Acknowledgments

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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) 2023 TRM 10.0 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	10.0 update
Lighting	ENERGY STAR® general service LED lamps	–	–	X	–	–	Updated for compliance with the new Department of Energy (DOE) general service lamp (GSL) definition and reinstatement of the Energy Independence Security Act (EISA) 45 lumens/watt backstop
	ENERGY STAR® specialty and directional LED lamps	–	–	X	–	–	Updated for compliance with the new DOE GSL definition. Several lamp types previously considered *specialty lamps* moved to *general service lamp* measure
	LED nightlights	–	–	X	–	–	New measure
HVAC	Air conditioner or heat pump tune-up	–	–	X	–	–	Updated coincidence factors
	Central heat pumps without SEER2 ratings	–	X	–	–	–	Restricted measure for use with central heat pumps (HP) without a SEER2 rating. Updated early retirement age eligibility
	Mini-split heat pumps without SEER2 ratings	–	X	–	–	–	Restricted measure for use with mini-split HPs without a SEER2 rating. Updated early retirement age eligibility
	Central mini-split air conditioners and heat pumps with SEER2 ratings	–	–	X	–	–	New measure
	Room air conditioners	–	–	X	–	–	Update minimum combined energy efficiency ratio (CEER) requirement for units with connected functionality. Updated coincidence factors, early retirement age eligibility, and documentation requirements
	Packed terminal heat pumps	–	–	X	–	–	Clarified electric resistance baseline. Updated coincidence factors and early retirement age eligibility

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	10.0 update
	Ground source heat pumps	–	X	X	–	–	Updated coincidence factors and estimated useful life (EUL)
	Large capacity split system and single-package air conditioners and heat pumps	–	–	X	–	–	Updated coincidence factors
	Evaporative Cooling	–	X	–	–	–	Updated cooling degree days (CDD) reference
	ENERGY STAR® connected thermostats	–	X	–	–	–	No revision
	Smart thermostat load management	–	X	–	–	–	No revision
	Duct sealing	–	–	X	–	X	Corrected typo in leakage categorization guide; added language for additional rater certification options
Building envelope	Air infiltration	–	X	–	–	X	No revision
	Ceiling insulation	–	X	–	–	–	No revision
	Attic encapsulation	–	X	–	–	–	No revision
	Wall insulation	–	X	–	–	–	No revision
	Floor insulation	–	X	–	–	–	No revision
	Radiant barriers	–	X	–	–	–	New measure
	Cool roofs	–	X	–	–	–	Addressed sunsetting of ENERGY STAR® Roof program
	Solar screens	–	X	–	–	–	No revision
	ENERGY STAR® windows	–	X	–	–	–	Added option for a weighted single-pane and double-pane baseline
	ENERGY STAR® low-e storm windows		X	–	–	–	Added option for a weighted single-pane and double-pane baseline

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	10.0 update
Domestic water heating	Water heater installation—electric tankless and fuel substitution	–	–	X	–	–	Verified compliance with ENERGY STAR® Final Version 4.0 Requirements. Updated documentation requirements
	Heat pump water heaters	–	X	–	–	–	Verified compliance with ENERGY STAR® Final Version 4.0 Requirements. Updated savings methodology to algorithm approach. Updated documentation requirements
	Solar water heaters	–	X	–	–	–	Verified compliance with ENERGY STAR® Final Version 4.0 Requirements. Updated documentation requirements
	Water heater tank insulation	–	–	X	–	–	Updated documentation requirements
	Water heater pipe insulation	–	–	X	–	–	Updated documentation requirements
	Faucet aerators	–	–	X	–	–	Updated number of occupants per home
	Low-flow showerheads	–	–	X	–	–	Updated number of occupants per home
	Showerhead temperature sensitive restrictor valves	–	–	X	–	–	Updated number of occupants per home
	Tub spout and showerhead temperature-sensitive restrictor valves	–	–	X	–	–	Updated number of occupants per home
	Water heater temperature setback	–	–	X	–	–	New measure

Measure category	Measure description	Point estimates	Deemed savings tables	Savings algorithm	Calculator	M&V	10.0 update
Appliances	ENERGY STAR® ceiling fans	–	–	X	–	–	Reduce baseline lighting wattage and resulting deemed energy savings for compliance with reinstated EISA 2007 45 lumens/watt baseline
	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	–	–	–	Verified compliance with ENERGY STAR® Final Version 2.0 Requirements. Updated dust clean air delivery rate (CADR) references to refer to smoke CADR. Updated deemed savings ranges and values
	ENERGY STAR® pool pumps	–	–	X	–	–	Verified compliance with ENERGY STAR® Final Version 3.1 Requirements. Updated savings coefficient definitions
	Advanced power strips	–	X	–	–	–	Corrected typos in deemed savings tables from TRM v9.0 update
	ENERGY STAR® electric vehicle supply equipment	–	X	–	–	–	Verified compliance with ENERGY STAR® Final Version 1.1 Requirements. Updated savings calculation assumptions, deemed savings, and documentation requirements
	Induction cooking	–	X	–	–	–	New measure

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.

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 (see Table 2). 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.[5]

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.
[5] See TRM v9.0 for methodology and baseline.

Table 2. GSL LEDs—Baseline and Default Wattages for A-Shaped Lamps[6,7]

Minimum lumens	Maximum lumens	Incandescent equivalent wattage	1st tier EISA 2007 (W_{Base})[8]	2nd tier EISA 2007 (W_{Base})[9]	Default W_{Post} (if unknown)[10]
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[11,12]

Minimum lumens	Maximum lumens	Incandescent equivalent wattage[13]	1st tier EISA 2007 (W_{Base})[14]	2nd tier EISA 2007 (W_{Base})[15]	W_{Post} (if unknown)[16]
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	

[6] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.
[7] If exempt, refer to the incandescent equivalent wattage.
[8] 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.
[9] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.
[10] Average rated wattage from the ENERGY STAR QPL rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[11] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.
[12] If exempt, refer to incandescent equivalent wattage.
[13] 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.
[14] 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.
[15] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.
[16] 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[17] for the relevant lamp shape being installed as outlined in the latest ENERGY STAR specification.[18] Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are A, BT, P, PS, S, and T.

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_{post} = *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)*

[17] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[18] 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[19])*
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[20] = 0.97*
1,000	=	*Constant to convert from W to kW*

Table 4. GSL LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[21]

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

[19] 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.

[20] 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.

[21] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

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
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[22]	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.

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 5)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 6)*

Table 5. GSL LEDs—Coincidence Factors[23]

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

[22] 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.

[23] See Volume 1.

Table 6. GSL LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[24]

$IEF_{D,S}$					
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[25]	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[26]	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.

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:

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

[24] Refer to Table 4.
[25] Ibid.
[26] Ibid.

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.[27] 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.

[27] 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.

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*[28]

DF = *0.85 degradation factor*[29]

HOU = *2.2 hours per day*[30]

Table 7. 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.

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
- Number of LEDs installed
- Wattage of each replacement LED
- Lumen output of each replacement LED
    - Manufacturer-rated lifetime of each replacement LED in hours

[28] 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.

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

[30] 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.

- 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 lap 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 8. 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.

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[31] 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 5 inches or more
- MR-shape lamps that have a first symbol equal to 16 (diameter equal to 2 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 2 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.[32]

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

[32] 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.[33]
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens per watt efficacy.[34]

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 9. Specialty LEDs—Baseline and Default Wattages

Lamp type[36]	Minimum lumens	Maximum lumens	W_{Base}
G-shape with diameter ≥ 5 in.[37]	–	–	Qualified Products List (QPL)
G-shape with diameter ≥ 5 in.[38]	–	–	QPL
MR16/MRX16	800	–	75
R14	250	299	25

[33] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.
[34] DOE Final Rule: Energy Conservation Standards for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070.
[35] 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.
[36] 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.
[37] 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.
[38] 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[39] for the relevant lamp shape being removed as outlined in the latest ENERGY STAR specification.[40] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps.

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 9)*

W_{post} = *Actual wattage of LED purchased/installed*

[39] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[40] ENERGY STAR specification: 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[41])*
IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 10)*
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[42] = 0.97*
1,000	=	*Constant to convert from W to kW*

Table 10. 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.

[41] 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.

[42] 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.

[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.

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 11)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 12)*

Table 11. Specialty LEDs—Coincidence Factors[45]

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 12. Specialty LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[46]

$IEF_{D,s}$					
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

[45] See Volume 1
[46] Refer to Table 10.

$IEF_{D,S}$					
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
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[47]	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[48]	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, 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.[49] 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.

[47] 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.

[48] 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.

[49] 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.

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

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*[50]
DF	=	*0.85 degradation factor*[51]
HOU	=	*2.2 hours per day*[52]

[50] 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.

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

EISA Compliant Lamps

To account for a rapidly changing market, standard practice dictates that measure life assumptions be reduced to approximate the point at which the residential lighting market has been fully transformed to high-efficiency lamps. Due to market uncertainty in response to a recent rule issued by the Department of Energy, a simplified approach to claim half of the more conservative 16-year EUL will be implemented during the 2020 program year, resulting in an 8-year EUL. This assumption will be reviewed annually to account for current market trends.

Based on an expected delay in market adoption among certain customer bases, this measure life will be extended to 10 years for programs targeting low-income and hard-to-reach customers.

These reductions do not apply to specialty lamps.

Table 13. 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
- 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)
- 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,

[52] 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.

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 14. 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.
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.

TRM version	Date	Description of change
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.

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)*[53]
W_{post}	=	*Actual wattage of LED purchased/installed (default = 1 W for LED)*
HOU	=	*Average hours of use per year = 4,161 hours*[54]
IEF_E	=	*Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 15)*
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 16)*
1,000	=	*Constant to convert from W to kW*

Table 15. LED Nightlights—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[55]

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

[53] Mertz, Stanley. "LED Nightlights Energy Efficiency Retail products programs." March 2018.
[54] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights," Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 and 3.
[55] 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[56]	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 16. LED Nightlights—In-Service Rates by Program Type

Program type	ISR
Kit programs[57]	0.60
All other	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

Where:

$CF_{S/W}$ = *Seasonal peak coincidence factor (see* Table 17*)*

IEF_D = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see* Table 18*)*

[56] 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.

[57] From IL TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of total installations within three years of delivery.

Table 17. LED Nightlights—Coincidence Factors[58]

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 18. LED Nightlights—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[59]

$IEF_{D,S}$					
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[60]	1.39	1.28	1.58	1.20	1.38

[58] From TX TRM *commercial lamps & fixtures* measure for dusk-to-dawn operation.
[59] Refer to Table 15.
[60] 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[61]	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.[62] 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.

[61] Ibid.

[62] 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.[63]

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
- 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.

Document Revision History

Table 19. LED Nightlights—Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.

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

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:[64]

- 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

[64] 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

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 in the last 5 years.

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

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[65]. A 13 SEER is equivalent to approximately 11.2 EER[66] 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.[67]

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

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[65] Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

[66] 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.

[67] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

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 20. AC/HP Tune-Ups—Equivalent Full Load Cooling/Heating Hours[68]

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

Demand Savings Algorithms

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

Equation 17

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

Equation 18

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

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:

$DF_{S/W}$ = *Summer/winter peak demand factor (see Table 21)*

Table 21. AC/HP Tune-Ups—Demand Factors[69]

Season	DF
Summer[70]	0.87
Winter[71]	0.83

Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 22. Heating savings are only applicable for heat pumps.

Table 22. 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

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

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

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

Deemed Summer Demand Savings Tables

Applying the above algorithms results in the deemed summer demand savings per ton in Table 23.

Table 23. AC/HP Tune-Ups—Summer Peak Demand Savings (kW/ton)

Climate zone	Summer kW/ton
Zone 1: Amarillo	0.036
Zone 2: Dallas	0.040
Zone 3: Houston	0.036
Zone 4: Corpus Christi	0.033
Zone 5: El Paso	0.044

Deemed Winter Demand Savings Tables

Applying the above algorithms results in the deemed winter demand savings per ton in Table 24. Winter peak demand savings are only applicable for heat pumps.

Table 24. AC/HP Tune-Ups—Peak Demand Savings (kW/ton)

Climate zone	Winter kW/ton
Zone 1: Amarillo	0.033
Zone 2: Dallas	0.025
Zone 3: Houston	0.028
Zone 4: Corpus Christi	0.024
Zone 5: El Paso	0.036

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. [72]

[72] 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.

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
- Manufacturer
- Model Number
- Cooling capacity of the installed unit (tons)
- Heating capacity of the installed unit (algorithm approach only)
- Type of unit (air conditioner, air source heat pump)
- Serial number
- 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.

Relevant Standards and Reference Sources

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

Document Revision History

Table 25. 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.

TRM version	Date	Description of change
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.

2.2.2 Central Heat Pumps Without SEER2 Ratings Measure Overview

TRM Measure ID: R-HV-CH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive, direct install (early retirement)

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering spreadsheets and estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new central air-source heat pump (HP) without a SEER2 rating in an existing building, or the installation of a new central AC or HP in a new residential construction. Downsized systems that are right-sized 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 that meet all existing measure eligibility criteria.

This measure is a one-year allowance that will be retired for program year 2024. It is only applicable to HPs based on a sell-through allowance for units manufactured prior to January 1, 2023.

Eligibility Criteria

This measure only applies to HPs without a SEER2 rating. For units that do not have SEER2 ratings at the time of purchase but that have SEER2 ratings added to the Air Conditioning, Heating, and Refrigeration Institute (AHRI) prior to evaluation, the baselines in this measure will apply if project documentation can demonstrate that no SEER2 rating was available at the time of purchase. Appropriate documentation may include a copy of the AHRI certificate, manufacturer specification sheet, or other evaluator pre-approved documentation dated to match approximate installation or purchase date.

Newly-installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings.

Equipment shall be properly sized to dwelling based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) or Air Conditioning Contractors of America Association, Inc. (ACCA) Manual J standards. Manufacturer datasheets for installed equipment or documentation of AHRI or the Department of Energy (DOE) Compliance

Certification Management System (CCMS) certification must be provided[73,74]. Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

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.

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

New construction projects are not eligible to receive deemed savings for system rightsizing.[75] For system upsizing, savings should generally be claimed against the new construction baseline; however, upsizing is allowed for the following 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.

- Replacing a single, larger-capacity system with multiple, smaller-capacity systems where the total pre- and post-tonnage are within one-half ton.[76] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.
- Replacing a single-stage system with a multi-stage system operating at variable speeds where the total pre- and post-tonnage are within one-half ton.[77] This scenario does not apply to the replacement of a multi-stage unit with another multi-stage unit.

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[73] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[74] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
[75] For projects using a custom baseline, see TRM Volume 4.
[76] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.
[77] This exception is allowed to account for efficiency improvements due to operating at variable speeds that are not reflected in the current savings methodology.

- If a Manual J load calculation is completed and included with project documentation, upsizing will be allowed where the total pre- and post-tonnage are within one ton.[78] This guidance is also extended to the previous scenarios when a Manual J load calculation is provided.

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

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

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

Baseline Condition

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

New construction baseline efficiency values for HPs are compliant with the previous federal standard,[79] effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to HP installations replacing ACs with central gas heat, evaporative coolers with central, space, or no heating, or room/window ACs with central, space, or no heating.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[80]

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[78] 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.

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

[80] 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

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

For ROB projects, heating baseline efficiency values for HPs are compliant with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems and 8.0 for packaged systems. This baseline reflects updates to federal standards that take effect on January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[81] For ER projects where the existing system was installed on or after January 23, 2006, the heating baseline efficiency is assumed to be an HSPF of 7.7 based on the federal minimum standard in effect from January 23, 2006, through December 31, 2014.[82] For ER projects where the existing system was installed before January 23, 2006, the heating baseline efficiency is reduced to 6.8 HSPF based on the federal minimum standard in effect prior to January 23, 2006.

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

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[83] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[84] 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 = 3.41.[85] 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.

Table 26. Central HPs—Efficiencies

Project type	Cooling mode	Heating mode
New construction	14 SEER	8.2 HSPF
Replace-on-burnout, heat pump	13.08 SEER	8.2 HSPF
Replace-on-burnout, electric resistance furnace		3.41 HSPF
Early retirement, heat pump (manufactured as of 1/1/2015)	13.08 SEER	8.2 HSPF
Early retirement, heat pump (manufactured 1/23/2006 through 12/31/2014)	12.44 SEER	7.7 HSPF

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.

[81] *10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[82] Ibid.

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

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

[85] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

Project type	Cooling mode	Heating mode
Early retirement, electric resistance furnace (manufactured 1/23/2006 through 12/31/2014)		3.41 HSPF
Early retirement, heat pump (when applying default age)	12.44 SEER	7.7 HSPF
Early retirement, electric resistance furnace (when applying default age)		3.41 HSPF
Early retirement, heat pump (manufactured before 1/23/2006)	10 SEER	6.8 HSPF
Early retirement, electric resistance furnace (manufactured before 1/23/2006)		3.41 HSPF

High-Efficiency Condition

Table 27 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 0 HPs as of January 1, 2015. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 0 requirements.

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER and HSPF requirements but do not comply with the EER requirements outlined in Table 27 may still be eligible to claim savings. Systems with qualifying SEER and HSPF energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems, but not summer demand savings where the EER does not comply with the below requirement.

Table 27. Central HPs—Tier 0 Requirements[86]

SEER	EER	HSPF
14.5	12.0	8.5

Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high efficiency 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.

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

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.

Replace-on-Burnout or New Construction

Energy, summer demand, and winter demand savings were estimated using AC and HP performance curves developed by the National Renewable Energy Laboratory[87] for typical units in each of the following SEER ranges:

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

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

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

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

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

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

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

Equation 19

Table 28. Central HPs—Curve Coefficients[88]

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

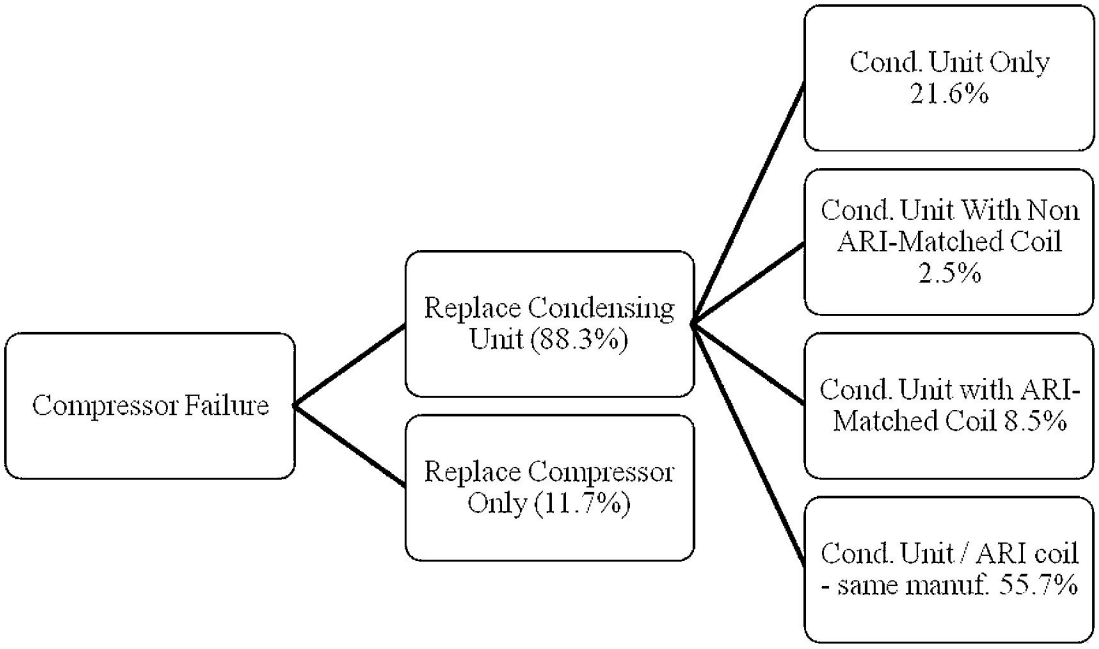
Table 29. Central HPs—Curve Coefficients[89]

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

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

[88] Using air conditioner capacity curve coefficients for heat pump cooling savings.
[89] Using air conditioner capacity EIR coefficients for heat pump cooling savings.

Figure 1. Central HPs—Unit Replacement Percentages upon Compressor Failure



Source: Docket No. 36780

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

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

Equation 20

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

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

Adjusting for the increased 14 SEER baseline:

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

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

Early Retirement

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

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

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

Where:

RUL	=	*Remaining useful life (see Table 30 or Table 31). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. For HPs replacing an AC with an electric resistance furnace, use the AC RUL table.*
EUL	=	*Estimated useful life = 15 years*

For early retirement, if age is unknown, assume a default age equal to the replaced unit EUL resulting in an 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 26 for use with the default age.

Table 30. Central HPs—RUL of Replaced AC[90]

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

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

Age of replaced unit (years)	Remaining useful life (years)
7	11.9
8	11.3
9	10.8
10	10.3
11	9.8
12	9.4
13	9.0

Age of replaced unit (years)	Remaining useful life (years)
20	5.0
21	4.0
22	3.0
23	2.0
24	1.0
25[91,92]	0.0

Table 31. Central HPs—RUL of Replaced HP[93]

Age of replaced unit (years)	Remaining useful life (years)
1	13.7
2	12.7
3	12.0
4	11.3
5	10.7
6	10.2
7	9.7
8	9.3
9	8.9
10	8.5
11	8.2

Age of replaced unit (years)	Remaining useful life (years)
12	7.9
13	7.6
14	7.0
15	6.0
16	5.0
17	4.0
18	3.0
19	2.0
20	1.0
21[94,95]	0.0

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

[92] 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.

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

[94] RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (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.

[95] 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.

Derivation of RULs

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

Figure 2. Central AC/HPs—AC Survival Function[96]

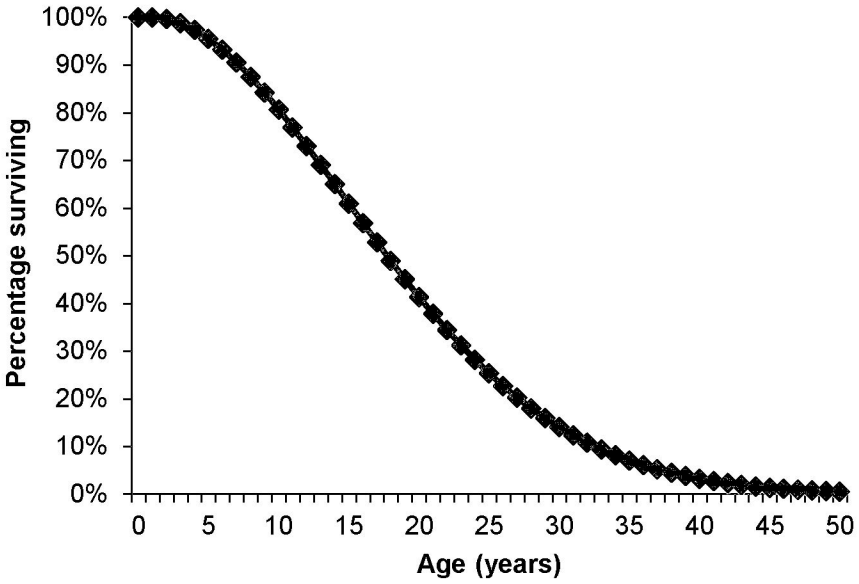
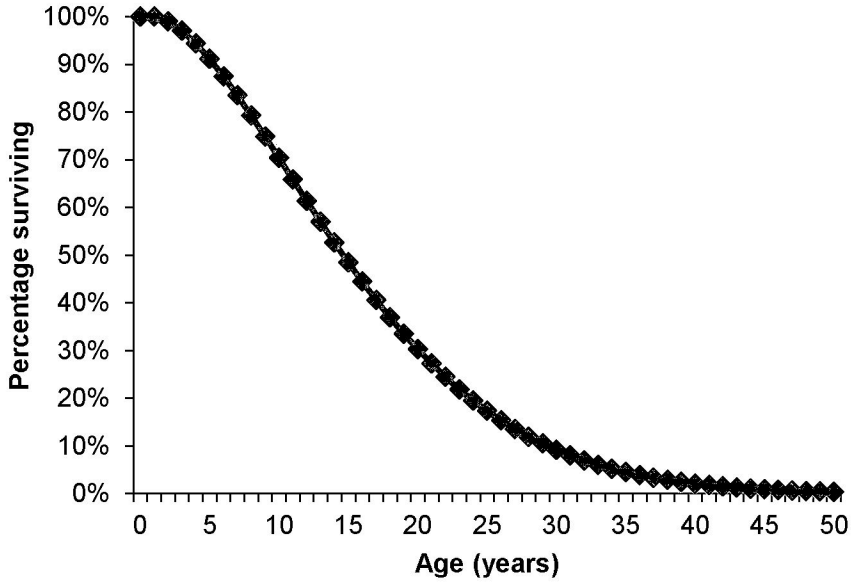


Figure 3. Central AC/HPs—HP Survival Function[97]



[96] 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: https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012.

[97] Ibid.

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.

Deemed Energy Savings Tables[98]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[99] Both cooling and heating savings are specified according to AHRI-rated cooling capacity.

Deemed Summer Demand Savings Tables[100]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[101] Summer demand savings are specified according to AHRI-rated cooling capacity.

Deemed Winter Demand Savings Tables[102]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[103] Winter demand savings are specified according to AHRI-rated cooling capacity.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

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

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

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

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

[102] Rated capacity ranges are specified with a 5 percent tolerance in accordance with AHRI Standard 210/240 to account for systems that are rated slightly below the applicable nominal capacity. AHRI Standard 210/240. Table J1. https://www.ahrinet.org/sites/default/files/2022-07/AHRI_Standard_210-240_2017.pdf.

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for HPs based on the DOE 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for central ACs and HPs.[104]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the newly installed unit (Btuh)
- Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of the newly installed unit
- Heating Seasonal Performance Factor (HSPF) of the newly installed unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air source HP)
- Baseline equipment used for savings (if different from unit replaced)
- Type of unit installed (central HP or dual-fuel HP)
- Compressor type for newly-installed unit (single-stage, multi-stage, variable speed)
    - Recommended to assist with development of future deemed savings for multi-stage systems operating at variable speeds
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program)
- Manual J load calculation (when rightsizing upward by more than one-half tons). See Eligibility Criteria section for applicable scenarios
- Photograph of retired cooling unit nameplate (required for all rightsizing and early

[104] 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. https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012.

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.
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment
- Proof of purchase – with date of purchase and quantity
  - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, and serial number of newly installed unit
  - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- AHRI certificate or manufacturer specification sheet with date corresponding to time of application or purchase demonstrating that the unit does not have a SEER2 efficiency rating.

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 32. Central HPs—History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Low-income and hard-to-reach Market Transformation section merged with main measure as "early retirement" option. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated.
v3.1	11/05/2015	TRM v3.1 update. Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of early retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.
v4.0	10/10/2016	TRM v4.0 update. Added RUL value for units with an age of one year. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years. Updated savings for 15.0-15.9 SEER range.
v5.0	10/2017	TRM v5.0 update. Switched to air conditioner capacity and EIR curve coefficients for estimated heat pump cooling savings. Updated energy savings to use TMY3 temperature bin hours. Updated demand savings for compliance with current peak definition. Added 12.44 SEER and 6.8 HSPF baseline savings tables previously referencing earlier version of TRM. Updated baseline to include replacing air conditioners with gas heat.
v6.0	11/2018	TRM v6.0 update. Updated baseline and eligibility requirements. Added rightsizing savings for replace on burnout in winter demand tables. Added language clarifying use of rated capacity vs nominal and updated the deemed savings tables to show rated Btuh. Clarified required documentation for early retirement.
v7.0	10/2019	TRM v7.0 update. Consolidated central air conditioner and heat pump measures. Moved deemed savings tables to Appendix A. Updated eligibility for low-income and hard-to-reach.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Updated electric resistance baseline documentation.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for systems where EER does not meet CEE Tier 0 requirements.
v10.0	10/2022	TRM v10.0 update. Restricted measure for use with central HPs without a SEER2 rating. Updated early retirement age eligibility.

2.2.3 Mini-Split Heat Pumps Without SEER2 Ratings Measure Overview

TRM Measure ID: R-HV-MS

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive, direct Install (early retirement)

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering spreadsheets and estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new mini-split heat pump (HP) without a SEER2 rating in an existing building, or the installation of a new mini-split AC or HP in a new residential construction. Downsized systems that are right-sized per a heat load calculation are also eligible. This measure also applies to the installation of DC inverter systems that meet all existing measure eligibility criteria.

This measure is a one-year allowance that will be retired for program year 2024. It is only applicable to HPs based on a sell-through allowance for units manufactured prior to January 1, 2023.

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

Eligibility Criteria

This measure only applies to HPs without a SEER2 rating. For units that do not have SEER2 ratings at the time of purchase but that have SEER2 ratings added to the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) prior to evaluation, the baselines in this measure will apply if project documentation can demonstrate that no SEER2 rating was available at the time of purchase. Appropriate documentation may include a copy of the AHRI certificate, manufacturer specification sheet, or other evaluator pre-approved documentation dated to match approximate installation or purchase date.

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings.

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[105,106]. Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

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.

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

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

New construction projects are not eligible to receive deemed savings for system rightsizing.[107] For system upsizing, savings should generally be claimed against the new construction baseline. However, upsizing is allowed for 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.

- Replacing a single larger-capacity system with multiple smaller-capacity systems where the total pre- and post-tonnage are within one-half ton.[108] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.

- Replacing a single-stage system with a multi-stage system operating at variable

[105] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[106] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
[107] For projects using a custom baseline, see TRM Volume 4.
[108] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

speeds where the total pre- and post-tonnage are within one-half ton.[109] This scenario does not apply to the replacement of a multi-stage unit with another multi-stage unit.

- If a Manual J load calculation is completed and included with project documentation, upsizing will be allowed where the total pre- and post-tonnage are within one ton.[110] This guidance is also extended to the previous scenarios when a Manual J load calculation is provided.

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

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

Baseline Condition

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

New construction baseline efficiency values for HPs are compliant with the previous federal standard,[111] effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to HP installations replacing ACs with central gas heat, evaporative coolers with central, space, or no heating, or room/window ACs with central, space, or no heating.

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

[110] 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.

[111] 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 projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[112]

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

For ROB projects, heating baseline efficiency values for HPs are compliant with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems, or 8.0 for packaged systems. This baseline reflects updates to federal standards that took effect on January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[113] For ER projects where the existing system was installed on or after January 23, 2006, the heating baseline efficiency is assumed to be an HSPF of 7.7 based on the federal minimum standard in effect from January 23, 2006, through December 31, 2014.[114] For ER projects where the existing system was installed before January 23, 2006, the heating baseline efficiency is reduced to 6.8 HSPF based on the federal minimum standard in effect prior to January 23, 2006.

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

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[115] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[116] 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 = 3.41.[117] 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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[112] 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/Documents/36780_41_624513.PDF. Adapted for new 14 SEER baseline.

[113] *10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule*. Online. Available: https://www.govinfo.gov/content/pkg/CFR-2016-title10-vol3/xml/CFR-2016-title10-vol3-part430.xml.

[114] Ibid.

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

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

[117] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

Table 33. Mini-Split HPs—Baseline Efficiencies

Project type	Cooling mode	Heating mode
New construction	14 SEER	8.2 HSPF
Replace-on-burnout, heat pump	13.08 SEER	8.2 HSPF
Replace-on-burnout, electric resistance furnace		3.41 HSPF
Early retirement, heat pump (manufactured as of 1/1/2015)	13.08 SEER	8.2 HSPF
Early retirement, heat pump (manufactured 1/23/2006 through 12/31/2014)	12.44 SEER	7.7 HSPF
Early retirement, electric resistance furnace (manufactured 1/23/2006 through 12/31/2014)		3.41 HSPF
Early retirement, heat pump (when applying default age)	12.44 SEER	7.7 HSPF
Early retirement, electric resistance furnace (when applying default age		3.41 HSPF
Early retirement, heat pump (before 1/23/2006)	10 SEER	6.8 HSPF
Early retirement, electric resistance furnace (before 1/23/2006)		3.41 HSPF

High-Efficiency Condition

Table 27 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 0 systems as of January 1, 2015. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 0 requirements.

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER and HSPF requirements but do not comply with the EER requirements outlined in Table 27 may still be eligible to claim savings. Systems with qualifying SEER and HSPF energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems, but not summer demand savings where the EER does not comply with the below requirement.

Table 34. Mini-Split HPs—System CEE Tier 0 Requirements[118]

SEER	EER	HSPF
14.5	12.0	8.5

Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high efficiency 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.

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

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.

Replace-on-Burnout or New Construction

Energy, summer demand, and winter demand savings were estimated using the AC and HP performance curves developed by the National Renewable Energy Laboratory[119] for typical units in each of the following SEER ranges:

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

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

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

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

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

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

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

Equation 21

Table 35. Mini-Split HPs—Capacity Curve Coefficients[120]

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

Table 36. Mini-Split HPs—EIR Curve Coefficients[121]

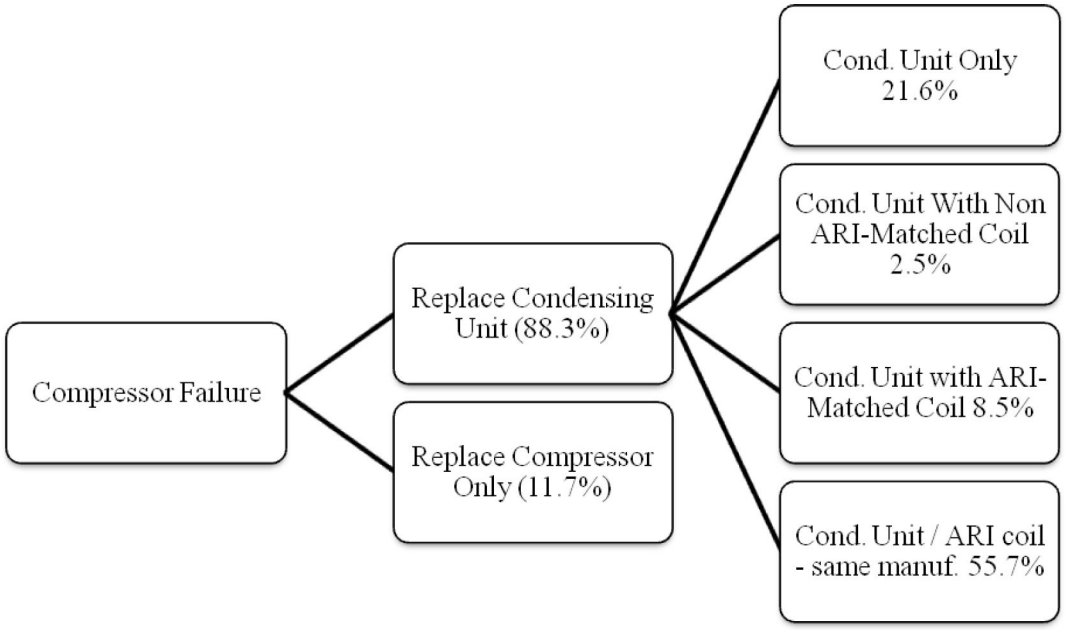
Coeff.	Cooling			Heating		
		Multi-stage/speed			Multi-stage/speed	
	Single-stage	Low	High	Single-stage	Low	High
a	-3.302695861	-3.87752688	-1.990708931	0.718398423	0.36338171	0.981100941
b	0.137871531	0.164566276	0.093969249	0.003498178	0.013523725	-0.005158493
c	-0.001056996	-0.001272755	-0.00073335	0.000142202	0.000258872	0.000243416

[120] Using air conditioner capacity curve coefficients for heat pump cooling savings.
[121] Using air conditioner capacity EIR coefficients for heat pump cooling savings.

Coeff.	Cooling			Heating		
		Multi-stage/speed			Multi-stage/speed	
	Single-stage	Low	High	Single-stage	Low	High
d	-0.012573945	-0.019956043	-0.009062553	-0.005724331	-0.009450269	-0.005274352
e	0.000214638	0.000256512	0.000165099	0.00014085	0.000439519	0.000230742
f	-0.000145054	-0.000133539	-0.0000997	-0.000215321	-0.000653723	-0.000336954

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

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



Source: Docket No. 36780

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER and that the SEER of a condensing unit installed without a matching coil would be 85 percent of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given using Equation 22.

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

Equation 22

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

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

Adjusting for the increased 14 SEER baseline:

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

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

Early Retirement

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

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

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

Where:

RUL	=	*Remaining useful life (see Table 37 or Table 38). 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 = 15 years*

For early retirement, if age is unknown, assume a default age equal to the replaced unit EUL resulting in an 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 33 for use with the default age.

Table 37. Mini-Split HPs—Remaining Useful Life of Replaced ACs[122]

Age of replaced unit (years)	Remaining useful life (years)
1	16.8
2	15.8
3	14.9
4	14.1
5	13.3
6	12.6
7	11.9
8	11.3
9	10.8
10	10.3
11	9.8
12	9.4
13	9.0
14	8.6
15	8.2
16	7.9
17	7.6
18	7.0
19	6.0
20	5.0
21	4.0
22	3.0
23	2.0
24	1.0
25[123,124]	0.0

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

[123] RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (see Figure 5). 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.

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

Table 38. Mini-Split HPs—Remaining Useful Life of Replaced HPs[125]

Age of replaced unit (years)	Remaining useful life (years)
1	13.7
2	12.7
3	12.0
4	11.3
5	10.7
6	10.2
7	9.7
8	9.3
9	8.9
10	8.5
11	8.2
12	7.9
13	7.6
14	7.0
15	6.0
16	5.0
17	4.0
18	3.0
19	2.0
20	1.0
21[126,127]	0.0

Derivation of RULs

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

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

[126] RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (Figure 6). 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.

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

Figure 5. Mini-Split HPs—AC Survival Function[128]

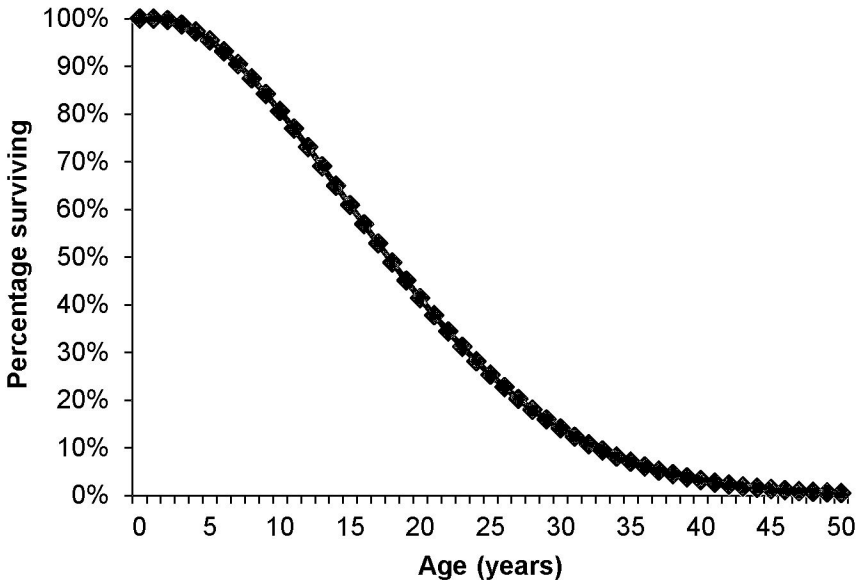
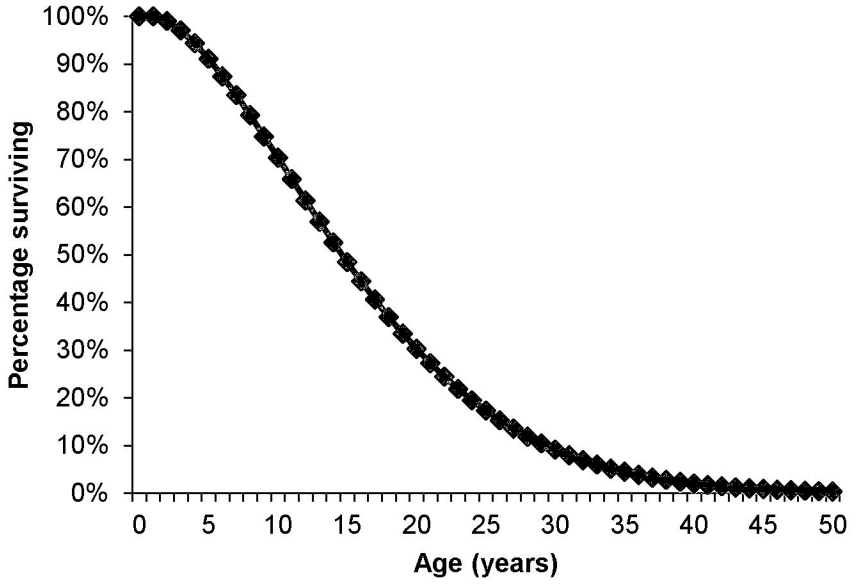


Figure 6. Mini-Split HPs—HP Survival Function [129]



[128] 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: https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012.

[129] 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: https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012.

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 5 and Figure 6. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Deemed Energy Savings Tables[130]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[131] Both cooling and heating savings are specified for AHRI-rated cooling capacity.

Deemed Summer Demand Savings Tables[132]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[133] Summer demand savings are specified according to AHRI-rated cooling capacity.

Deemed Winter Demand Savings Tables[134]

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume.[135] Winter demand savings are specified according to AHRI-rated cooling capacity.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

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

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

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

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

[134] Rated capacity ranges are specified with a 5 percent tolerance in accordance with AHRI Standard 210/240 to account for systems that are rated slightly below the applicable nominal capacity. AHRI Standard 210/240. Table J1. https://www.ahrinet.org/sites/default/files/2022-07/AHRI_Standard_210-240_2017.pdf.

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for HPs based on the DOE 76 Final Rule 37408 technical support document for energy conservation standards for central ACs and HPs.[136]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (Btuh)
- Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of the installed unit
- Heating Seasonal Performance Factor (HSPF) of the installed unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air source HP)
    - Baseline equipment used for savings (if different from unit replaced)
- Type of unit installed (mini-split HP or DC inverter HP)
- Compressor type for newly installed unit (single-stage, multi-stage, variable speed)
    - Recommended to assist with development of future deemed savings for multi-stage systems operating at variable speeds
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, or other evaluator-approved approach. Sampling is allowed for multifamily complexes.
- Retired unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program)
- Manual J load calculation (when rightsizing upward by more than one-half tons). See Eligibility Criteria section for applicable scenarios.
- Photograph of retired cooling unit nameplate (required for all rightsizing and early retirement projects unless default age is applied consistently across the program)

[136] 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. https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012.

    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide estimated square footage of conditioned area served by the retired unit (rightsizing only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only). This requirement also applies to projects using the default age.
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, and serial number of newly installed unit
    - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- AHRI certificate or manufacturer specification sheet with date corresponding to time of application or purchase demonstrating that the unit does not have a SEER2 efficiency rating.
- When claiming savings for duct removal in combination with the installation of a ductless mini-split:
    - Pre-improvement duct leakage at 25 Pa (cu. ft./min)
    - Pre and post photos demonstrating removal of existing ductwork

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 39. Mini-Split HPs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. Clarified early retirement age eligibility. Updated electric resistance baseline documentation.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for systems where EER does not meet CEE Tier 0 requirements.
v10.0	10/2022	TRM v10.0 update. Restricted measure for use with mini-split HPs without a SEER2 rating. Updated early retirement age eligibility.

2.2.4 Central and Mini-Split Air Conditioners and Heat Pumps with SEER2 Ratings 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.[137,138] 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

[137] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[138] 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.

New construction projects are not eligible to receive deemed savings for system rightsizing.[139]

For system upsizing, savings should generally be claimed against the new construction baseline. However, upsizing is allowed 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.

- Replacing a single larger capacity system with multiple smaller capacity systems where the total pre and post tonnage are within one-half ton.[140] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.
- Replacing a single-stage system with a multi-stage system operating at variable speeds where the total pre and post tonnage are within one-half ton.[141] This scenario does not apply to the replacement of a multi-stage unit with another multi-stage unit.
- If a Manual J load calculation is completed and included with project documentation, upsizing will be allowed where the total pre- and post-tonnage

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

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

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

are within one ton.[142] This guidance is also extended to the previous scenarios when a Manual J load calculation is provided.

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

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

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

Baseline Condition

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

New construction baseline efficiency values for ACs or HPs are compliant with the current federal standard,[143,144] 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 40 and Table 41. These baselines are also applicable to HP installations replacing ACs with central gas heat; evaporative coolers with central, space, or no heating; or room/window ACs with central, space, or no heating.

[142] 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.

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

[144] 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.[145,146] Heating baselines were not included in original ESL survey data and are not adjusted.

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

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

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

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[147] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[148] 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.[149] 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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[145] 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.

[146] 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.

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

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

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

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

Project type	Capacity (Btu/hr)	Cooling mode
New 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)[150]	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[151]	All	9.8 EER2

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

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

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

[151] 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)[152]	12.3 SEER2 10.0 EER2	6.7 HSPF2
Early retirement, packaged heat pumps (when applying default age)[153]	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[154]	9.8 EER2	–
Replace-on-burnout or early retirement, electric resistance furnace[155]	–	3.412 HSPF2

High-Efficiency Condition

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

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

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

[153] Ibid.

[154] 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.

[155] 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.

For reference, both ENERGY STAR[156] and the Consortium for Energy Efficiency (CEE)[157] offer suggested guidelines for high-efficiency equipment.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

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

Energy Savings Algorithms

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

Equation 23

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

Equation 24

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

Equation 25

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

Demand Savings Algorithms

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

Equation 26

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

Equation 27

Where:

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

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

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

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

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

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

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

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

$DF_{S/W}$ = *Summer/winter seasonal peak demand factor (Table 43)*

Table 42. Central and Mini-Split AC/HPs—Equivalent Full Load Cooling/Heating Hours[158]

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 43. Central and Mini-Split AC/HPs—Demand Factors[159]

Season	DF
Summer[160]	0.87
Winter[161]	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.

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

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

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

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

Where:

RUL = *Remaining useful life (see Table 44 or Table 45). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. For HPs replacing an AC with an electric resistance furnace, use the AC RUL table.*

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

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

Age of replaced unit (years)	Remaining useful life (years)	Age of replaced unit (years)	Remaining useful life (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[162,163]	0.0
13	9.0		

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

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

[162] RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (see Figure 2Figure 7). 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.

[163] 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.

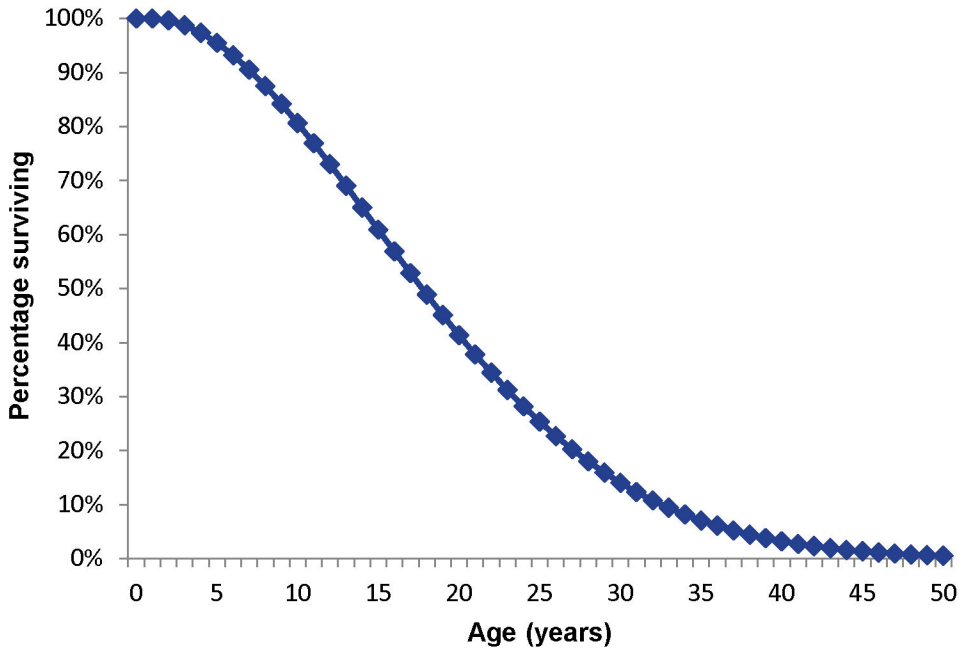
Age of replaced unit (years)	Remaining useful life (years)
8	9.3
9	8.9
10	8.5
11	8.2

Age of replaced unit (years)	Remaining useful life (years)
19	2.0
20	1.0
21[164]	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 7 and Figure 8.

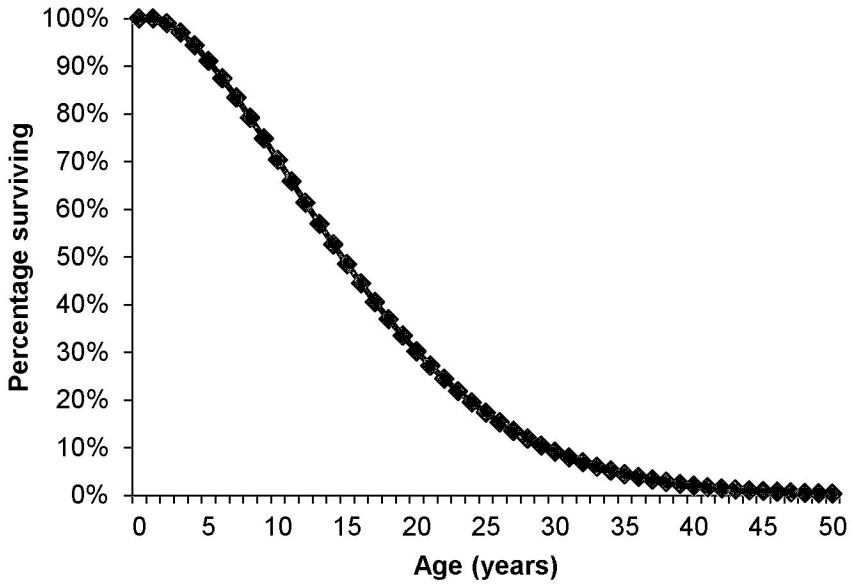
Figure 7. Central and Mini-Split AC/HPs—AC Survival Function[165]



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

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

Figure 8. Central and Mini-Split AC/HPs—HP Survival Function[166]



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

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

[166] 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.[167]

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.[168]

Program Tracking Data and Evaluation Requirements

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

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

[167] 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.

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