zone 5: El Paso	0.036	0.067

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-SWH.[336]

---

[335] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

[336] 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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Solar DHW quantity
- Manufacturer and model number of new solar water heater
- Baseline volume (gallons), FHR, and UEF
- New solar water heater volume (gallons), FHR, and SUEF
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 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.

Relevant Standards and Reference Sources

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

Document Revision History

Table 293. Solar DHW—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.
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. No revision.

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated algorithms and coincidence factors.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Verified compliance with ENERGY STAR Version 4.0 Requirements. Updated documentation requirements.
v11.0	10/2023	TRM v11.0 update. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.

2.4.4 Water Heater Tank Insulation Measure Overview

TRM Measure ID: R-WH-TI

Market Sector: Residential

Measure Category: Water heating

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

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 tank wrap insulation on an uninsulated water heater tank.

Eligibility Criteria

Water heater tank insulation is a residential retrofit measure. New construction and water heater replacements are not eligible for this measure because they must meet current code requirements. Tank insulation must be installed on an uninsulated electric resistance water heater.

To be eligible for this measure, water heaters must have been installed prior to April 16, 2015. Water heaters manufactured after this date are compliant with the current federal standard[337] and are built with a thicker tank with a higher baseline R-value. Modern water heaters are expected to be rated at a minimum of R-24.[338,339]

[337] "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters". Effective 6/15/2010 with compliance starting 5/16/2015. https://www.federalregister.gov/documents/2010/04/16/2010-7611/energy-conservation-program-energy-conservation-standards-for-residential-water-heaters-direct.

[338] "Do-It-Yourself Savings Project: Insulate Water Heater Tank," U.S. Department of Energy. https://www.energy.gov/energysaver/do-it-yourself-savings-project-insulate-water-heater-tank.

[339] "Water Heating Products," Air-Conditioning, Heating, and Refrigeration Institute (AHRI). https://www.ahrinet.org/scholarships-education/education/homeowners/save-energy/water-heating-products.

Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation. The baseline tank is assumed to be one to two inches thick with an assumed R-value of approximately R-8 per inch.[340]

High-Efficiency Condition

The high-efficiency condition is a water heater tank wrap or insulated blanket with an R-value of at least 8.

The manufacturer's instructions on the water heater jacket and the water heater itself should be followed. Thermostat and heating element access panels must be left uncovered.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Hot water tank insulation energy savings are calculated using the following formula:

$$Energy\ Savings\ [\Delta kWh] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{tank} - T_{ambient,annual}\right) \times \left(\frac{1}{RE}\right) \times \frac{hours}{3{,}412}$$

Equation 76

Where:

R_{pre}	=	*Uninsulated tank R-value = 12 [sq. ft. °F hr/Btu][341]*
R_{post}	=	*Tank insulation R-value = 12 + 8 = 20 = [sq. ft. °F hr/Btu]*
U_{pre}	=	*1 / R_{pre} = 1 / 12 = 0.083 [Btu/hr sq. ft. °F]*
U_{post}	=	*1 / R_{post} = 1 / 20 = 0.05 [Btu/hr sq. ft. °F]*
A	=	*Tank surface area insulated in square feet* (πDL) *with L (length) and D (tank diameter) in feet; if the tank area is not known, use Table 294*

[340] "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Water Heaters", Section V. Analytical Results and Conclusion, subsection C. Lessening of Utility or Performance of Products. Effective 1/20/2004. https://www.federalregister.gov/documents/2001/01/17/01-1081/energy-conservation-program-for-consumer-products-energy-conservation-standards-for-water-heaters.

[341] Baseline storage tank assembly is assumed to have thermal performance of R12, assuming an average tank thickness of 1-2 inches (average 1.5) and an approximate R-value of R-8 per inch.

Table 294. DHW Tank Insulation—Estimated Tank Area[342]

Volume (gal)	A (sq. ft.)
30	17.45
40	21.81
50	22.63
60	26.94
80	30.36
120	38.73

T_{tank}	=	*Average tank water temperature [°F]; default = 120°F* [343]
$T_{ambient,annual}$	=	*Average annual ambient temperature [°F] (see Table 295)*
RE	=	*Recovery efficiency; default = 0.98 for electric resistance water heaters*[344]
hours	=	*8,760 hours per year*
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{tank} - T_{ambient,seasonal}\right) \times \frac{1}{RE} \times \frac{CF_{S/W}}{3{,}412}$$

Equation 77

Where:

$T_{ambient,seasonal}$	=	*Seasonal ambient temperature [°F] (see Table 295)*
$CF_{S/W}$	=	*Seasonal peak coincidence factor*[345] *= 1*

[342] Tank area was obtained from a survey of electric water heater manufacturer data from A.O. Smith and Whirlpool conducted in 2013. Dimensions for each tank size were collected and averaged to determine typical square footage of each size water heater.

[343] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), supports a default value of 120°F.

[344] Default based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

[345] Coincidence factor of 1 assumes that a constant tank temperature is maintained across all hours of the year.

Table 295. DHW Tank Insulation—Ambient Temperature (°F)

Climate zone	Water heater location: unconditioned space[346]			Water heater location: conditioned space[347]		
	Annual	Peak seasonal		Annual	Peak seasonal	
		Summer	Winter		Summer	Winter
Zone 1: Amarillo	65.5	106.0	32.0	71.8	73.9	69.6
Zone 2: Dallas	73.1	108.1	42.0			
Zone 3: Houston	76.3	108.2	46.0			
Zone 4: Corpus Christi	78.4	103.0	55.0			
Zone 5: El Paso	71.8	108.0	41.1			

Deemed Energy Savings Tables

Table 296. DHW Tank Insulation—Energy Savings

Tank volume	Unconditioned					Conditioned
	Amarillo	Dallas	Houston	Corpus Christi	El Paso	All zones
30	83	71	67	63	73	73
40	104	89	83	79	92	92
50	108	93	86	82	95	95
60	128	110	103	98	113	113
80	144	124	116	110	128	128
120	184	159	148	141	163	163

[346] Average ambient temperatures for unconditioned space were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System and Cooling System Location Temperatures (Garage).

[347] Average ambient temperatures for conditioned space were taken from the US Energy Information Administration Residential Energy Consumption Survey (RECS), tables hc7.9 and hc6.8. Summer and winter indoor temperature averages are weighted by the number of homes. Annual temperature is the average of summer and winter weighted by number of days.

Deemed Summer Demand Savings Tables

Table 297. DHW Tank Insulation—Energy Savings

Tank volume	Unconditioned					Conditioned
	Amarillo	Dallas	Houston	Corpus Christi	El Paso	All zones
30	0.0024	0.0021	0.0021	0.0030	0.0021	0.0080
40	0.0030	0.0026	0.0026	0.0037	0.0026	0.0100
50	0.0032	0.0027	0.0027	0.0038	0.0027	0.0104
60	0.0038	0.0032	0.0032	0.0046	0.0032	0.0124
80	0.0042	0.0036	0.0036	0.0051	0.0036	0.0140
120	0.0054	0.0046	0.0046	0.0066	0.0046	0.0178

Deemed Winter Demand Savings Tables

Table 298. DHW Tank Insulation—Energy Savings

Tank volume	Unconditioned					Conditioned
	Amarillo	Dallas	Houston	Corpus Christi	El Paso	All zones
30	0.0153	0.0136	0.0129	0.0113	0.0137	0.0088
40	0.0191	0.0170	0.0161	0.0141	0.0172	0.0110
50	0.0199	0.0176	0.0167	0.0147	0.0178	0.0114
60	0.0236	0.0209	0.0199	0.0175	0.0212	0.0135
80	0.0266	0.0236	0.0224	0.0197	0.0239	0.0153
120	0.0340	0.0301	0.0286	0.0251	0.0305	0.0195

Claimed Peak Demand Savings

Refer to Volume 1, Section 4.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 7 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-TankIns-Elec.[348]

[348] 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
- Water heater location (conditioned, unconditioned)
- Tank volume (30, 40, 50, 60, 80, 120)
- The R-value of the installed tank insulation
- Water heater model number and manufacture date

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 299. DHW Tank 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. Minor edits to language.
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. Supplemented reference for water heater setpoint temperature.
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. No revision.
v7.0	11/2019	TRM v7.0 update. No revision.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. Updated ambient temperatures.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated documentation requirements.
v11.0	10/2023	TRM v11.0 update. Clarified baseline and added deemed savings. Updated documentation requirements.

2.4.5 Water Heater Pipe Insulation Measure Overview

TRM Measure ID: R-WH-PI

Market Sector: Residential

Measure Category: Water heating

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

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 pipe insulation on uninsulated water heater pipes that are served by an electric water heater.

Eligibility Criteria

Water heaters plumbed with heat traps are not eligible to receive incentives for this measure. It is recommended that the installer (or contractor) checks to see if the water heater heat trap works properly before declaring the water heater ineligible.

Water heater pipe insulation is a residential retrofit measure. New construction and retrofits involving the installation of new water heaters are not eligible for this measure, because they must meet current code requirements. To use these deemed savings, the fuel type of the water heater must be electricity.

Baseline Condition

The baseline is assumed to be a typical electric water heater with no heat traps and no insulation on water heater pipes.

High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3. The International Residential Code (IRC) 2018 section N1103.4: Mechanical system piping insulation requires R-3 insulation.

All visible hot water piping must be insulated. Savings are based on a maximum allowable insulation length of 6 feet of piping.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Hot water pipe insulation energy savings are calculated using the following formula:

$$Energy\ Savings\ [\Delta kWh] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{pipe} - T_{ambient,avg}\right) \times \left(\frac{1}{RE}\right) \times \frac{hours}{3{,}412}$$

Equation 78

Where:

U_{pre} = $\frac{1}{2.03} = 0.49\ {}^{Btu}/_{hr \cdot sq.ft. \cdot °F}$[349]

U_{post} = $\frac{1}{2.03 + R_{Insulation}}\ {}^{Btu}/_{hr \cdot sq.ft. \cdot °F}$

$R_{Insulation}$ = *R-value of installed insulation*

A = *Pipe surface area insulated in square feet* (πDL) *with L (length) and D (pipe diameter) in feet. The maximum length allowable for insulation is 6 feet; if the pipe area is unknown, use the following table.*

Table 300. DHW Pipe Insulation—Estimated Pipe Surface Area

Pipe diameter (inches)	Pipe surface area (square feet)[350]
0.5	0.16 x required input "Pipe Length insulated (feet)"
0.75	0.23 x required input "Pipe Length insulated (feet)"
1.0	0.29 x required input "Pipe Length insulated (feet)"

[349] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe, and between the surface and air. Mark's Standard Handbook for Mechanical Engineers, 8th edition.

[350] Factors used in the calculation for pipe area were determined by using the outside diameter of the pipe in inches, converting it to feet, and multiplying by π as shown below.

Nominal diameter (inches)	Outside diameter (inches)	Factor to calculate pipe area
0.5	0.625	0.16
0.75	0.875	0.23
1.0	1.125	0.29

T_{pipe}	=	*Average pipe water temperature [°F]; default[351] = 120*
$T_{ambient,avg}$	=	*Average annual ambient temperature [°F] (see Table 301)*
RE	=	*Recovery efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.[352]*
hours	=	*8,760 hours per year*

Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = (U_{pre} - U_{post}) \times A \times (T_{Pipe} - T_{ambient,seasonal}) \times \left(\frac{1}{RE}\right) \times \frac{CF_{S/W}}{3{,}412}$$

Equation 79

Where:

$T_{ambient,seasonal}$	=	*Seasonal ambient temperature [°F] (see Table 301)*
$CF_{S/W}$	=	*Seasonal peak coincidence factor[353] = 1*

Table 301. DHW Pipe Insulation—Ambient Temperature (°F)

Climate zone	Water heater location: unconditioned space[354]			Water heater location: conditioned space[355]		
	Annual	Peak seasonal		Annual	Peak seasonal	
		Summer	Winter		Summer	Winter
Zone 1: Amarillo	65.5	106.0	32.0	71.8	73.9	69.6
Zone 2: Dallas	73.1	108.1	42.0			
Zone 3: Houston	76.3	108.2	46.0			

[351] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 102. Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[352] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

[353] Coincidence factor of 1 assumes that a constant tank and near tank piping temperature is maintained across all hours of the year.

[354] Average ambient temperatures for unconditioned space were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System and Cooling System Location Temperatures (Garage).

[355] Average ambient temperatures for conditioned space were taken from the US Energy Information Administration Residential Energy Consumption Survey (RECS), tables hc7.9 and hc6.8. Summer and winter indoor temperature averages are weighted by the number of homes. Annual temperature is the average of summer and winter weighted by number of days.

Climate zone	Water heater location: unconditioned space[354]			Water heater location: conditioned space[355]		
	Annual	Peak seasonal		Annual	Peak seasonal	
		Summer	Winter		Summer	Winter
Zone 4: Corpus Christi	78.4	103	55.0	71.8	73.9	69.6
Zone 5: El Paso	71.8	108	41.1			

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 13 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-PipeIns-Elec.[356]

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
- Water heater location (conditioned, unconditioned)
- The R-value of the installed insulation

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

- Recovery efficiency (RE) or COP, if available
- Pipe length insulated (feet)
- The pipe surface area insulated in square feet (at least the pipe diameter in inches)

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 302. DHW Pipe 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. Minor edits to language.
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. Supplemented reference for water heater setpoint temperature.
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. No revision.
v7.0	11/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated ambient temperatures.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated documentation requirements.
v11.0	10/2023	TRM v11.0 update. No revision.

2.4.6 Faucet Aerators Measure Overview

TRM Measure ID: R-WH-FA

Market Sector: Residential

Measure Category: Water heating

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 involves installing aerators on kitchen and bathroom water faucets as a retrofit measure.

Eligibility Criteria

The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable.

These deemed savings are for residential, retrofit or new construction, and installations of kitchen and bathroom faucet aerators. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Department of Energy (DOE) maximum flow rate standard.[357] The deemed savings assume that the existing faucet aerators have a minimum flow rate of 2.2 GPM. The US EPA WaterSense specification for faucet aerators is 1.5 GPM.[358]

High-Efficiency Condition

Aerators that have been defaced to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

---

[357] DOE maximum flow rate for faucet aerators. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=40.

[358] https://www.epa.gov/watersense/bathroom-faucets.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

The deemed savings, for any faucet aerator change case using aerators with flow rates of 1.5 GPM or lower, are calculated as follows:

$$Energy\ Savings\ per\ aerator\ [\Delta kWh] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times \left(T_{faucet,avg} - T_{supply,avg}\right)}{FPH \times RE \times 3{,}412}$$

Equation 80

Where:

ρ	=	*Water density [lbs/gal] = 8.33*
C_p	=	*Specific heat of water [Btu/lb°F] = 1*
GPM_{Base}	=	*Average baseline flow rate of aerator = 2.2 gallons per minute*
GPM_{Low}	=	*Post-installation flow rate of aerator, typically 1.5, 1.0, or 0.5 gallons per minute; if unknown, assume 1.5 gallons per minute*
N	=	*Average number of persons per household = 2.83 persons*[359]
t	=	*Average time in minutes of hot water usage per person per day; default = 2.34 min/person/day*[360]
$T_{faucet,avg}$	=	*Average faucet temperature [°F]*[361] *= 88*
$T_{supply,avg}$	=	*Average annual supply water temperature [°F] (see Table 303)*
FPH	=	*Average number of faucets per household = 3.87 faucets*[362]

[359] Occupants per home for Texas from US Census Bureau, "Persons Per Household, 2016-2020". https://www.census.gov/quickfacts/fact/table/TX,US/PST045221.

[360] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average minutes per person per day specified for kitchens (4.5) and bathrooms (1.6) assuming 1 kitchen aerator and 2.93 bathrooms.

[361] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average temperature for kitchens (93°F) and bathrooms (86°F) assuming 1 kitchen aerator and 2.93 bathrooms.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[362] Faucets per home assumed to be equal to one per kitchen and each half-bath plus 1.5 per each full bathroom per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS), Table HC2.8 Structural and Geographic Characteristics of Homes in West South-Central Region.

RE	=	*Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[363]
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$Peak\ Demand\ Savings\ per\ aerator\ [\Delta kW] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times \left(T_{faucet,avg} - T_{supply,seasonal}\right)}{FPH \times RE \times 3{,}412} \times CF_{S/W}$$

Equation 81

Where:

$T_{supply,seasonal}$	=	*Seasonal supply water temperature [°F] (Table 303)*
$CF_{S/W}$	=	*Seasonal peak coincidence factor (Table 304)*

Table 303. Faucet Aerators—Water Mains Temperature (°F)[364]

Climate zone	$T_{supply,avg}$	$T_{supply,seasonal}$	
		Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

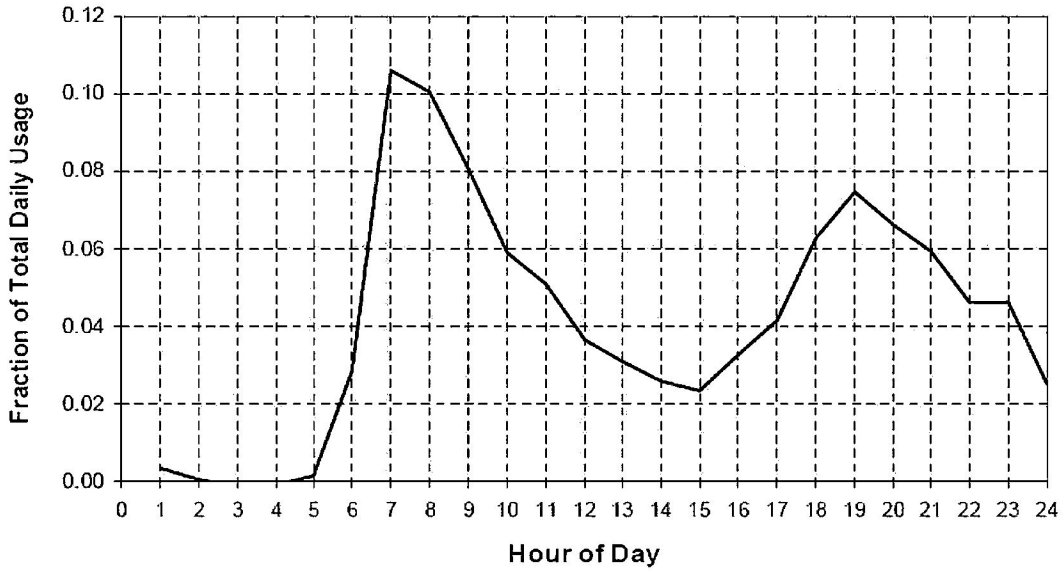
[363] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, https://www.ahridirectory.org/.

[364] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

Table 304. Faucet Aerators—Coincidence Factors

Climate zone	Summer	Winter
Zone 1: Amarillo	0.039	0.073
Zone 2: Dallas	0.035	0.075
Zone 3: Houston	0.038	0.080
Zone 4: Corpus Christi	0.038	0.068
Zone 5: El Paso	0.028	0.069

Figure 4. Faucet Aerators—Shower, Bath, and Sink Hot Water Use Profile[365]



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.

[365] Building America performance analysis procedures for existing homes.

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 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Aertr.[366]

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
- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of faucet installed
- Water heater type (e.g., heat pump, electric resistance)

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.

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

Document Revision History

Table 305. Faucet Aerators—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.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	10/30/2015	TRM v3.1 update. Supplemented reference for water heater setpoint temperature.
v4.0	10/10/2016	TRM v4.0 update. Updated methodology to calculate energy and demand savings.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	11/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated coincidence factors.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated number of occupants per home.
v11.0	10/2023	TRM v11.0 update. No revision.

2.4.7 Low-Flow Showerheads Measure Overview

TRM Measure ID: R-WH-SH

Market Sector: Residential

Measure Category: Water heating

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 consists of removing existing showerheads and installing low-flow showerheads in residences.

Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at or below 2.0gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit or new construction measure. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[367] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[368]

High-Efficiency Condition

In addition to meeting the baseline requirements above, existing showerheads that have been defaced to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

[367] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37.
[368] http://www.epa.gov/watersense/products/showerheads.html.