Acknowledgments

The Texas Technical Reference Manual is maintained by the Public Utility Commission of Texas' independent evaluation, measurement, and verification (EM&V) team led by Tetra Tech. This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Energy (TXu 1-904-705), ICF, CLEAResult, and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2017 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2018 by Frontier Energy. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as a consistent structure and level of information.

TRM Technical Support

Technical support and questions can be emailed to the EM&V project manager, Lark.Lee@tetratech.com, and the PUCT, Therese.Harris@puc.texas.gov.

1 INTRODUCTION

This volume of the TRM contains the deemed savings for residential measures that have been approved for use in Texas by the Public Utility Commission of Texas (PUCT). This volume includes instructions regarding various savings calculators and reference sources of the information. The TRM serves as a centralized source of deemed savings values. Where appropriate, measurement and verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1 provides an overview of the residential measures contained within this program year (PY) 2024 TRM 11.0 Volume 2 and the types of deemed savings estimates available for each one. There are five types of deemed savings estimates identified:

- *Point estimates* that provided a single deemed savings value correspond to a single measure or type of technology.
- *Deemed saving tables* that provide energy and peak savings as a function of size, capacity, building type, efficiency level, or other inputs.
- *Savings algorithms* that require specified primary inputs that must be gathered on site and the identification of default inputs where primary data could not be collected. In many cases, these algorithms are provided as references to deemed savings tables, point estimates, or calculator explanations.
- *Calculators* are used by different utilities and implementers to calculate energy savings for different measures. In many cases, there are several different calculators available for a single measure. Sometimes their background calculators are similar, and in other cases, estimates can vary greatly between each calculator.
- *M&V methods* are also used for some measures to calculate savings in the event that standard equipment is not used, or the specified building types do not apply. For some of these measures, both a simplified M&V approach and a full M&V approach may be allowed by the utility. M&V methods as a source of claimed and projected savings are noted for informational purposes only.

Please consult Volume 1: Overview and User Guide, Section 5: Structure and Content, for details on the organization of the measure templates presented in this volume.

Table 1. Residential Deemed Savings by Measure Category

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
Lighting	ENERGY STAR® general service LED lamps	–	–	X	–	–	Added in-service rates by program type and clarification of lamp types.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
	ENERGY STAR® specialty and directional LED lamps	–	–	X	–	–	Added in-service rates by program type.
	LED nightlights	–	–	X	–	–	Added in-service rates by program type.
HVAC	Air conditioner or heat pump tune-up	–	–	X	–	–	Updated demand savings. Clarified eligibility for PTACs and PTHPs.
	Central heat pumps without SEER2 ratings	–	X	–	–	–	Measure and Appendix A retired.
	Mini-split heat pumps without SEER2 ratings	–	X	–	–	–	Measure and Appendix B retired.
	Central mini-split air conditioners and heat pumps with SEER2 ratings	–	–	X	–	–	Defined rightsizing and documentation requirements. Updated early retirement age eligibility.
	Room air conditioners	–	–	X	–	–	Incorporated updated DOE final rule and ENERGY STAR specification v5.0. Updated early retirement age eligibility.
	Packed terminal heat pumps	–	–	X	–	–	Updated early retirement age eligibility.
	Ground source heat pumps	–	X	X	–	–	Integrated federal standard change and SEER2 test procedure.
	Large capacity split system and single-package air conditioners and heat pumps	–	–	X	–	–	Updated GSHP EUL.
	Evaporative cooling	–	X	–	–	–	No revision.
	ENERGY STAR® connected thermostats	–	X	–	–	–	Incorporated algorithm approach. Incorporated new SEER2 test procedure.
	Smart thermostat load management	–	X	–	–	–	No revision.
	Duct sealing	–	–	X	–	X	No revision.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
Building envelope	Air infiltration	–	X	–	–	X	Added electric resistance documentation adjustment factor.
	Ceiling insulation	–	X	–	–	–	Added electric resistance documentation adjustment factor.
	Attic encapsulation	–	X	–	–	–	Added electric resistance documentation adjustment factor.
	Wall insulation	–	X	–	–	–	Added electric resistance documentation adjustment factor.
	Floor insulation	–	X	–	–	–	Added electric resistance documentation adjustment factor.
	Duct insulation	–	X	–	–	–	Measure origin.
	Radiant barriers	–	X	–	–	–	Clarified savings normalization by area. Added electric resistance documentation adjustment factor.
	Cool roofs	–	X	–	–	–	No revision.
	Solar screens	–	X	–	–	–	No revision.
	ENERGY STAR® windows	–	X	–	–	–	Updated ENERGY STAR specification. Added electric resistance documentation adjustment factor.
	ENERGY STAR® low-e storm windows		X	–	–	–	Added electric resistance documentation adjustment factor.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
Domestic water heating	Water heater installation—electric tankless and fuel substitution	–	–	X	–	–	Removed requirement to install HPWH for DHW > 55 gallons. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.
	Heat pump water heaters	–	X	–	–	–	Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.
	Solar water heaters	–	X	–	–	–	Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements.
	Water heater tank insulation	–	X	–	–	–	Clarified baseline and added deemed savings. Updated documentation requirements.
	Water heater pipe insulation	–	–	X	–	–	No revision.
	Faucet aerators	–	–	X	–	–	No revision.
	Low-flow showerheads	–	–	X	–	–	No revision.
	Showerhead temperature sensitive restrictor valves	–	–	X	–	–	No revision.
	Tub spout and showerhead temperature-sensitive restrictor valves	–	–	X	–	–	No revision.
	Water heater temperature setback	–	–	X	–	–	No revision.

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	11.0 update
Appliances	ENERGY STAR® ceiling fans	–	–	X	–	–	No revision.
	ENERGY STAR® clothes washers	–	X	–	–	–	No revision.
	ENERGY STAR® clothes dryers	–	X	–	–	–	No revision.
	ENERGY STAR® dishwashers	–	X	–	–	–	No revision.
	ENERGY STAR® refrigerators	–	–	X	–	X	Updated early retirement age eligibility.
	ENERGY STAR® freezers	–	X	–	–	–	Updated early retirement age eligibility.
	Refrigerator/ freezer recycling	X	–	X	–	–	No revision.
	ENERGY STAR® air purifiers	–	X	–	–	–	Updated baseline to Tier 1 federal standard.
	ENERGY STAR® pool pumps	–	–	X	–	–	Updated baseline to current federal standard. Added new savings tiers. Updated documentation requirements.
	Advanced power strips	–	X	–	–	–	Added in-service rates.
	ENERGY STAR® electric vehicle supply equipment	–	X	–	–	–	Updated algorithm with days coefficient. Updated documentation requirements.
	Induction cooking	–	X	–	–	–	Updated documentation requirements.

2 RESIDENTIAL MEASURES

2.1 RESIDENTIAL: LIGHTING

2.1.1 ENERGY STAR® General Service LED Lamps Measure Overview

TRM Measure ID: R-LT-GS

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, multifamily; manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive and direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure provides a method for calculating savings for the replacement of a standard-efficiency lamp with an ENERGY STAR-compliant LED general service lamp (GSL) in a residential application.[1] This measure applies to all lamps not included in the subsequent measure for Specialty LED Lamps. All lamp types not defined in the Specialty LED Lamps measure should be treated as GSLs.

Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5 percent indoor and 9.5 percent outdoor may be assumed.[2]

New homes must exceed the lighting equipment requirements of the current state building code (IECC 2015) to be eligible for prescriptive lighting savings.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

[1] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[2] 2015 US Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

Baseline Condition

On May 8, 2022, the Department of Energy (DOE) issued two final rules relating to GSLs:

- Energy Conservation Program: Definitions for General Service Lamps, effective July 8, 2022, which expanded the definition of GSLs.[3]
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens/watt efficacy.[4]

The baseline is assumed to be the second-tier Energy Independence and Security Act of 2007 (EISA)-mandated efficiency for a GSL. The EISA regulations dictate that GSLs must comply with a 45 lumen/watt efficacy standard at time of sale beginning January 1, 2023. However, due to the DOE enforcement schedule, savings may be claimed against the first-tier EISA baseline through February 28, 2023, at the utility's discretion.

For low-income and hard-to-reach direct install programs, utilities may claim additional savings for early retirement of incandescent and halogen lamps with LEDs when documentation requirements are met. It is assumed that the remaining useful life (RUL) of the existing lamps is two years. This is when the incandescent or halogen lamp baseline bulbs will be at the end of their useful life and need to be replaced. First year savings are weighted using the dual baseline methodology for the first-tier and second-tier baselines found in Table 2 and Table 3. The first-tier baseline may only be used in this scenario.

New construction applications use the same baselines; however, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75 percent high-efficacy lighting. Therefore, if 100 percent of installed lighting is high-efficacy, savings can be claimed for the remaining 25 percent of installed lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in Table 2 and Table 3. These wattages are available on the ENERGY STAR certificate and can be used in combination with the deemed savings methodologies provided in this measure.

[3] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[4] DOE Final Rule: Energy Conservation Standards for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070.

Table 2. GSL LEDs—Baseline and Default Wattages for A-Shaped Lamps[5,6]

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	1st tier EISA 2007 (W_{Base})[7]	2nd tier EISA 2007 (W_{Base})[8]	Default W_{Post} (if unknown)[9]
250	309	25	Exempt	Exempt	3.5
310	749	40	29	12	5.5
750	1,049	60	43	20	9.0
1,050	1,489	75	53	28	11.5
1,490	2,600	100	72	45	15.0
2,601	3,300	150	Exempt	66	22.5

Table 3. GSL LEDs—Baseline and Default Wattages for Other Lamp Shapes[10,11]

Minimum lumens	Maximum lumens	Incandescent equivalent wattage[12]	1st tier EISA 2007 (W_{Base})[13]	2nd tier EISA 2007 (W_{Base})[14]	W_{Post} (if unknown)[15]
250	309	Qualified Products List (QPL)	Exempt	Exempt	QPL
310	749	–	29	12	
750	1,049	–	43	20	
1,050	1,489	–	53	28	
1,490	2,600	–	72	45	
2,601	3,300	QPL	Exempt	66	

[5] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.
[6] If exempt, refer to the incandescent equivalent wattage.
[7] 1st tier baseline is only applicable to low-income and hard-to-reach direct install programs. This baseline is only applicable for two years, equivalent to the expected life of an incandescent lamp.
[8] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.
[9] Average rated wattage from the ENERGY STAR QPL rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[10] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.
[11] If exempt, refer to incandescent equivalent wattage.
[12] Due to large variation in lamp types, use rated value from the ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[13] 1st tier baseline is only applicable to low-income and hard-to-reach direct install programs. This baseline is only applicable for two years, equivalent to the expected life of an incandescent lamp.
[14] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.
[15] Due to large variation in lamp types, use rated value from ENERGY STAR: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

High-Efficiency Condition

The high-efficiency condition is the wattage of the replacement lamp. LEDs must be ENERGY STAR-compliant[16] for the relevant lamp shape being installed as outlined in the latest ENERGY STAR specification.[17] Alternatively, lab testing reports (e.g., LM-79, LM-80, TM-21, ISTMT) are also accepted as a method of certification.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a standard baseline lamp, according to EISA 2007 (see Table 2 and Table 3) and the wattage of a comparable GSL LED. An LED is considered comparable to the baseline lamp if they are aligned on the lumen output ranges set out in EISA 2007.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75 percent of lamps. For example, if a new home is built with high-efficacy lamps in 85 percent of the permanently installed fixtures, the program would claim 10 percent of the total calculated savings.

Energy Savings

Annual energy (kWh) savings are calculated as follows.

$$Energy\ Savings\ [\Delta kWh] = \frac{(W_{base} - W_{post})}{1{,}000} \times Hours \times ISR \times IEF_E$$

Equation 1

Where:

W_{base} = *Baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed; reduced baselines are provided for EISA-compliant lamps in Table 2*

W_{post} = *Actual wattage of LED purchased/installed (if unknown, use default wattages from Table 2)*

[16] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[17] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

HOU	=	*Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[18])*
IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 4)*
ISR	=	*In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnout) to account for units incentivized but not operating (see Table 5)*
1,000	=	*Constant to convert from W to kW*

Table 4. GSL LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[19]

	IEF_E				
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.06	1.13	1.17	1.15	1.12
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.91	1.00	1.05	1.11	0.97
Electric resistance heat with AC	0.65	0.80	0.90	1.00	0.75
Electric resistance heat with no AC	0.57	0.69	0.76	0.83	0.65
No heat with AC	1.06	1.13	1.17	1.15	1.12
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[20]	0.88	0.98	1.04	1.07	0.95

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

[18] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy. June 2009.

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

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

Table 5. GSL LEDs—In-Service Rates by Program Type

Program type	ISR
Low-income community kits[21]	0.88
All other kit programs[22]	0.60
Retail (time of sale)[23]	0.76
Midstream/upstream	
Direct install[24]	0.97

Demand Savings

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

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

Equation 2

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

Equation 3

Where:

$CF_{S/W}$ = *Seasonal peak coincidence factor (see Table 6)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 7)*

[21] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[22] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[23] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[24] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

Table 6. GSL LEDs—Coincidence Factors[25]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.275	0.232	0.199	0.263	0.358

Table 7. GSL LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[26]

$IEF_{D,s}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.45	1.33	1.68	1.23	1.44
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with AC	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.45	1.33	1.68	1.23	1.44
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[27]	1.39	1.28	1.58	1.20	1.38
$IEF_{D,W}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4 Corpus Christi	Climate Zone 5 El Paso
Gas heat with AC	0.98	0.98	0.98	0.98	0.98
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.71	0.67	0.65	0.74	0.81
Electric resistance heat with AC	0.44	0.36	0.38	0.42	0.52
Electric resistance heat with no AC	0.44	0.36	0.38	0.42	0.52
No heat with AC	0.98	0.98	0.98	0.98	0.98
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[28]	0.76	0.72	0.73	0.75	0.80

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

[25] See Volume 1.
[26] Refer to Table 4.
[27] Ibid.
[28] Ibid.

Low-Income and Hard-to-Reach Direct Install Programs

Annual energy (kilowatt-hours, kWh) and peak demand (kilowatts, kW) may be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed (incandescent or halogen lamp), designated the remaining useful life (RUL), and
- The remaining time in the EUL period (EUL – RUL).

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

Where:

RUL	=	*Remaining useful life = 2 years*
EUL	=	*Estimated useful life = 16 or 20 years (see Measure Life and Lifetime Savings section)*

Upstream/Midstream Program Assumptions

All GSLs with an equivalent wattage of 100 W or lower distributed though upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining five percent of savings allocated to the commercial sector.[29] While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

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.

[29] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V Upstream Lighting memo.

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

Historically, the average measure life is based upon the rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$EUL_{Total} = \frac{Rated\ Life \times DF}{HOU \times 365.25}$$

Equation 4

Where:

Rated Life = *10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacture; if unknown, assume a 10,000-hour lifetime*[30]

DF = *0.85 degradation factor*[31]

HOU = *2.2 hours per day*[32]

Table 8. GSL LEDs—Estimated Useful Life

Range of rated measure life (hours)	Assumed rated measure life (hours)	Rated product lifetime (years)
≤ 17,500	15,000	16
> 17,500	20,000	20*

* Measure life capped at 20 years. EUL may be deemed at 16 years in lieu of documenting the customer baseline.

[30] Minimum lifetime requirement under ENERGY STAR Lamps Specification V2.1, effective January 2, 2017. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

[31] ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[32] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy. June 2009.

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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LEDs installed
- Wattage of each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative, none, unknown)
- Location of replacement lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
    - Alternative: another pre-approved method of certification (e.g., LM-79, LM-80, TM-21 ISTMT Iap reports)
- For low-income and hard-to-reach direct install programs, photo documentation clearly showing the lamp type and approximate quantity replaced or other pre-approved method of verification
- For new construction projects only, these data points must be gathered for all permanently installed fixtures in the home to document the percentage that are high-efficacy.

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 9. GSL LEDs—Revision History

TRM version	Date	Description of change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	TRM v3.1 update. Modification of in-service rate, revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types. Provided default input assumptions for upstream lighting programs. Capped estimated measure life.
v3.1	3/28/2016	TRM v3.1 March revision. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated IEF values and useful life estimates.
v5.0	10/2017	TRM v5.0 update. Updated EUL algorithm to account for baseline change beginning in 2021. Included language to deem EUL.
v6.0	11/2018	TRM v6.0 update. Updated useful life estimates. Updated interactive effects factors.
v7.0	10/2019	TRM v7.0 update. Removed dual baseline and updated useful life estimates. Added invoice and certificate requirements. Added option for new construction savings.
v8.0	10/2020	TRM v8.0 update. Defined midstream methodology and clarified default wattages by lumen range.
v9.0	10/2021	TRM v9.0 update. Updated midstream methodology and added path for fixtures.
v10.0	10/2022	TRM v10.0 update. Updated for compliance with new DOE GSL definition and reinstatement of EISA 45 lumens/watt backstop.
v11.0	10/2023	TRM v11.0 update. Added in-service rates by program type.

2.1.2 ENERGY STAR® Specialty LED Lamps Measure Overview

TRM Measure ID: R-LT-SP

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive and direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure provides a method for calculating savings for replacement of an incandescent or halogen reflector or decorative lamp with an ENERGY STAR-compliant LED specialty lamp in a residential application. These lamps are limited to the following lamp types, defined by the current federal standard[33] and further reduced to only include lamps that are common to utility rebate programs.

- G-shape lamps that have a first number symbol less than or equal to 12.5 (diameter less than or equal to 1.5625 inches)
- G-shape lamps with a diameter of five inches or more
- MR-shape lamps that have a first symbol equal to 16 (diameter equal to two inches) and have a lumen output greater than or equal to 800 lumens
- Reflector lamps that have a first number symbol less than 16 (diameter less than two inches) and that do not have E26/E24, E26d, E26/50x39, E26/53x39, E29/28, E29/53x39, E39, E39d, EP39, or EX39 bases

Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5 percent indoor and 9.5 percent outdoor may be assumed.[34]

New homes must exceed the lighting equipment requirements of the current state building code (IECC 2015) to be eligible for prescriptive lighting savings.

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[33] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[34] 2015 US Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

Baseline Condition

On May 8, 2022, the Department of Energy (DOE) issued two final rules relating to general service lamps:

- Energy Conservation Program: Definitions for General Service Lamps (GSL), effective July 8, 2022, which expanded the definition of general service lamp.[35]
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens per watt efficacy.[36]

For all products not defined as GSLs, the baseline is assumed to be the incandescent equivalent wattage. The baseline wattage will be determined based on the bulb shape of the installed lamp, as outlined below. New construction applications use the same baselines. However, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75 percent high-efficacy lighting. Therefore, if 100 percent of installed lighting is high-efficacy, savings can be claimed for the remaining 25 percent of installed lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in this section. These wattages are available on the ENERGY STAR certificate and can be used in combination with the deemed savings methodologies provided in this measure.

Table 10. Specialty LEDs—Baseline and Default Wattages[37]

Lamp type[38]	Minimum lumens	Maximum lumens	W_{Base}
G-shape with diameter ≥ 5 in.[39]	–	–	Qualified Products List (QPL)
MR16/MRX16	800	–	75
R14	250	299	25

[35] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.
[36] DOE Final Rule: Energy Conservation Standards for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070.
[37] Due to large variation in lamp types, use rated value from ENERGY STAR QPL where not specified: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[38] Lamp types excluded from this table were not included on the ENERGY STAR QPL. For missing lamp types, refer to the equivalent and rated wattages from the ENERGY STAR certification.
[39] G-shape lamps are not included because there were very few ENERGY STAR-qualified products with a diameter of 5 inches or more. For these products, use the equivalent and rated wattages from the ENERGY STAR certification.

High- Efficiency Condition

The high-efficiency condition is the wattage of the replacement lamp. LEDs must be ENERGY STAR-compliant[40] for the relevant lamp shape being removed as outlined in the latest ENERGY STAR specification.[41] Alternatively, lab testing reports (e.g., LM-79, LM-80, TM-21, ISTMT) are also accepted as a method of certification.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a specialty baseline lamp and the wattage of a directional or specialty LED.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75 percent of lamps. For example, if a new home is built with high-efficacy lamps in 85 percent of the permanently installed fixtures, the program would claim 10 percent of the total calculated savings.

Energy Savings Algorithms

Annual energy (kWh) savings are calculated as follows:

$$Energy\ Savings\ [\Delta kWh] = \frac{(W_{base} - W_{post})}{1{,}000} \times HOU \times ISR \times IEF_E$$

Equation 5

Where:

W_{base}	=	*EISA-exempt specialty lamp or a DOE-ruling-exempt reflector (see Table 10)*
W_{post}	=	*Actual wattage of LED purchased/installed*
HOU	=	*Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[42])*

[40] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[41] ENERGY STAR specification: http://www.energystar.gov/products/certified-products/detail/light-bulbs.
[42] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy (formerly Associates). June 2009.

IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 11)*
ISR	=	*In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating (see Table 12)*
1,000	=	*Constant to convert from W to kW*

Table 11. Specialty LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[43]

IEF_E					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.06	1.13	1.17	1.15	1.12
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.91	1.00	1.05	1.11	0.97
Electric resistance heat with AC	0.65	0.80	0.90	1.00	0.75
Electric resistance heat with no AC	0.57	0.69	0.76	0.83	0.65
No heat with AC	1.06	1.13	1.17	1.15	1.12
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[44]	0.88	0.98	1.04	1.07	0.95

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

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

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

Table 12. Specialty LEDs—In-Service Rates by Program Type

Program type	ISR
Low-income community kits[45]	0.88
All other kit programs[46]	0.60
Retail (time of sale)[47]	0.76
Direct install[48]	0.97

Demand Savings Algorithms

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

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

Equation 6

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

Equation 7

Where:

$CF_{S/W}$ = *Seasonal peak coincidence factor (Table 13)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 14)*

Table 13. Specialty LEDs—Coincidence Factors[49]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.275	0.232	0.199	0.263	0.358

[45] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[46] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[47] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[48] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

[49] See Volume 1

Table 14. Specialty LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[50]

$IEF_{D,S}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.45	1.33	1.68	1.23	1.44
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with AC	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.45	1.33	1.68	1.23	1.44
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[51]	1.39	1.28	1.58	1.20	1.38
$IEF_{D,W}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	0.98	0.98	0.98	0.98	0.98
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.71	0.67	0.65	0.74	0.81
Electric resistance heat with AC	0.44	0.36	0.38	0.42	0.52
Electric resistance heat with no AC	0.44	0.36	0.38	0.42	0.52
No heat with AC	0.98	0.98	0.98	0.98	0.98
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[52]	0.76	0.72	0.73	0.75	0.80

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

[50] Refer to Table 11.

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

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

Upstream/Midstream Program Assumptions

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed though upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining five percent of savings allocated to the commercial sector.[53] While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

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

Historically, the average measure life is based upon rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$EUL_{Total} = \frac{Rated\ Life \times DF}{HOU \times 365.25}$$

Equation 8

[53] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

Where:

Rated Life	=	*10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacturer; if unknown, assume a 10,000-hour lifetime*[54]
DF	=	*0.85 degradation factor*[55]
HOU	=	*2.2 hours per day*[56]

Table 15. Specialty LEDs—Estimated Useful Life

Range of rated measure life (hours)	Assumed rated measure life (hours)	Specialty measure life (years)
≤ 17,500	15,000	16
> 17,500	20,000	20*

* Measure life capped at 20 years. EUL may be deemed at 16 years in lieu of collecting manufacturer rated life or documenting customer baseline.

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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LEDs installed
- ANSI C79.1-2002 nomenclature of LED installed (G40, PAR, etc.)
- Baseline and rated wattages of each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative cooler, none, unknown)

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[54] Minimum lifetime requirement under ENERGY STAR Lamps Specification V2.1, effective January 2, 2017. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

[55] ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[56] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy (formerly Associates). June 2009.

- Location of installed lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Baseline calculation methodology (EISA-affected non-reflector, EISA-exempt non-reflector, DOE-ruling-affected reflector, DOE-ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of installed units or other pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
    - Alternative: other pre-approved method of certification (e.g., LM-79, LM-80, TM-21, ISTMT lap reports)
- For new construction projects only, these data points must be gathered for all permanently installed fixtures in the home to document the percentage that are high-efficacy.

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 16. Specialty LEDs—Revision History

TRM version	Date	Description of change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	TRM v3.1 update. Modification of in-service rate, revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types. Consolidated default input assumptions for upstream lighting programs. Capped estimated measure life.
v3.1	3/28/2016	TRM v3.1 March revision. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated IEF values.
v5.0	10/2017	TRM v5.0 update. Updated useful life estimates.
v6.0	11/2018	TRM v6.0 update. Updated useful life estimates. Updated interactive effects factors.

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 update. Removed dual baseline and updated useful life estimates. Added invoice and certificate requirements. Added option for new construction savings.
v8.0	10/2020	TRM v8.0 update. Defined midstream methodology and clarified default wattages by lumen range. Updated specialty lamps baselines.
v9.0	10/2021	TRM v9.0 update. Updated midstream methodology and added path for fixtures.
v10.0	10/2022	TRM v10.0 update. Updated for compliance with new DOE GSL definition. Several lamp types previously considered *specialty lamps* moved to *general service lamp* measure.
v11.0	10/2023	TRM v11.0 update. Added in-service rates by program type.

2.1.3 LED Nightlights Measure Overview

TRM Measure ID: R-LT-NL

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive and direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure provides a method for calculating savings for the replacement of an incandescent nightlight with an LED or electroluminescent nightlight.

Eligibility Criteria

This measure applies to all LED nightlights installed in a residential application.

Baseline Condition

The baseline condition is assumed to be an incandescent/halogen nightlight.

High-Efficiency Condition

The high-efficiency condition is a qualified LED nightlight.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

Annual energy (kilowatt-hours, kWh) savings are calculated as follows.

$$Energy\ Savings\ [\Delta kWh] = \frac{(W_{base} - W_{post})}{1{,}000} \times Hours \times ISR \times IEF_E$$

Equation 9

Where:

W_{base}	=	*Baseline wattage. Use actual wattage if known (default = 7 W)*[57]
W_{post}	=	*Actual wattage of LED purchased/installed (default = 1 W for LED)*
HOU	=	*Average hours of use per year = 4,161 hours*[58]
IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 17)*
ISR	=	*In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating (see Table 18)*
1,000	=	*Constant to convert from W to kW*

Table 17. LED Nightlights—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[59]

IEF_E					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.06	1.13	1.17	1.15	1.12
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.91	1.00	1.05	1.11	0.97
Electric resistance heat with AC	0.65	0.80	0.90	1.00	0.75
Electric resistance heat with no AC	0.57	0.69	0.76	0.83	0.65
No heat with AC	1.06	1.13	1.17	1.15	1.12

[57] Mertz, Stanley. "LED Nightlights Energy Efficiency Retail products programs." March 2018.
[58] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights," Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 and 3.
[59] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: 1 + $HVAC_{savings}$/$Lighting_{savings}$.

IEF_E					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[60]	0.88	0.98	1.04	1.07	0.95

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

Table 18. LED Nightlights—In-Service Rates by Program Type

Program type	ISR
Low-income community kits[61]	0.88
All other kit programs[62]	0.60
Retail (time of sale)[63]	0.76
Direct install[64]	0.97

Demand Savings

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

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

Equation 10

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

Equation 11

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

[61] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[62] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[63] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[64] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

Where:

$CF_{S/W}$ = *Seasonal peak coincidence factor (see Table 19)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 20)*

Table 19. LED Nightlights—Coincidence Factors[65]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.00	0.00	0.00	0.00	0.00
Winter	0.67	0.71	0.61	0.75	1.00

Table 20. LED Nightlights—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[66]

$IEF_{D,s}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	1.45	1.33	1.68	1.23	1.44
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with AC	1.45	1.33	1.68	1.23	1.44
Electric resistance heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.45	1.33	1.68	1.23	1.44
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[67]	1.39	1.28	1.58	1.20	1.38

[65] From TX TRM *commercial lamps & fixtures* measure for dusk-to-dawn operation.
[66] Refer to Table 20.
[67] Ibid.

$IEF_{D,W}$					
Heating/cooling type*	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Gas heat with AC	0.98	0.98	0.98	0.98	0.98
Gas heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat pump	0.71	0.67	0.65	0.74	0.81
Electric resistance heat with AC	0.44	0.36	0.38	0.42	0.52
Electric resistance heat with no AC	0.44	0.36	0.38	0.42	0.52
No heat with AC	0.98	0.98	0.98	0.98	0.98
Unconditioned space	1.00	1.00	1.00	1.00	1.00
Heating/cooling unknown[68]	0.76	0.72	0.73	0.75	0.80

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

Upstream/Midstream Program Assumptions

All general service lamps with an equivalent wattage of 100 W or lower distributed though upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining 5 percent of savings allocated to the commercial sector.[69] While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

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.

[68] Ibid.

[69] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for LED nightlights is 8 years.[70]

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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LED nightlights installed
- LED nightlight wattage
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative, none, unknown)
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification

References and Efficiency Standards

Not applicable.

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

[70] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights," Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 and 3.

Document Revision History

Table 21. LED Nightlights—Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. Added in-service rates by program type.

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview

TRM Measure ID: R-HV-TU

Market Sector: Residential

Measure Category: HVAC

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 applies to central air conditioners (AC) and heat pumps (HP) of any configuration where all applicable actions from the checklist below are completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions to restore operating efficiencies, on average, closer to as-new performance. This measure applies to all residential applications.

For this measure, the service technician must complete the following tasks according to industry best practices. To properly assess and adjust the refrigerant charge level, the unit must be operating under significant (normal) cooling load conditions. Therefore, this measure may only be performed for energy savings reporting purposes when the outdoor ambient dry bulb temperature is above 75˚F, and the indoor return air dry bulb temperature is above 70˚F.

Air conditioner inspection and tune-up checklist:[71]

- Tighten all electrical connections, measure motor voltage and current
- Lubricate all moving parts, including motor and fan bearings
- Inspect and clean the condensate drain
- Inspect controls of the system to ensure proper and safe operation. Check the startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Clean evaporator and condenser coils

[71] Based on ENERGY STAR HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

- Clean indoor blower fan components
- Inspect and clean or change air filters; replacement preferred best practice
- Measure airflow via static pressure across the cooling coil and adjust to manufacturers specifications
- Check refrigerant level and adjust to manufacturer specifications
- Check capacitor functionality and capacitance; compare to OEM specifications

Eligibility Criteria

HVAC systems must be manufactured before January 1, 2023, to be eligible for this measure.[72] All residential customers are eligible for this measure if they have refrigerated air conditioning 65,000 Btu/hr or less in cooling capacity that has not been serviced through a utility program in the last five years.

This measure is also applicable to packaged terminal air conditioners and heat pumps (PTAC/PTHPs).

Baseline Condition

The baseline is a system with some or all of the following issues:

- Dirty condenser coil
- Dirty evaporator coil
- Dirty blower wheel
- Dirty filter
- Improper airflow
- Incorrect refrigerant charge

The baseline system efficiency should be calculated using the following formulas:

$$EER_{pre} = (1 - EL) \times EER_{post}$$

Equation 12

$$HSPF_{pre} = (1 - EL) \times HSPF_{post}$$

Equation 13

[72] The current federal standard became effective on January 1, 2023, with full manufacturing compliance of the new SEER2 testing procedure being enforced as of April 24, 2023. This measure will be updated in the future to address the new efficiency ratings. https://www.regulations.gov/document/EERE-2021-BT-TP-0030-0027.

Where:

EER_{pre}	=	*Efficiency of the cooling equipment before tune-up*
EL	=	*Efficiency loss due to dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05*
EER_{post}	=	*Deemed cooling efficiency of the equipment after tune-up = 11.2 EER*
$HSPF_{pre}$	=	*Heating efficiency of the air source heat pump before tune-up*
$HSPF_{post}$	=	*Deemed heating efficiency of air source heat pumps after tune-up = 7.7 HSPF*

High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above, with the added specification that refrigerant charge adjustments must be within ±3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and ±5 degrees of target super heat for units with fixed orifices or capillary tubes.

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the majority of existing, functioning units were installed under the federal standard in place between January 23, 2006, and January 1, 2015, which set a baseline of 13 SEER and 7.7 HSPF[73]. A 13 SEER is equivalent to approximately 11.2 EER[74] using the conversion developed by Lawrence Berkeley Lab and US DOE: EER = -0.02 x $SEER^2$ + 1.12 x SEER.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of 5 percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[75]

[73] Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.
[74] Code specified 13 SEER from federal standard effective January 23, 2006 through January 1, 2015, converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." US Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.
[75] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

Energy Savings Algorithms

Heating energy savings are only applicable to heat pumps.

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

Equation 14

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

Equation 15

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times EFLH_H \times \frac{1\ kW}{1{,}000\ W}$$

Equation 16

Where:

Cap_C	=	*Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)*
Cap_H	=	*Rated heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)*
EER_{pre}	=	*Cooling efficiency of the equipment pre-tune-up using Equation 12 [Btuh/W]*
EER_{post}	=	*Cooling efficiency of the equipment after the tune-up [Btuh/W]; assume 11.2*
$HSPF_{pre}$	=	*Heating efficiency of the equipment pre-tune-up using Equation 13 [Btuh/W]*
$HSPF_{post}$	=	*Heating efficiency of the equipment after the tune-up [Btuh/W]; assume 7.7*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone [hours]*

Table 22. AC/HP Tune-Ups—Equivalent Full Load Cooling/Heating Hours[76]

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

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

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

Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times CF_S \times \frac{1\ kW}{1{,}000\ W}$$

Equation 17

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times CF_W \times \frac{1\ kW}{1{,}000\ W}$$

Equation 18

Summer and winter demand savings are determined by applying a coincidence factor for each season. Winter peak demand savings are only applicable to heat pumps.

Where:

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 23)*

Table 23. AC/HP Tune-Ups—Coincidence Factors[77]

Season	CF
Summer[78]	0.87
Winter[79]	0.83

Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 24. Heating savings are only applicable for heat pumps.

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

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

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

Table 24. AC/HP Tune-Ups—Energy Savings (kWh/ton)

Climate zone	Cooling (kWh/ton)	Heating (kWh/ton)
Zone 1: Amarillo	64.4	154.2
Zone 2: Dallas	108.6	110.2
Zone 3: Houston	124.6	92.4
Zone 4: Corpus Christi	166.8	63.7
Zone 5: El Paso	85.9	127.9

Deemed Summer Demand Savings Tables

Applying the above algorithms results in the deemed summer demand savings per ton in Table 25.

Table 25. AC/HP Tune-Ups—Summer Peak Demand Savings (kW/ton)

Climate zone	Summer kW/ton
Zone 1: Amarillo	0.049
Zone 2: Dallas	
Zone 3: Houston	
Zone 4: Corpus Christi	
Zone 5: El Paso	

Deemed Winter Demand Savings Tables

Applying the above algorithms results in the deemed winter demand savings per ton in Table 26. Winter peak demand savings are only applicable for heat pumps.

Table 26. AC/HP Tune-Ups—Peak Demand Savings (kW/ton)

Climate zone	Winter kW/ton
Zone 1: Amarillo	0.068
Zone 2: Dallas	
Zone 3: Houston	
Zone 4: Corpus Christi	
Zone 5: El Paso	

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 a tune-up is five years. [80]

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:

- Most recent tune-up service date or confirmation that system has not been serviced within the previous five years
- Climate zone or county
- Equipment type (split AC, split HP, packaged AC, packaged HP, PTAC, PTHP)
- Manufacturer, model number, and serial number
- Cooling and heating capacity of the serviced unit (tons)
- Heating capacity of the serviced unit if applicable (tons)
- Refrigerant type
- Target superheat or subcooling
- Post tune-up superheat or subcooling
- Amount of refrigerant added or removed
- Static pressures before and after tune-up
- Return and supply dry bulb and wet bulb temperatures
- Before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment name plates are useful).

References and Efficiency Standards

Petitions and Rulings

Not applicable.

[80] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

Relevant Standards and Reference Sources

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

Document Revision History

Table 27. AC/HP Tune-Ups—History

TRM version	Date	Description of change
v4.0	10/10/2015	TRM v4.0 origin.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. 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 coincidence factors.
v11.0	10/2023	TRM v11.0 update. Updated demand savings. Clarified eligibility for PTACs and PTHPs.

2.2.2 Central and Mini-Split Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: R-HV-CM

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new central or mini-split air-source air conditioner (AC) or heat pump (HP) in an existing building, or the installation of a new central AC or HP in a new residential construction. Downsized systems that are rightsized per heat-load calculation are also eligible. A new central system includes an entire packaged unit or a split system consisting of an indoor unit with a matching remote condensing unit. This measure also applies to the installation of dual-fuel HPs and DC inverter systems that meet all existing measure eligibility criteria.

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

Eligibility Criteria

The deemed savings apply to units with a capacity of ≤ 65,000 Btu/hour (5.4 tons).

Equipment shall be properly sized to the dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[81,82] Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination

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

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

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

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

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

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

System rightsizing refers to installing an HVAC system that has been sized in accordance with a load calculation, such as a Manual J, considering specific home characteristics. Rightsizing retrofit projects could include upsizing or downsizing by one-half ton or more from the existing system. New construction projects are not eligible to receive deemed savings for system rightsizing.[83]

For system downsizing, savings may be claimed against the applicable replace-on-burnout or early retirement scenario using the existing higher system pre-capacity with the lower system post-capacity if a Manual J load calculation is completed and included with project documentation.

For system upsizing, savings should generally be claimed against the new construction baseline. However, optional rightsizing savings are available for upsizing up to one ton for the scenarios outlined below. In these cases, savings may be claimed against the applicable replace-on-burnout or early retirement scenario if the specified conditions are met. For these scenarios, savings must be determined using the lower pre-tonnage. These exceptions should be applied consistently at the program level for the duration of the program year.

- Replacing a single larger capacity system with multiple smaller capacity systems.[84] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.

[83] For projects using a custom baseline, see TRM Volume 4.

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

- Replacing a single-stage system with a variable-speed system.[85] This scenario only applies to the replacement of a single-stage system.
- If a Manual J load calculation is completed and included with project documentation.[86]

Additionally, low-income or hard-to-reach programs may use the electric resistance baseline for the following two scenarios:

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

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

Baseline Condition

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

New construction baseline efficiency values for ACs or HPs are compliant with the current federal standard,[87,88] effective January 1, 2023. The baseline is assumed to be a new system with an AHRI-listed SEER2 rating consistent with the values listed in Table 28 and Table 29. These baselines are also applicable to central ACs with gas, electric resistance, or unknown heating replacing an HP; evaporative coolers with central, space, or no heating; and room/window ACs with central, space, or no heating.

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

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

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

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

For replace-on-burnout projects, the cooling baselines are reduced by 4.3 percent. This value is based on Energy Systems Laboratory (ESL) survey data and incorporates an adjustment to the baseline SEER2/EER2 value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[89,90] Heating baselines were not included in original ESL survey data and are not adjusted.

For early retirement projects, baselines are defined in Table 28 and Table 29 based on the applicable federal standard base on manufacture year. These baselines have been converted to SEER2, EER2, and HSPF2 by extrapolating from known values referenced in the current federal standard. Systems manufactured as of January 1, 2023, are not eligible for early retirement.

For early retirement projects involving an HP replacing an AC with gas heat, early retirement cooling baselines should be used in combination with new construction heating baselines.

For all systems with a part-load efficiency rating of 15.2 SEER2 or higher, the full-load efficiency baseline is reduced to 9.8 EER2, consistent with the EER2 federal standard specified for the Southwest region. While this standard does not directly apply to Texas, it is used here to recognize a reduced full-load allowance for systems achieving higher part-load efficiency ratings. This value is not reduced based on ESL survey data. Where applicable, the reduced 9.8 EER2 baseline should be applied in lieu of the EER2 baseline value presented in Table 28 and Table 29 except where the specified baseline EER2 value is lower than 9.8 EER2.

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

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[91] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[92] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters should calculate savings using a HP baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.412.[93] Projects in which an electric resistance furnace is replaced, either in replace-on-burnout or early retirement scenarios, use this baseline for heating-side savings.

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

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

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

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

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

Table 28. Central and Mini-Split ACs—Baseline Efficiencies

Project type	Capacity (Btu/hr)	Cooling mode
New construction, split air conditioners	< 45,000	14.3 SEER2 11.7 EER2
	≥ 45,000	13.8 SEER2 11.2 EER2
New construction, packaged air conditioners	All	13.4 SEER2 10.9 EER2
Replace-on-burnout, split air conditioners	< 45,000	13.7 SEER2 11.2 EER2
	≥ 45,000	13.2 SEER2 10.7 EER2
Replace-on-burnout, packaged air conditioners	All	12.8 SEER2 10.4 EER2
Early retirement, air conditioners (manufactured 1/1/2015 through 12/31/2022)	All	12.8 SEER2 10.4 EER2
Early retirement, air conditioners (when applying default age)[94]	All	12.3 SEER2 10.0 EER2
Early retirement, air conditioners (manufactured 1/23/2006 through 12/31/2014)	All	11.9 SEER2 9.7 EER2
Early retirement, air conditioners (manufactured before 1/23/2006)	All	9.1 SEER2 7.4 EER2
All systems rated at 15.2 SEER2 or higher[95]	All	9.8 EER2

Table 29. Central and Mini-Split HPs—Baseline Efficiencies

Project type	Cooling mode	Heating mode
New construction, split heat pumps	14.3 SEER2 11.7 EER2	7.5 HSPF2
New construction, packaged heat pumps	13.4 SEER2 10.9 EER2	6.7 HSPF2
Replace-on-burnout, split heat pumps	13.7 SEER2 11.2 EER2	7.5 HSPF2
Replace-on-burnout, packaged heat pumps	12.8 SEER2 10.4 EER2	6.7 HSPF2

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

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

Project type	Cooling mode	Heating mode
Early retirement, split heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2 10.4 EER2	6.9 HSPF2
Early retirement, packaged heat pumps (manufactured 1/1/2015 through 12/31/2022)	12.8 SEER2 10.4 EER2	6.7 HSPF2
Early retirement, split heat pumps (when applying default age)[96]	12.3 SEER2 10.0 EER2	6.7 HSPF2
Early retirement, packaged heat pumps (when applying default age)[97]	12.3 SEER2 10.0 EER2	6.6 HSPF2
Early retirement, heat pumps (manufactured 1/23/2006 through 12/31/2014)	11.9 SEER2 9.7 EER2	6.5 HSPF2
Early retirement, heat pumps (manufactured before 1/23/2006)	9.1 SEER2 7.4 EER2	5.7 HSPF2
All systems rated at 15.2 SEER2 or higher[98]	9.8 EER2	–
Replace-on-burnout or early retirement, electric resistance furnace[99]	–	3.412 HSPF2

High-Efficiency Condition

Rated system cooling (SEER2) and heating (HSPF2) efficiencies must meet or exceed the federal standard specified in Table 28 and Table 29. HVAC equipment with SEER2 meeting federal standard minimum requirements is eligible for early retirement cooling savings with verification of age of existing equipment and removal of functional inefficient equipment. HPs with HSPF2 meeting the minimum federal standard replacing electric resistance furnaces should follow the electric resistance documentation requirements.

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER2 and HSPF2 requirements but do not comply with the EER2 requirements outlined in Table 28 and Table 29 may still be eligible to claim savings. Systems with qualifying SEER2 and HSPF2 energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems, but not summer demand savings where the EER2 rating does not comply with the minimum requirement.

[96] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006–2014 and 2015–2022.
[97] Ibid.
[98] When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.
[99] When installing a heat pump replacing a split air conditioner with an electric resistance furnace, the reduced 3.412 HSPF2 heating baseline efficiency should be applied in lieu of the applicable value presented earlier in the table.

Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

For early retirement, if age is unknown, assume a default age equal to the replaced unit estimated useful life (EUL) resulting in a remaining useful life (RUL) of 7 (ACs) or 6 years (HPs). Default age may be used exclusively if applied consistently for all early retirement projects. This is the only scenario where an early retirement baseline can be applied to systems older than 24 years for ACs and 20 years for HPs. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Default early retirement baselines are specified in Table 28 and Table 29 for use with the default age.

Energy Savings Algorithms

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

Equation 19

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

Equation 20

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

Equation 21

Demand Savings Algorithms

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

Equation 22

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

Equation 23

Where:

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

$Cap_{C/H,post}$ = *Cooling/heating capacity of the new equipment [Btuh]; 1 ton = 12,000 Btuh*

Note: When claiming early retirement or rightsizing savings, pre- and post-capacity should be expressed as a nominal tonnage multiplied by 12,000 Btuh/ton. In all other cases, pre- and post-capacity should be set equal to the rated post-capacity at AHRI standard conditions.

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

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (must exceed ROB/NC baseline efficiency standards in Table 28 and Table 29) [Btuh/W]*

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

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (must exceed baseline efficiency standards in Table 29) [Btuh/W]*

Note: Use SEER2 for cooling kWh, EER2 for summer kW, and HSPF2 for heating kWh and winter kW savings calculations.

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours (Table 30)*

$CF_{S/W}$ = *Summer/winter seasonal peak coincidence factor (Table 31)*

Table 30. Central and Mini-Split AC/HPs—Equivalent Full Load Cooling/Heating Hours[100]

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

Table 31. Central and Mini-Split AC/HPs—Coincidence Factors[101]

Season	CF
Summer[102]	0.87
Winter[103]	0.83

Early Retirement

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

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

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

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

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

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

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

Where:

RUL = *Remaining useful life (see Table 32 or Table 33). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. For HPs replacing an AC with an electric resistance furnace, use the AC RUL table.*

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

Table 32. Central and Mini-Split AC/HPs—RUL of Replaced AC

Age of replaced unit (years)	Remaining useful life (years)	Age of replaced unit (years)	Remaining useful life (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[104,105]	0.0
13	9.0		

Table 33. Central and Mini-Split AC/HPs—RUL of Replaced HP

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

[104] RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (see Figure 1). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

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

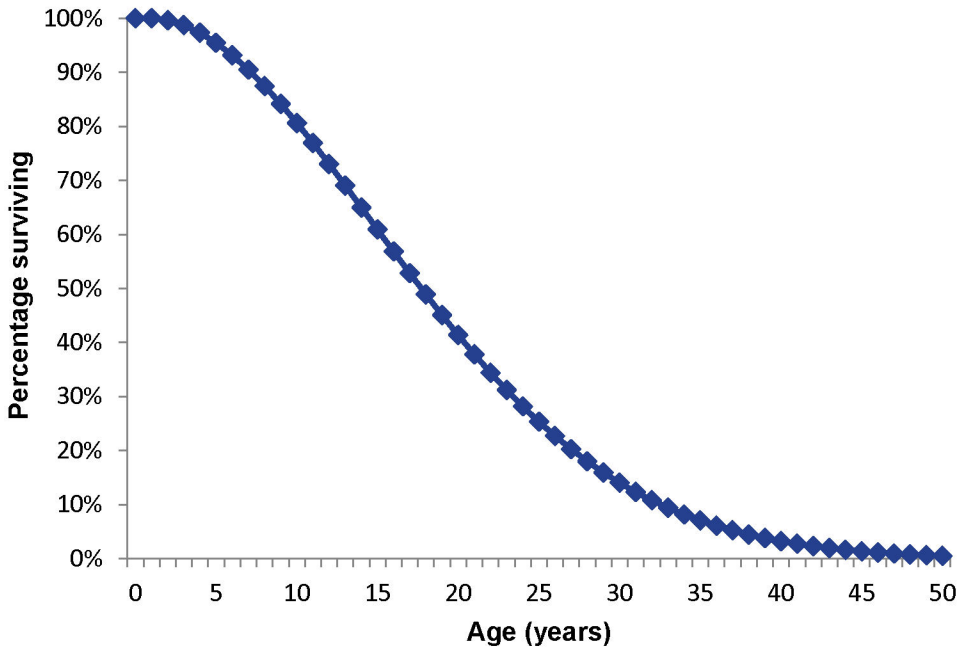
Age of replaced unit (years)	Remaining useful life (years)
8	9.3
9	8.9
10	8.5
11	8.2

Age of replaced unit (years)	Remaining useful life (years)
19	2.0
20	1.0
21[106]	0.0

Derivation of RULs

ACs have an estimated useful life of 18 years, and HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of ACs and HPs installed in a given year will no longer be in service, as described by the survival function in Figure 1 and Figure 2.

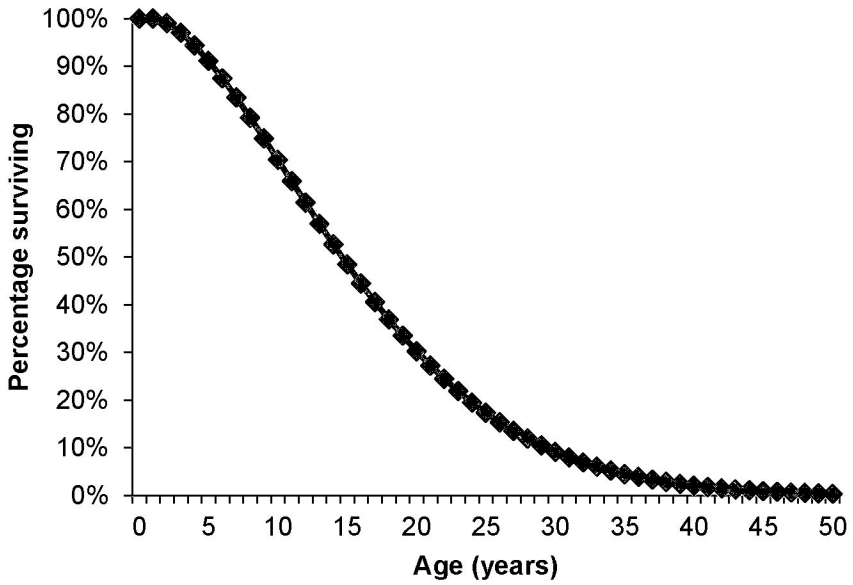
Figure 1. Central and Mini-Split AC/HPs—AC Survival Function[107]



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

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

Figure 2. Central and Mini-Split AC/HPs—HP Survival Function[108]



The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 1 and Figure 2. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving system is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

[108] Ibid.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for an AC and 15 years for a HP unit based on the current DOE Final Rule standards for ACs and HPs.[109]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Air Conditioners and Heat Pumps.[110]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of newly installed unit
    - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- Cooling capacity of the newly installed unit (Btuh)
- Heating capacity of the newly installed unit (Btuh) (HPs only)
- Seasonal energy efficiency ratio (SEER2) and energy efficiency ratio (EER2) of the newly installed unit
- Heating seasonal performance factor (HSPF2) of the newly installed unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air-source HP)
    - Baseline equipment used for savings (if different from unit replaced)
- Type of unit installed (central AC, central HP, dual-fuel HP, mini-split AC, mini-split HP, DC inverter AC, DC inverter HP)
- Unit type subcategory (split, packaged)

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

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

- Compressor type for newly installed unit (single-stage, multi-stage, variable speed)
    - Recommended to assist with development of future deemed savings for variable-speed systems
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, recording nameplate information, 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
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program)
- Manual J load calculation (rightsizing). See the Eligibility Criteria section for applicable scenarios.
- Photograph of retired cooling unit nameplate (required for all rightsizing projects and early retirement projects unless default age is applied consistently across the program)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide estimated square footage of conditioned area served by the retired unit (rightsizing only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only). This requirement also applies to projects using the default age.
- For installed HVAC systems meeting minimum federal standard SEER2 efficiency:
    - Age of existing equipment
    - Proof of functionality of existing equipment
    - Rated SEER, if available
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment

- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

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

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. Defined rightsizing and documentation requirements. Updated early retirement age eligibility.

2.2.3 ENERGY STAR® Room Air Conditioners Measure Overview

TRM Measure ID: R-HV-RA

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

To claim early retirement savings, the replaced unit must be functioning at the time of removal with a maximum age of 12 years, coinciding with the point at which there is no assumed remaining useful life.

Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit that is compliant with the current federal standard,[111] effective June 1, 2014. The standard refers to a revised efficiency rating, Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

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

[111] Legacy DOE minimum efficiency standard for residential room air conditioners effective during current federal standard manufacturer lag period.https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.[112]

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

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

High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 5.0 Requirements for eligible room air conditioners effective October 30, 2023.[113] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

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

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

Table 36. RACs—Efficient Condition Requirements

Reverse cycle (Yes/No)	Louvered sides (Yes/No)	Capacity (Btu/hr)	Minimum CEER[114]
No	Yes	< 6,000	13.1
		6,000-7,999	13.7
		8,000-13,999	14.7
		14,000-19,999	14.4
		20,000-27,999	12.7
		≥ 28,000	12.2
No	No	< 6,000	12.8
		6,000-7,999	12.8
		8,000-10,999	13.0
		11,000-13,999	12.8
		14,000-19,999	12.6
		≥ 20,000	12.7
Yes	Yes	< 20,000	13.2
		≥ 20,000	12.6
Yes	No	< 14,000	12.6
		≥ 14,000	11.7
Casement-only		All capacities	12.8
Casement-slider		All capacities	14.0

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

New Construction or Replace-on-Burnout

Energy Savings Algorithms

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

Equation 24

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

Where:

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

Table 37. RACs—Annual Operating Hours for Cooling[115]

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

Demand Savings Algorithms

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

Equation 25

Where:

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

Table 38. RACs—Coincidence Factor[116]

Season	CF
Summer[117]	0.87

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

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

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

Early Retirement

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

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

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

Where:

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

EUL = *Estimated useful life = 10 years*

Table 39. RACs—RUL of Replaced Unit[118]

Age of replaced unit (years)	RUL (years)
1	8.0
2	7.2
3	6.2
4	5.2
5	5.2
6	5.2
7	5.2
8	5.0
9	4.0
10	3.0
11	2.0
12	1.0
13[119,120]	0.0

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

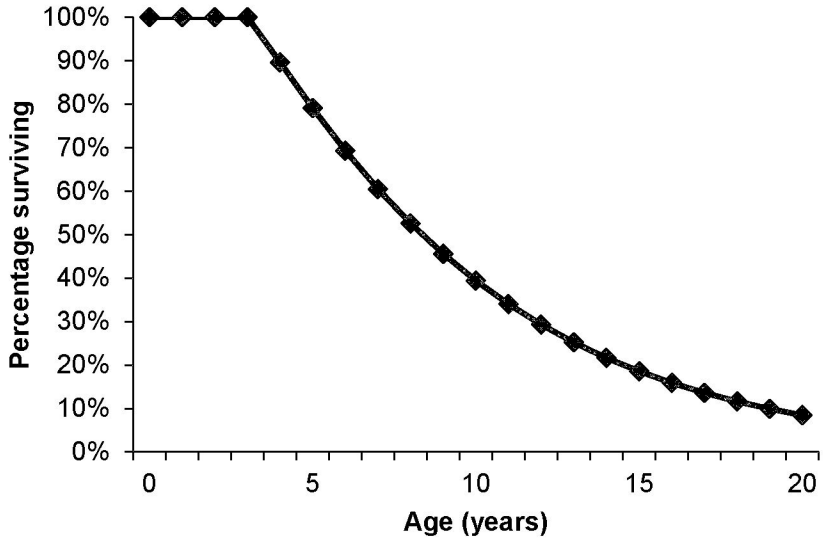
[119] RULs are capped at the seventy-fifth percentile of equipment age as determined based on DOE survival curves (see Figure 3). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

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

Derivation of RULs

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

Figure 3. RACs—Survival Function[121]



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

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

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

Energy Savings Algorithms

For the RUL time period:

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

Equation 26

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

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

Equation 27

Where:

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

Summer Demand Savings Algorithms

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

For the RUL time period:

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

Equation 28

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

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

Equation 29

Where:

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

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

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

This value is consistent with the EUL reported in the DOE Technical Support Document for RACs.[122]

Program Tracking Data and Evaluation Requirements

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

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

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

- Age of the replaced unit (early retirement only)
- Photograph of retired unit nameplate (early retirement)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 40. RACs—Revision History

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

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Update to documentation requirements.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for units with connected functionality.
v10.0	10/2022	TRM v10.0 update. Update minimum CEER requirement for units with connected functionality. Updated coincidence factors, early retirement age eligibility, and documentation requirements.
v11.0	10/2023	TRM v11.0 update. Incorporated updated DOE final rule and ENERGY STAR specification v5.0. Updated early retirement age eligibility.

2.2.4 Packaged Terminal Heat Pumps Measure Overview

TRM Measure ID: R-HV-PT

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Multifamily

Fuels Affected: Electricity

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

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

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

Eligibility Criteria

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

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

Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[123,124]

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

Baseline Condition

Early Retirement

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL – RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC), and age (based on year of manufacture) of the replaced system.[125] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 41, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

When the system age is unknown, assume 15 years.[126] A default RUL may be used exclusively if applied consistently for all eligible early retirement projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

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

Table 41. PTHPs—ER Baseline Efficiency Levels for Standard Size PTACs[127]

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

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

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

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

Replace-on-Burnout

Table 42 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for packaged terminal air-conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 42. PTHPs—ROB Minimum Efficiency Levels[128,129]

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

[128] IECC 2015 Table C403.2.3(3).

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

High-Efficiency Condition

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

The high-efficiency retrofits must also meet the following criteria:[130]

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 30

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

Equation 31

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

Equation 32

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

Equation 33

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

Equation 34

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

Where:

$Cap_{C/H,pre}$	=	*For ER, rated equipment cooling/heating*[131] *capacity of the existing equipment at AHRI standard conditions*; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI standard conditions *[BTUH]; 1 ton = 12,000 Btuh*
$Cap_{C/H,post}$	=	*Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh*
$\eta_{baseline,C}$	=	*Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 41 through Table 42)*
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] (must exceed minimum requirements from Table 42)*[132]
$\eta_{baseline,H}$	=	*Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 41 through Table 42)*
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment [COP] (must exceed minimum requirements from Table 42)*[133]
$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor (Table 43)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours] (Table 44)*

[131] Baseline cooling capacity refers to the rated cooling capacity of the existing PTAC. Assume baseline heating capacity is equal to rated heating capacity for newly installed PTHP.
[132] Rated efficiency is commonly reported at both 230 V and 208 V. Savings calculations should reference efficiency at 230 V, as AHRI rating conditions specify that voltage.
[133] Ibid.

Table 43. PTHPs—Coincidence Factors[134]

Season	CF
Summer[135]	0.87
Winter[136]	0.83

Table 44. PTHPs—Cooling/Heating EFLHs[137]

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

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

Claimed Peak Demand Savings

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

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

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

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

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

Deemed Energy and Demand Savings Tables

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

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL is 15 years, as specified in as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[138]

Remaining Useful Life (RUL) for PTHP Systems

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

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

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

Where:

RUL	=	*Remaining useful life (see Table 45); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.8 years*
EUL	=	*Estimated useful life = 15 years*

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

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

Table 45. PTHPs—RUL of Replaced PTAC[139,140]

Age of replaced system (years)	PTAC RUL (Years)	Age of replaced system (years)	PTAC RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18[141]	0.0

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ROB or ER
- Climate zone or county
- Equipment configuration category: standard/non-standard
- Baseline equipment rated cooling capacity (Btuh)
- Baseline number of units
- Installed equipment rated cooling and heating capacities
- Installed number of units
- Installed cooling and heating efficiency rating
- Installed make and model
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available) (early retirement only)

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

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

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 46. PTHPs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Added winter demand algorithm. Updated coincidence factors and documentation requirements
v9.0	10/2021	TRM v9.0 update. Clarified early retirement age eligibility. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Clarified electric resistance baseline. Updated coincidence factors and early retirement age eligibility.
v11.0	10/2023	TRM v11.0 update. Updated early retirement age eligibility.

2.2.5 ENERGY STAR® Ground Source Heat Pumps Measure Overview

TRM Measure ID: R-HV-GH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

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

Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an air conditioner with an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard, effective January 1, 2023.[142]

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

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.7 SEER2. This value incorporates an adjustment to the baseline SEER2 value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[143] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 47. GSHPs—Baseline Efficiencies

Project type	Cooling mode[144]	Heating mode[145]
New construction	9.8 EER2 (14.3 SEER2)	2.2 COP (7.5 HSPF2)
ROB—air source heat pump baseline	9.8 EER2 (13.7 SEER2)	2.2 COP (7.5 HSPF2)
ROB—air conditioner with electric resistance furnace baseline		1 COP (3.412 HSPF2)

High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 3.2 requirements for eligible geothermal heat pumps effective January 1, 2012.[146] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 48. GSHPs—ENERGY STAR Requirements

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

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

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

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

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

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[147]

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

Equation 35

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

Equation 36

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on GSHPs in Texas.[148] Desuperheater savings were calculated for each climate zone by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high-efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to the replacement of air source heat pumps with GSHPs. These estimates were found to be within 5 percent of actual post-retrofit savings. Building models were developed using TRNSYS.[149]

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

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

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

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

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

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

Energy Savings Algorithms

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

Equation 37

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

Equation 38

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

Equation 39

Where:

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

Table 49. GSHPs—Equivalent Full Load Cooling/Heating Hours[150]

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

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

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

Demand Savings Algorithms

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

Equation 40

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

Equation 41

Where:

$EER2_{Base}$ = *Energy efficiency ratio of the baseline cooling equipment (see Table 47)*

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 50)*

kW_{DSH} = *Summer demand savings (kW) associated with installation of a desuperheater (see Table 52); these savings should only be added if a desuperheater is installed*

Table 50. GSHPs—Coincidence Factors[151]

Season	CF
Summer[152]	0.87
Winter[153]	0.83

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

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

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

Deemed Energy Savings Tables

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

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

Deemed Summer Demand Savings Tables

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

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

Deemed Winter Demand Savings Tables

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

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

This value is consistent with the life expectancy of the heat pump components reported in multiple Department of Energy GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [154,155]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type (new construction, replace-on-burnout)
- Replaced unit heating type (heat pump, electric resistance furnace)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Manufacturer, model number, and serial number
- ENERGY STAR certificate matching installed model number
- Installed GSHP type (closed loop water-to-air, open loop water-to-air, closed loop water-to-water, open loop water-to-water, direct geoexchange)
- Energy efficiency ratio (EER) of the new unit
- Coefficient of performance (COP) of the new unit
- Product specification sheet
- Rated cooling and heating capacity of the new unit (Btu/hr)[156]
- Whether a desuperheater was also installed or present
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

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

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

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 53. GSHPs—Revision History

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

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

TRM Measure ID: R-HV-LC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

- The deemed savings apply to central AC/HPs with a capacity of 65,000-240,000 Btu/hr (5.4-20 tons) and GSHPs with a capacity of 65,000-135,000 Btu/hr (5.4-11.3 tons).
- Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.
- Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[157,158]

Baseline Condition

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

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

Table 54. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for AC/HPs[159]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[160]
Air conditioners	> 5.4 to < 11.3	None or Electric resistance	11.2 EER 12.8 IEER	DOE Standards/ IECC 2015
		All Other	11.0 EER 12.6 IEER	
	≥ 11.3 to ≤ 20	None or Electric resistance	11.0 EER 12.4 IEER	
		All other	10.8 EER 12.2 IEER	
Heat pump (cooling)[161]	5.4 to < 11.3	Heat pump	11.0 EER 12.0 IEER	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20		10.6 EER 11.6 IEER	
Heat pump (heating)[162]	5.4 to < 11.3	Heat pump	3.3 COP	DOE Standards/ IECC 2015
	≥ 11.3 to ≤ 20		3.2 COP	

[159] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[160] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR 431.97. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf.
[161] ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type "No Heating or Electric Resistance Heating", excluding systems with "All Other Types of Heating".
[162] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

Table 55. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for GSHPs[163]

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

High-Efficiency Condition

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

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 42

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

Equation 43

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

Equation 44

[163] Values from ASHRAE 90.1-2013.

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

Equation 45

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

Equation 46

Where:

$Cap_{C/H}$	=	*Rated equipment cooling/heating capacity of the installed equipment at AHRI standard conditions (Btu/hr); 1 ton = 12,000 Btu/hr*
$\eta_{baseline,C}$	=	*Cooling efficiency of standard equipment (Btuh/W)*
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment (Btuh/W)*
$\eta_{baseline,H}$	=	*Heating efficiency of standard equipment (Btuh/W or COP)*
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment (Btuh/W or COP)*

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

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

Equation 47

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

Table 56. Large Capacity AC/HPs—Coincidence Factors[164]

Season	CF
Summer[165]	0.87
Winter[166]	0.83

Table 57. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours[167]

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

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

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

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

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

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for a large-capacity air conditioner and 15 years for a large capacity heat pump based on the current DOE Final Rule standards for central heat pumps.[168] The EUL of a high-efficiency ground source heat pump unit is 24 years, consistent with the EUL reported in the DOE GSHP guide.[169]

These values are consistent with the life expectancy of the heat pump components reported in multiple DOE GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [170,171]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type (new construction, retrofit)
- Cooling and heating capacities (Btu/hr)
- Full-load efficiency rating (EER) of the installed unit
- Part-load efficiency rating (SEER/IEER) of the installed unit (if applicable)
- Coefficient of Performance (COP) of the unit installed (heat pumps and GSHPs only)
- Proof of purchase – with date of purchase and quantity
- Alternative: photo of unit installed or other pre-approved method of installation verification

[168] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.
[169] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.
[170] Department of Energy. Geothermal Heat Pump Energy Saver article. https://www.energy.gov/energysaver/geothermal-heat-pumps.
[171] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 58. Large Capacity AC/HPs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Measure removed from TRM.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. Consolidated AC and HP measures and reintroduced to TRM. Extended measure applicability to GSHPs. Updated from deemed savings to algorithm approach.
v7.0	10/2019	TRM v7.0 update. Updated documentation requirements.
v8.0	10/2020	TRM v8.0 update. Updated coincidence factors
v9.0	10/2021	TRM v9.0 update. Updated baseline efficiency table to remove categories applicable to larger capacity ranges. Added GSHP coincidence factors.
v10.0	10/2022	TRM v10.0 update. Updated coincidence factors.
v11.0	10/2023	TRM v11.0 update. Updated GSHP EUL.

2.2.7 Evaporative Cooling Measure Overview

TRM Measure ID: R-HV-EC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculations

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

The baseline condition is a new refrigerated air conditioner with a rated efficiency at 14 SEER, the federal minimum standard.[172] The system being replaced is likely to be a less efficient evaporative cooling system, but the alternative to the new evaporative cooling unit is a minimally efficient refrigerated air conditioning system.

High-Efficiency Condition

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

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings for this measure were derived using a reference metering study of evaporative cooling projects for Xcel Energy.[173] The energy savings from the Xcel study are adjusted for climate using a cooling degree day (CDD) ratio derived from TMY 2020 weather data.[174] Demand savings are calculated using the coincidence factor for the room air conditioner measure and an EFLH estimation simulated in a calibrated BEopt model that is used for other modeled measures in the Texas TRM.

Energy Savings Algorithms

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

Equation 48

Where:

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

Demand Savings Algorithms

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

Equation 49

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

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

Where:

$EFLH_{Site}$ = *Equivalent full-load hours of an evaporative cooling system for the project site location, El Paso, TX: 1,288*[175]

CF_S = *Summer coincidence factor*[176] *= 0.87*

Deemed Savings Tables

Table 59. Evaporative Cooling—Deemed Savings per System

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-Evap.[177]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Retired system model number and serial number (if applicable)
- Installed evaporative cooler model number and serial number
- Installed evaporative cooler saturation effectiveness

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

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

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

- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 60. Evaporative Cooling—Revision History

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

2.2.8 ENERGY STAR® Connected Thermostats Measure Overview

TRM Measure ID: R-HV-CT

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering spreadsheets and estimates

Measure Description

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

Eligibility Criteria

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

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

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

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