Acknowledgments

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

TRM Technical Support

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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. TRM v7.0 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) 2019 TRM 7.0 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 I: 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	7.0 Update
Lighting	Standard compact fluorescent lamps	–	–	X	–	–	Updated useful life estimates and removed dual baseline
	Specialty compact fluorescent lamps	–	–	X	–	–	Updated useful life estimates and removed dual baseline
	ENERGY STAR® omni-directional LED lamps	–	–	X	–	–	Updated useful life estimates and removed dual baseline. Added option for new construction savings
	ENERGY STAR® specialty and directional LED lamps	–	–	X	–	–	Updated useful life estimates and removed dual baseline. Added option for new construction savings
HVAC	Air conditioner or heat pump tune-up	–	–	X	–	–	No revision.
	Duct sealing	–	–	X	–	X	No revision.
	Ground source heat pumps	–	X	X	–	–	No revision.
	Central air conditioners and heat pumps	–	X	–	–	–	Merged central air conditioner and heat pumps into one measure.
	Mini-split air conditioners and heat pumps	-	X	-	-	-	TRM v7.0 origin.
	Large capacity split system and single-package air conditioners and heat pumps	-	-	X	-	-	No revision.
	Packed terminal heat pumps	-	-	X	-	-	TRM v7.0 origin.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
Load management	Room air conditioners	–	–	X	–	–	No revision.
	ENERGY STAR® connected thermostats	-	X	-	-	-	No revision.
	Evaporative Cooling	-	X	-	-	-	TRM v7.0 origin.
	Smart thermostat load management	–	X	–	–	–	Clarified participant definition
Building Envelope	Air infiltration	–	X	–	–	X	No revision.
	Ceiling insulation	–	X	–	–	–	Added U-factor methodology.
	Attic encapsulation	–	X	–	–	–	Incorporated guidance from EM&V memo.
	Wall insulation	–	X	–	–	–	No revision.
	Floor insulation	–	X	–	–	–	No revision.
	ENERGY STAR® windows	–	X	–	–	–	No revision.
	Solar screens	–	X	–	–	–	No revision.
	Cool roofs	-	X	-	-	-	Added savings for R-30 insulation.
Domestic Water Heating	Faucet aerators	–	–	X	–	–	No revision.
	Low-flow showerheads	–	–	X	–	–	No revision.
	Water heater pipe insulation	–	–	X	–	–	No revision.
	Water heater tank insulation	–	–	X	–	–	No revision.
	Water heater installation-electric tankless and fuel substitution	–	–	X	–	–	Implemented new baseline and high-efficiency standards.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
	Heat pump water heaters	–	X	–	–	–	No revision.
	Solar water heaters	–	X	–	–	–	No revision.
	Showerhead temperature sensitive restrictor valves	--	--	X	--	--	No revision.
	Tub spout and showerhead temperature-sensitive restrictor valves	--	--	X	--	--	No revision.
	ENERGY STAR® ceiling fans	–	–	X	–	–	Established deemed savings.
	ENERGY STAR® clothes washers	–	X	–	–	–	No revision.
	ENERGY STAR® clothes dryers	-	X	-	-	-	TRM v7.0 origin.
	ENERGY STAR® dishwashers	–	X	–	–	–	No revision.
Appliances	ENERGY STAR® refrigerators	–	–	X	–	X	Established deemed savings.
	ENERGY STAR® freezers	-	X	-	-	-	TRM v7.0 origin.
	ENERGY STAR® pool pumps	--	--	X	--	--	Updated eligibility to include ENERGY STAR® version 2.0
	ENERGY STAR® Air purifiers	-	X	-	-	-	TRM v7.0 origin.
	Advanced power strips	-	X	-	-	-	TRM v7.0 origin.
	ENERGY STAR® Electric	-	X	-	-	-	TRM v7.0 origin.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	7.0 Update
	vehicle supply equipment						
	Solar attic fans			X			TRM v7.0 origin
Appliance Recycling	Refrigerator/ freezer recycling	X	–	X	–	–	No revision.

2 RESIDENTIAL MEASURES

2.1 RESIDENTIAL: LIGHTING

2.1.1 ENERGY STAR® Standard Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-CF

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex, and triplex; 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 lamp with an ENERGY STAR®-qualified standard CFL in residential applications.

A standard lamp is also called a general service lamp. General service lamps are omnidirectional bulbs that are A, BT, P, PS, S, or T shape bulbs (as defined by the ANSI Standard Lamp Shapes). These lamps are not globe, bullet, candle, flood, reflector, or decorative-shaped (B, BA, C, CA, DC, F, G, R, BR, ER, MR, MRX, or PAR shapes). These bulbs do encompass both twist/spiral and A-lamp shaped CFLs.

Please see https://www.lightingfacts.com/Library/Content/FAQs/EISA for more information on general service lamps and CFLs.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

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% indoor and 9.5% outdoor may be assumed.[1]

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

Baseline Condition

The baseline is assumed to be the first-tier Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2). Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. A potential second-tier EISA baseline adjustment was scheduled to go into effect beginning January 2020. At that time, general service lamps would need to comply with a 45 lumen-per-watt efficacy standard. However, the Department of Energy (DOE) issued a definition for general service lamps on September 5, 2019, concluding that "no backstop energy conservation has been imposed."[2] Therefore, no additional baseline adjustment will be imposed starting in 2020. However, standard practice must also be considered in determining an appropriate baseline for this measure. To account for a rapidly changing market, measure life assumptions have been reduced as described later in this measure.

Table 2: ENERGY STAR® Standard CFLs—EISA Baselines[3]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (W_{Base})
310	749	40	29
750	1,049	60	43
1,050	1,489	75	53
1,490	2,600	100	72

New construction applications use the same baselines; however, savings can only be claimed for efficient lighting installed above the minimum amount required by code.

[1] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

[2] "Energy Conservation Program: Definition for General Service Lamps", Department of Energy. 9/5/2019. https://www.federalregister.gov/documents/2019/09/05/2019-18940/energy-conservation-program-definition-for-general-service-lamps.

[3] In new ENERGY STAR® lighting standards effective September 2014, lumen bins associated with incandescent wattages have been assigned that do not align with those set out in EISA 2007. Due to the likelihood of continuing sell-through of existing ENERGY STAR® lighting and the on-going use of the EISA bin definitions, this TRM maintains the EISA lumen bins for assigning baseline wattage. Future iterations of the Texas TRM, however, may incorporate these new ENERGY STAR® lumen bins for baseline wattage estimates.

High-efficiency Condition

New CFLs must be standard (general service) ENERGY STAR® -qualified CFLs as outlined in the latest ENERGY STAR® specification.[4] These CFLs are designed to replace incandescent lamps of the following ANSI Standard Lamp Shape: A, BT, P, PS, S and T.[5] These lamps have medium screw or pin bases, are designed for light output between 310 and 2600 lumens, and are capable of operating at a voltage range at least partially within 110 and 130 volts.[6]

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 the wattage of a comparable CFL. A CFL 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% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently-installed fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

Annual energy (kWh)

$$\Delta kWh = \frac{(W_{base,FT} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 1

Equation 2

Where:

$W_{base,FT}$ = *First-tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. First-tier EISA baseline lamp wattage provided in Table 2 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 3 for 1st Tier EISA 2007default wattages)*

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[4] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[5] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

[6] https://www.lightingfacts.com/Library/Content/FAQs/EISA.

Table 3: ENERGY STAR® Standard CFLs—Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[7]	7–10 W	9–14 W	18–20 W	15–26 W
If Unknown: Default Installed CFL Wattage[8]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W

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

HOU = *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[9])*

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 burnt-out) to account for units incentivized but not operating = 0.97[10]*

Table 4: ENERGY STAR® Standard CFLs—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[11]

	IEF_E				
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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

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7 Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated October 2016. Accessed December 22, 2016. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

8 ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/product/certified-light-bulbs/results. Accessed December 22, 2016. Mean wattages of omnidirectional, general purpose replacement CFL lamps by incandescent wattage equivalent.

9 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 Associates. June 2009.

10 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.

11 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: $1 + HVAC_{savings}/Lighting_{savings}$.

Heating/Cooling Type*	IEF_E Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[12]	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. However, summer demand savings should not be claimed for outdoor lamps.

$$\Delta kWsummer = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 3

$$\Delta kW_{winter} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 4

Equation 5

Equation 6

Where:

CF = *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: ENERGY STAR® Standard CFLs—Coincidence Factors[13]

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

[12] 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.

[13] See Volume 1, Appendix B.

Table 6: ENERGY STAR® Standard CFLs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[14]

Heating/Cooling Type*	IEF$_{D,summer}$				
	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[15]	1.39	1.28	1.58	1.20	1.38
	IEF$_{D,winter}$				
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[16]	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.

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[14] 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: $1 + HVAC_{savings}/Lighting_{saving}$

[15] 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.

[16] 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.

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

Historically the average measure life is based upon the rated lamp life of the CFL. 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 CFLs.

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

Equation 7

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.*[17]

DF = *0.85 degradation factor*[18]

[17] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

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

HOU = 2.2 *hours per day*[19]

However, 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 2030 for programs targeting low-income and hard-to-reach customers, resulting in a 10-year EUL.

Table 7: ENERGY STAR® Standard CFLs—Estimated Useful Life

Range of Rated Measure Life (Hours)	Assumed Rated Measure Life (Hours)	Product Lifetime (Years)	Standard Baseline Measure Life (Years)	Low Income Baseline Measure Life (Years)
10,000–11,000	10,000	11	8	10
11,001–13,500	12,000	13	8	10
13,501–17,500	15,000	16	8	10
≥ 17,501	20,000	20*	8	10

* Measure life capped at 10 years. EUL may be deemed at 8 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 CFLs installed
- Wattage of each installed CFL
- Lumen output of each installed CFL
- Manufacturer-rated lifetime of each installed CFL in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a CFL is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Program type (direct install, retail)

[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 Associates. June 2009.

- Proof of purchase – with date of purchase and quantity
  - Alternative: representative photos of installed units or another pre-approved method of installation verification
- ENERGY STAR® certificate matching installed model number
  - Alternative: another pre-approved method of certification
- For new construction projects only, these data points must be gathered for all permanently-installed fixtures in the home in order to document the percentage that are high-efficacy.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.
- Docket No. 39899. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, and Southwestern Public Service Company to Revise Existing Commission-Approved Deemed Savings for CFLs in Residential Hard-to-reach Programs. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- ENERGY STAR® specifications for CFL lamps.

Document Revision History

Table 8: Residential Compact Fluorescent Lamps Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor corrections due to phase-in of EISA regulations, updated EUL from DEER 2014. Legacy EISA tables removed.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Introduction of interactive effects factors and in-service rates. Incorporation of Second Tier EISA standards. New peak savings calculated according to revised peak definition. Modified estimation of measure life.
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. Restricted estimated measure life to several discrete values.
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 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.

2.1.2 ENERGY STAR® Specialty Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-SC

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex, and triplex; 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 a specialty incandescent or halogen lamp with an ENERGY STAR®-qualified specialty CFL in residential applications. These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

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% indoor and 9.5% outdoor may be assumed.[20]

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

[20] 2015 U.S. 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

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.

Some baseline conditions for specialty CFLs are affected by EISA and/or a DOE 2009 ruling on incandescent reflector lamps (IRLs). Based on the shape, lumen output, and/or wattage-equivalent of the installed lamp, the appropriate baseline shall be determined from one of the following categories:

- Non-reflector lamps, affected by EISA 2007
- Non-reflector lamps, not affected by EISA 2007
- Reflector lamps affected by the DOE ruling in 2009 on IRLs
- Reflector lamps not affected by the DOE ruling in 2009 on IRLs

Appropriate baseline wattages are presented in Table 11 through Table 14. If a baseline cannot be determined using these tables, the following guidelines may be used to determine appropriate default baseline wattage:

- Non-reflector lamps, affected by EISA 2007: using the exact or range of the installed wattage, determine the appropriate First-tier EISA baseline default wattage in the table below

Table 9: ENERGY STAR® CFLs—Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[21]	9–11 W	12–15 W	18–20 W	23–27 W
If Unknown: Default Installed CFL Wattage[22]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W

- Non-reflector lamps, not affected by EISA 2007: 60 watts[23]
- Reflector lamps affected by the DOE ruling in 2009 on IRLs: 60 watts[24]
- Reflector lamps not affected by the DOE ruling in 2009 on IRLs: the appropriate default baseline may be determined using Table 10

[21] Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated October 2016. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[22] ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs/. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement CFL lamps by incandescent wattage equivalent.

[23] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc., The Cadmus Group, Itron, Inc., PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[24] Ibid.

Table 10: DOE-ruling Exempt Reflectors—Default Wattages

Lamp Type	W_{Base}
BR30 (65 W)	65 W
BR40 (65 W)	
ER40 (65 W)	
R20 (≤ 45 W)	45 W
BR30 (≤ 50 W)	50 W
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	
Indeterminate	60 W[25]

EISA Standards: Baseline for Non-reflector Lamps

EISA-Affected

EISA-affected bulbs are:

- G-shape lamps with a diameter less than 5 inches
- T-shape lamps greater than 40 watts or a length of 10 inches or less
- B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps greater than 40 watts.[26]

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards.

[25] Ibid.

[26] https://www.lightingfacts.com/Library/Content/FAQs/EISA

Table 11: EISA-Affected Specialty CFL Baselines (Non-reflectors)[27]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{Base,FT}$)
• G-shape lamps with a diameter less than 5 inches	310	749	29
• T-shape lamps greater than 40 watts or a length of 10 inches or less	750	1,049	43
	1,050	1,489	53
• B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps greater than 40 watts	1,490	2,600	72

EISA-Exempt

EISA-exempt bulbs are:

- Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamps, marine lamps, marine signal service lamps, mine service lamps, plant light lamps, reflector lamps, rough service lamps, shatter-resistant lamps, sign service lamps, silver bowl lamps, showcase lamps, 3-way incandescent lamps, and vibration service lamps
- G-shape lamp with a diameter of 5 inches or more
- T-shape lamp of 40 watts or less or a length of more than 10 inches
- B, BA, CA, F, G16-1/2, G25, G30, S, or M14 lamp of 40 watts or less[28]

[27] Ibid.
[28] https://www.lightingfacts.com/Library/Content/FAQs/EISA

Table 12: EISA-Exempt Specialty CFL Baselines (Non-reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	W_{Base}
• Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamp, marine lamp, marine signal service lamp, mine service lamp, plant light lamp, reflector lamp, rough service lamp, shatter-resistant lamp, sign service lamp, silver bowl lamp, showcase lamp, 3-way incandescent lamp, vibration service lamp • G-shape lamp with a diameter of 5 inches or more • T-shape lamp of 40 watts or less or a length of more than 10 inches • B, BA, CA, F, G16-1/2, G25, G30, S, or M14 lamp of 40 watts or less	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 60 watts.[29]		

DOE Standards for Incandescent Reflector Lamps (IRLs): Baseline for Reflector Lamps

DOE-ruling-affected

Certain types of incandescent reflector bulbs are affected by a DOE 2009 ruling on reflector lamps. Products affected by the IRL ruling are:

- R, PAR, ER, BR, BPAR lamps
- BR and ER lamps rated at more than 50 watts
- Reflector lamps between 2.25" (R18) and 2.75" (R22) in diameter
- 40-205 Watt incandescent PAR lamps[30]

Where available, the nameplate wattage of the removed lamp should be used as the baseline. Otherwise, the baseline wattage can be determined according to the lumen range of the installed lamp (see Table 13).

[29] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc., The Cadmus Group, Itron, Inc., PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

[30] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/ https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=23 http://www.bulbrite.com/eisa.php.

Table 13: DOE IRL Ruling-affected Specialty CFL Baselines (Reflectors)[31,32]

Lamp Type	Lumen Range	W_{Base}
BR19	300-500	50
BR30	600-800	75
	801-1000	85
BR38	600-900	75
	901-1400	150
BR40	600-700	75
	701-900	85
	901-950	100
	951-1300	120
	1301-1700	125
	1701-2000	150
	2001-2400	200
ER30	300-450	50
	451-701	75
ER40	1000-1300	120
PAR20	300-450	50
	451-550	40
	551-650	50
PAR30	450-550	35
	551-600	40
	601-850	50
	851-950	60
	951-1200	75
PAR38	550-750	65
	751-1100	75
	1101-1300	100
	1301-1600	120
	1601-2500	150
	2501-3500	175

[31] Wattage values and lumen ranged from a review of GE, Osram Sylvania, and Philips catalogs in January 2015, as well as the Illinois TRM 2014.

[32] Table 13 is based on manufacturers' lumen and wattage data for the most commonly used reflector lamps. However, other manufacturers' ratings may differ from this list. Where available, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer.

Lamp Type	Lumen Range	W_{Base}
	401-500	50
R20	501-600	75
	601-1000	100
	700-800	75
R30	801-950	110
	951-1100	125
R40	1300-1900	125

DOE-ruling-exempt

The DOE 2009 ruling standards do not apply to the following types of IRLs:

- IRLs rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps
- IRLs rated at 65 watts that are BR30, BR40, or ER40 lamps
- R20 IRLs rated 45 watts or less[33]

Table 14: DOE-ruling Exempt Reflectors

Lamp Type	W_{Base}
BR30 (65 watt) BR40 (65 watt) ER40 (65 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 65 watts.
R20 (≤ 45 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 45 watts.
BR30 (≤ 50 watt) BR40 (≤ 50 watt) ER30 (≤ 50 watt) ER40 (≤ 50 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 50 watts.

High-efficiency Condition

New CFLs must be ENERGY STAR® specialty CFLs as outlined in the latest ENERGY STAR® specification.[34] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps.

These ENERGY STAR® specialty CFLs are the equivalent of the specialty incandescent or halogen lamps being replaced. The high-efficiency condition is the wattage of the lamp installed.

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[33] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58.

[34] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 comparable CFL.

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% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently-installed fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 8

For EISA- exempt lamps and reflectors (both DOE-ruling-exempt and DOE-ruling-affected), annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = \frac{\left(W_{base} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 9

Where:

$W_{base,FT}$ = *First-tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. First-tier EISA baseline lamp wattage provided in Table 11 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

W_{base} = *EISA-exempt specialty lamp or a DOE-ruling-exempt reflector, use the nameplate wattage (see Table 12 and Table 14). If a DOE-ruling-affected IRL, use the wattages provided in Table 13.*

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

HOU	=	*Average hours of use per year = 803 hours for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[35])*
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 = 0.97* [36]

Table 15: ENERGY STAR® Specialty CFLs—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[37]

	IEF_E				
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
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[39]	0.88	0.98	1.04	1.07	0.95

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

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[35] 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 Associates. June 2009.

[36] 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.

[37] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[38] 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.

[39] 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

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. However, summer demand savings should not be claimed for outdoor lamps.

$$\Delta kW_{summer} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 10

$$\Delta kW_{winter} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 11

For EISA- exempt lamps and reflectors (both DOE-ruling-exempt and DOE-ruling-affected), peak demand (kW) savings are calculated as follows.

$$\Delta kW_{summer} = \frac{(W_{base} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 12

$$\Delta kW_{winter} = \frac{(W_{base} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 13

Where:

CF = *Coincidence Factor (see Table 16)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 17)*

Table 16: ENERGY STAR® CFLs—Coincidence Factors[40]

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 17: ENERGY STAR® CFLs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[41]

$IEF_{D,summer}$

[40] See Volume 1, Appendix B.

[41] 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

Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[42]	1.39	1.28	1.58	1.20	1.38

$IEF_{D,winter}$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[43]	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.

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.

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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: $1 + HVAC_{savings}/Lighting_{savings}$.

[42] 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.

[43] 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.

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

Historically, the average measure life is based upon the rated lamp life of the specialty CFL shown in the following table. The measure life assumes an average daily 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 CFLs.

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

Equation 14

$$EUL_{Tier1} = 2021 - Purchase\ Year$$

Equation 15

$$EUL_{Tier2} = EUL_{Total} - EUL_{Tier1}$$

Equation 16

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.*[44]

DF = *0.85 degradation factor*[45]

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[44] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective 9/30/2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

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

HOU = 2.2 hours per day[46]

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.[47]

DF = 0.85 degradation factor[48]

HOU = 2.2 hours per day[49]

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 2030 for programs targeting low-income and hard-to-reach customers, resulting in a 10-year EUL.

These reductions do not apply to specialty lamps.

[46] 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 Associates. June 2009.

[47] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective 9/30/2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

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

[49] 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 Associates. June 2009.

Table 18: ENERGY STAR® Specialty CFLs—Estimated Useful Life

Range of Rated Measure Life (Hours)	Assumed Rated Measure Life (Hours)	Specialty Measure Life (Years)	If EISA Compliant:	
			Standard Baseline Measure Life (Years)	Low-income Baseline Measure Life (Years)
10,000–11,000	10,000	11	8	10
11,001–13,500	12,000	13	8	10
13,501–17,500	15,000	16	8	10
≥ 17,501	20,000	20*	8	10

* Measure life capped at 20 or 10 years depending on the applicable baseline. EUL may be deemed at 11 or 8 years in lieu of collecting manufacturer rated life or documenting customer baseline for EISA compliant lamps.

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 CFLs installed
- ANSI C79.1-2002 nomenclature of CFL installed (G40, PAR, etc.)
- Wattage of each installed CFL
- Lumen output of each installed CFL
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed CFL in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a CFL is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Program type (direct install, retail)
- Baseline calculation methodology (replaced lamp nameplate wattage, EISA-affected non-reflector, EISA-exempt non-reflector, DOE-ruling-affected reflector, DOE-ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of installed units or another pre-approved method of installation verification
- ENERGY STAR® certificate matching installed model number
    - Alternative: another pre-approved method of certification

- For new construction projects only, these data points must be gathered for all permanently-installed fixtures in the home in order to document the percent that are high-efficacy.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, Energy Efficiency and Renewable Energy Office (EERE), 2009
- ENERGY STAR® specifications for CFL lamps.

Document Revision History

Table 19: Residential Specialty Compact Fluorescent Lamps 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. Restricted estimated measure life to several discrete values.
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 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.

2.1.3 ENERGY STAR® Omni-directional LED Lamps Measure Overview

TRM Measure ID: R-LT-OD

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex, and triplex; 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 lamp with an omni-directional LED[50] in a residential application. Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are A, BT, P, PS, S, and T.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

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% indoor and 9.5% outdoor may be assumed.[51]

[50] According to ENERGY STAR® omni-directional LED products ".. shall have an even distribution of luminous intensity (candelas) within the 0° to 135° zone (vertically axially symmetrical). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20 percent. At least 5 percent of total flux (lumens) must be emitted in the 135°-180° zone. Distribution shall be vertically symmetrical as measured in three vertical planes at 0°, 45°, and 90°." http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf.

[51] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

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

Baseline Condition

The baseline is assumed to be the first-tier Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2). Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. A potential second-tier EISA baseline adjustment was scheduled to go into effect beginning January 2020. At that time, general service lamps would need to comply with a 45 lumen-per-watt efficacy standard. However, the Department of Energy (DOE) issued a definition for general service lamps on September 5, 2019, concluding that "no backstop energy conservation has been imposed."[52] Therefore, no additional baseline adjustment will be imposed starting in 2020. However, standard practice must also be considered in determining an appropriate baseline for this measure. To account for a rapidly changing market, measure life assumptions have been reduced as described later in this measure.

Table 20: ENERGY STAR® Omni-directional LEDs—EISA Baselines[53]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (W_{Base})
310	749	40	29
750	1,049	60	43
1,050	1,489	75	53
1,490	2,600	100	72

New construction applications use the same baselines; however savings can only be claimed for efficient lighting installed above the minimum amount required by code.

High-efficiency Condition

LEDs must be ENERGY STAR®-qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[54] Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are A, BT, P, PS, S, and T.

The high-efficiency condition is the wattage of the lamp installed.

[52] "Energy Conservation Program: Definition for General Service Lamps", Department of Energy. 9/5/2019. https://www.federalregister.gov/documents/2019/09/05/2019-18940/energy-conservation-program-definition-for-general-service-lamps.

[53] In new ENERGY STAR® lighting standards effective September 2014, lumen bins associated with incandescent wattages have been assigned that do not align with those set out in EISA 2007. Due to the likelihood of continuing sell-through of existing ENERGY STAR® lighting and the on-going use of the EISA bin definitions, this TRM maintains the EISA lumen bins for assigning baseline wattage. Future iterations of the Texas TRM, however, may incorporate these new ENERGY STAR® lumen bins for baseline wattage estimates.

[54] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 20) and the wattage of a comparable omni-directional 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% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently-installed fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

Annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = \frac{(W_{base,FT} - W_{post})}{1000} \times Hours \times ISR \times IEF_E$$

Where:

$W_{base,FT}$ = *First-tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. First-tier EISA baseline lamp wattage provided in Table 20 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 21 for 1st Tier EISA 2007default wattages)*

Table 21: ENERGY STAR® Omni-directional LEDs—Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[55]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[56]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W

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

[55] Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[56] ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs/. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement LED lamps by incandescent wattage equivalent.

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*[57]*)*
IEF_E	=	*Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 22)*
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 = 0.97* [58]

Table 22: ENERGY STAR® Omni-directional LEDs Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[59]

Heating/Cooling Type*	IEF_E				
	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[60]	0.88	0.98	1.04	1.07	0.95

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

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[57] 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 Associates. June 2009.

[58] 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.

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

[60] 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

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

$$\Delta kWsummer = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 17

$$\Delta kWwinter = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 18

Where:

CF = *Coincidence Factor (see Table 23)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 24)*

Table 23: ENERGY STAR® LEDs—Coincidence Factors[61]

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

[61] See Volume 1, Appendix B.

Table 24: ENERGY STAR® Omni-directional LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[62]

$IEF_{D,summer}$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[63]	1.39	1.28	1.58	1.20	1.38
$IEF_{D,winter}$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[64]	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.

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[62] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[63] 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.

[64] 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.

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

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

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

Equation 19

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.*[65]

DF = *0.85 degradation factor*[66]

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[65] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

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

$HOU \quad = \quad$ *2.2 hours per day*[67]

However, 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 2030 for programs targeting low-income and hard-to-reach customers, resulting in a 10-year EUL.

Table 25: ENERGY STAR® Omni-directional LEDs—Estimated Useful Life

Range of Rated Measure Life (Hours)	Assumed Rated Measure Life (Hours)	Rated Product Lifetime (Years)	Standard Baseline Measure Life (Years)	Low-income Baseline Measure Life (Years)
≤ 17,500	15,000	16	8	10
> 17,500	20,000	20*	8	10

* Measure life capped at 20 years. EUL may be deemed at 8 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 installed LED
- Lumen output of each installed LED
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed LED in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which an LED is installed
- Location of installed 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 installed units or another pre-approved method of installation verification

[67] 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 Associates. June 2009.

- ENERGY STAR® certificate matching installed model number
    - Alternative: another pre-approved method of certification
- For new construction projects only, these data points must be gathered for all permanently-installed fixtures in the home in order to document the percentage that are high-efficacy.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- ENERGY STAR® specifications for LED lamps

Document Revision History

Table 26: Residential Omni-directional LED Lamps 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.

2.1.4 ENERGY STAR® Specialty and Directional LED Lamps Measure Overview

TRM Measure ID: R-LT-SD

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex, and triplex; 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®-qualified LED lamp. These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps.[68]

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

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% indoor and 9.5% outdoor may be assumed.[69]

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

[68] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[69] 2015 U.S. 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

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.

Some baseline conditions for specialty LEDs are affected by EISA and/or a DOE 2009 ruling on incandescent reflector lamps (IRLs). Based on the shape, lumen output, and/or wattage-equivalent of the installed lamp, the appropriate baseline shall be determined from one of the following categories:

- Non-reflector lamps, affected by EISA 2007
- Non-reflector lamps, not affected by EISA 2007
- Reflector lamps affected by the DOE ruling in 2009 on IRLs
- Reflector lamps not affected by the DOE ruling in 2009 on IRLs

Appropriate baseline wattages are presented in Table 29 through Table 32. If a baseline cannot be determined using these tables, the following guidelines may be used to determine appropriate default baseline wattage:

- Non-reflector lamps, affected by EISA 2007: using the exact or range of the installed wattage, determine the appropriate First-tier EISA baseline default wattage in Table 27

Table 27: ENERGY STAR® Specialty LEDs—Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[70]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[71]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W

- Non-reflector lamps, not affected by EISA 2007: 60 watts[72]
- Reflector lamps affected by the DOE ruling in 2009 on IRLs: 60 watts[73]
- Reflector lamps not affected by the DOE ruling in 2009 on IRLs: the appropriate default baseline may be determined using Table 28

[70] Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[71] ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement LED lamps by incandescent wattage equivalent.

[72] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc., The Cadmus Group, Itron, Inc., PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[73] Ibid.

Table 28: DOE-ruling Exempt Reflectors—Default Wattages

Lamp Type	W_{Base}
BR30 (65 W)	
BR40 (65 W)	65 W
ER40 (65 W)	
R20 (≤ 45 W)	45 W
BR30 (≤ 50 W)	
BR40 (≤ 50 watt)	50 W
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	
Indeterminate	60 W[74]

EISA Standards: Baseline for Non-reflector Lamps

EISA-Affected

EISA-affected bulbs are:

- G-shape lamps with a diameter less than 5 inches
- T-shape lamps greater than 40 watts or a length of 10 inches or less
- B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps greater than 40 watts[75]

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards.

Table 29: EISA-Affected Specialty LED Baselines (Non-reflectors)[76]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{Base,FT}$)
	310	749	29

[74] Ibid.
[75] https://www.lightingfacts.com/Library/Content/FAQs/EISA.
[76] Ibid.

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{Base,FT}$)
• G-shape lamps with a diameter less than 5 inches	750	1,049	43
• T-shape lamps greater than 40 watts or a length of 10 inches or less	1,050	1,489	53
• B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps greater than 40 watts	1,490	2,600	72

EISA-Exempt

EISA-exempt bulbs are:

- Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamps, marine lamps, marine signal service lamps, mine service lamps, plant light lamps, reflector lamps, rough service lamps, shatter-resistant lamps, sign service lamps, silver bowl lamps, showcase lamps, 3-way incandescent lamps, and vibration service lamps
- G-shape lamp with a diameter of 5 inches or more
- T-shape lamp of 40 watts or less or a length of more than 10 inches
- B, BA, CA, F, G16-1/2, G25, G30, S, or M14 lamp of 40 watts or less[77]

[77] https://www.lightingfacts.com/Library/Content/FAQs/EISA

Table 30: EISA-exempt Specialty LED Baselines (Non-reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	W_{Base}
• Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamp, marine lamp, marine signal service lamp, mine service lamp, plant light lamp, reflector lamp, rough service lamp, shatter-resistant lamp, sign service lamp, silver bowl lamp, showcase lamp, 3-way incandescent lamp, vibration service lamp • G-shape lamp with a diameter of 5 inches or more • T-shape lamp of 40 watts or less or a length of more than 10 inches • B, BA, CA, F, G16-1/2, G25, G30, S, or M14 lamp of 40 watts or less	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 60 watts.[78]		

DOE Standards for Incandescent Reflector Lamps (IRLs): Baseline for Reflector Lamps

DOE-ruling-affected

Certain types of incandescent reflector bulbs are affected by a DOE 2009 ruling on reflector lamps. Products affected by the IRL ruling are:

- R, PAR, ER, BR, BPAR lamps
- BR and ER lamps rated at more than 50 watts
- Reflector lamps between 2.25" (R18) and 2.75" (R22) in diameter
- 40-205 Watt incandescent PAR lamps[79]

Where available, the nameplate wattage of the removed lamp should be used as the baseline. Otherwise, the baseline wattage can be determined according to the lumen range of the installed lamp (see Table 21).

[78] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc., The Cadmus Group, Itron, Inc., PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[79] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58
http://www.bulbrite.com/eisa.php

Table 31: DOE IRL Ruling-affected Specialty LED Baselines (Reflectors)[80,81]

Lamp Type	Lumen Range	W_{Base}
BR19	300-500	50
BR30	600-800	75
	801-1000	85
BR38	600-900	75
	901-1400	150
BR40	600-700	75
	701-900	85
	901-950	100
	951-1300	120
	1301-1700	125
	1701-2000	150
	2001-2400	200
ER30	300-450	50
	451-701	75
ER40	1000-1300	120
PAR20	300-450	50
	451-550	40
	551-650	50
PAR30	450-550	35
	551-600	40
	601-850	50
	851-950	60
	951-1200	75
PAR38	550-750	65
	751-1100	75
	1101-1300	100
	1301-1600	120
	1601-2500	150
	2501-3500	175
R20	401-500	50
	501-600	75
	601-1000	100

80 Wattage values and lumen ranged from a review of GE, Osram Sylvania, and Philips catalogs in January 2015, as well as the Illinois TRM 2014.

81 Table 31 is based on manufacturers' lumen and wattage data for the most commonly used reflector lamps. However, other manufacturers' ratings may differ from this list. Where available, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer.

Lamp Type	Lumen Range	W_{Base}
R30	700-800	75
	801-950	110
	951-1100	125
R40	1300-1900	125

DOE-ruling-exempt

The DOE 2009 ruling standards do not apply to the following types of IRLs:

- IRLs rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps
- IRLs rated at 65 watts that are BR30, BR40, or ER40 lamps
- R20 IRLs rated 45 watts or less.[82]

Table 32: DOE-ruling Exempt Reflectors

Lamp Type	W_{Base}
BR30 (65 watts) BR40 (65 watts) ER40 (65 watts)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 65 watts.
R20 (≤ 45 watts)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 45 watts.
BR30 (≤ 50 watts) BR40 (≤ 50 watts) ER30 (≤ 50 watts) ER40 (≤ 50 watts)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 50 watts.

High-efficiency Condition

LEDs must be ENERGY STAR®-qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[83] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S, or M14 lamps.

The high-efficiency condition is the wattage of the lamp installed.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[82] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58.

[83] http://www.energystar.gov/products/certified-products/detail/light-bulbs

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% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently-installed fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings are calculated as follows,

$$\Delta kWh = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 20

For EISA-exempt lamps and reflectors (both DOE-ruling-exempt and DOE-ruling-affected), annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = \frac{\left(W_{base} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 21

Where:

$W_{base,FT}$ = *First-tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. First-tier EISA baseline lamp wattage provided in Table 29 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

W_{base} = *EISA-exempt specialty lamp or a DOE-ruling-exempt reflector, use the nameplate wattage (see Table 30 and Table 32. If a DOE-ruling-affected IRL, use the wattages provided in Table 31.*

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

HOU = *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[84])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 33).*

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 = 0.97 [85]*

Table 33: ENERGY STAR® Specialty and Directional LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[86]

	IEF_E				
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
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

84 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 Associates. June 2009.

85 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.

86 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: $1 + HVAC_{savings}/Lighting_{savings}$.

Heating/Cooling Type*	IEF_E Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[87]	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.

$$\Delta kW_{summer} = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 22

$$\Delta kW_{winter} = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 23

For EISA-exempt lamps and reflectors (both DOE-ruling-exempt and DOE-ruling-affected), peak demand (kW) savings are not calculated using the two-tiered system. Instead, peak demand (kW) savings are calculated using one algorithm, depending on the season of the savings.

$$\Delta kW_{summer} = \frac{\left(W_{base} - W_{post}\right)}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 24

$$\Delta kW_{winter} = \frac{\left(W_{base} - W_{post}\right)}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 25

Where:

CF = *Coincidence Factor (Table 34)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 35)*

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

Table 34: ENERGY STAR® LEDs—Coincidence Factors[88]

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 35: ENERGY STAR® Specialty and Directional LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[89]

$IEF_{D,summer}$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[90]	1.39	1.28	1.58	1.20	1.38
$IEF_{D,winter}$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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[91]	0.76	0.72	0.73	0.75	0.80

[88] See Volume 1, Appendix B.

[89] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[90] 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.

[91] 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.

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

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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 26

Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

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.*[92]
DF	=	*0.85 degradation factor*[93]
HOU	=	*2.2 hours per day*[94]

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 2030 for programs targeting low-income and hard-to-reach customers, resulting in a 10-year EUL.

These reductions do not apply to specialty lamps.

Table 36: ENERGY STAR® Specialty LEDs—Estimated Useful Life

Range of Rated Measure Life (Hours)	Assumed Rated Measure Life (Hours)	Specialty Measure Life (Years)	If EISA Compliant:	
			Standard Baseline Measure Life (Years)	Low-income Baseline Measure Life (Years)
≤ 17,500	15,000	16	8	10
> 17,500	20,000	20*	8	10

* Measure life capped at 20 or 10 years depending on the applicable baseline. EUL may be deemed at 16 or 8 years in lieu of collecting manufacturer rated life or documenting customer baseline for EISA compliant lamps.

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program

[92] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

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

[94] 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 Associates. June 2009.

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.)
- Wattage of each installed LED
- Lumen output of each installed LED
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed LED in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a LED is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Baseline calculation methodology (replaced lamp nameplate wattage, EISA-affected non-reflector, EISA-exempt non-reflector, DOE-ruling-affected reflector, DOE-ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of installed units or other pre-approved method of installation verification
- ENERGY STAR® certificate matching installed model number
    - Alternative: other pre-approved method of certification
- For new construction projects only, these data points must be gathered for all permanently-installed fixtures in the home in order to document the percent that are high-efficacy.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, Energy Efficiency and Renewable Energy Office (EERE), 2009
- ENERGY STAR® specifications for LED lamps

Document Revision History

Table 37: Residential Specialty and Directional LED Lamps 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.

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

2.2.1 Air Conditioner or Heat Pump Tune-ups Measure Overview

TRM Measure ID: R-HV-TU

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex, and triplex; 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 in the understanding that such measures 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 (i.e., 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[95]

- Tighten all electrical connections and measure voltage and current on motors
- 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

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

startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly.

- Clean evaporator and condenser coils
- 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 and 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 27

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

Equation 28

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[96] HSPF. A 13 SEER is equivalent to approximately 11.2 EER[97] 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.[98]

Energy Savings Algorithms

Heating energy savings are only applicable to heat pumps.

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

Equation 29

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

Equation 30

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96 Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

97 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." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

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

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

Equation 31

Where:

Capacity = *Rated cooling 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 27 [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 28 [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 38: Equivalent Full Load Cooling/Heating Hours[99]

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

[99] ENERGY STAR® Central AC/HP Savings Calculator. https://www.energystar.gov/products/certified-products/detail/heat-pumps-air-source.

Demand Savings Algorithms

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

Equation 32

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

Equation 33

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_C = *Cooling demand factor*[100] *= 0.87*

DF_H = *Heating demand factor = 0.83 (heat pumps, default)*[101]

Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 39. Heating savings are only applicable for heat pumps.

Table 39: Deemed Energy Savings per Ton

Climate Zone	Cooling kWh Saved per Ton	Heating kWh Saved per Ton
Climate Zone 1: Panhandle	64.40	154.20
Climate Zone 2: North	108.61	110.16
Climate Zone 3: South	124.57	92.44
Climate Zone 4: Valley	166.80	63.65
Climate Zone 5: West	85.94	127.87

[100] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential air conditioners be sized at 115 percent of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours 4 to 5 PM, the guideline leads to a coincidence factor for residential HVAC measures of 1.0/1.15 = 0.87.

[101] 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 house (for cooling dominated climates). Based on AHRI data for 1.5 to 5-ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that the house's maximum cooling occurs during the hours 4 to 5 PM and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor for residential heat pumps 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 40.

Table 40: Deemed Summer Demand Savings per Ton

Climate Zone	Summer Peak Demand kW Savings per Ton
All Zones	0.04906

Deemed Winter Demand Savings Tables

Applying the above algorithms results in the deemed winter demand savings per ton in Table 41. Winter peak demand savings are only applicable for heat pumps.

Table 41: Deemed Winter Demand Savings per Ton

Climate Zone	Winter Peak Demand kW Savings per Ton
All Zones	0.06808

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is five years. [102]

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is three years [103], and the estimated useful life of refrigerant charge adjustment is ten years.[104] The other parts of the tune-up checklist are not listed in DEER, therefore five years, as referenced by the Measure Life Report, is used as the best representation of the entire tune-up.

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102 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.

103 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx.

104 ibid

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)
- Type of unit (i.e., 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

This section is not applicable.

Petitions and Rulings

This section is not applicable.

Document Revision History

Table 42: Residential Air Conditioner or Heat Pump Tune-ups Revision 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.

2.2.2 Duct Sealing Measure Overview

TRM Measure ID: R-HV-DS

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex, and triplex; multifamily; manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Building simulation modeling

Measure Description

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

Eligibility Criteria

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

For the standard approach with leakage testing, duct leakage should be assessed following the Building Performance Institute (BPI) standards. Duct leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[105]

[105] The Building Performance Institute, Inc. (BPI) Standard Reference: Building Performance Institute Technical Standards for the Building Analyst Professional, v2/28/05mda, Page 1 of 17, states: "Health and Safety: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling."*

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

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

Baseline Condition

The savings calculation methods for this measure (when implemented with duct leakage testing) are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[106] For homes with an initial leakage rate greater than 35 percent of total fan flow, savings will be awarded with respect to this cap rather than the initial leakage. Data from nearly 28,000 single-family and mobile home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[107]

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

Low-income customers[108] are exempt from the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow.

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

High-efficiency Condition

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

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

Duct Leakage Testing (Standard Approach)

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. For this measure, leakage-to-outside must be directly measured. The project sponsor shall use the Combination Duct Blaster™ (or equivalent) and blower door method. Prior to beginning any installations, the project sponsor

[106] $Total\ Fan\ Flow = Cooling\ Capacity\ (tons) \times 400\ cfm/ton$

[107] Based on data collected by Frontier Associates, LLC for investor-owned utilities in Texas.

[108] Low-income customers are income-eligible customers served through a targeted low-income energy efficiency program as described in 25.181(r). This may also apply to income-eligible customers served through a hard-to-reach program that is also delivered following the guidelines in 25.181(r).

must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician Excellence (NATE) certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[109]

Categorizing Achieved Duct Leakage Reduction (Absent Leakage Testing)

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

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

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

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

[109] See RESNET Technical Committee, Proposed Amendment: Chapter 8 RESNET Standards, 800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing; Section 803.2 and Table 803.1.

Table 43: Leakage Categorization Guide[110]

Category	Duct Location	Duct Insulation Value	Leakage Characteristics[111]
Low	> 90% Conditioned	> R7	Some observable leaks
			Substantial leaks
		R4 - R7	Some observable leaks
			Substantial leaks
		< R4	Some observable leaks
			Substantial leaks
	50-90% Conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
Average	> 90% Conditioned	> R7	Catastrophic leaks
		R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	50-90% Conditioned	> R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
		< R4	Substantial leaks
	< 50% Conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
High	50-90% Conditioned	R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	< 50% Conditioned	R4 - R7	Substantial leaks
		> R7	Catastrophic leaks
		R4 - R7	Substantial leaks
			Catastrophic leaks
		< R4	Substantial leaks
			Catastrophic leaks

Energy and Demand Savings Methodology

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

[110] Based on typical distribution efficiency assumptions from the Building Performance Institute (BPI) Technical Standards for the Heating Professional, November 20, 2007, page 7.

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

Savings Algorithms and Input Variables

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

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

Standard Approach (with Duct Leakage Testing)

The annual energy and summer and winter peak demand savings to be claimed according to the standard approach for this measure shall be calculated as a function of the reduction in duct leakage achieved, using the energy and demand savings coefficients from Table 44 through Table 46 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

Deemed Energy Savings Tables

Table 44 presents the annual energy savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate annual energy savings for duct leakage reduction:

$$\textbf{Deemed Energy Savings (kWh)} = (DL_{pre} - DL_{post}) \times V_E$$

Equation 34

Where:

DL_{pre}	=	*Pre-improvement duct leakage at 25 Pa (cu. ft./min)*
DL_{post}	=	*Post-improvement duct leakage at 25 Pa (cu. ft./min)*
$V_{E,C}$	=	*Cooling Energy Savings Coefficient in Table 44*
$V_{E,H}$	=	*Heating Energy Savings Coefficient in Table 44*

Table 44: Energy Savings V_E per CFM_{25} Reduction

Region	$V_{E,C}$: Cooling Savings		$V_{E,H}$: Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
Zone 1: Panhandle	0.82	0.21	0.07	2.75	0.71
Zone 2: North	1.05	N/A	0.03	1.19	0.31
Zone 3: South	1.23	N/A	0.02	0.85	0.26
Zone 4: Valley	1.46	N/A	0.01	0.61	0.19
Zone 5: West	1.20	0.38	0.03	1.44	0.37

Deemed Summer Demand Savings Tables

Table 45 presents the summer peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed summer demand savings for duct leakage reduction:

$$\textbf{Deemed Summer Demand Savings (kW)} = (DL_{pre} - DL_{post}) \times V_S$$

Equation 35

Where:

DL_{pre} = *Pre-improvement duct leakage at 25 Pa (cu. ft./min)*

DL_{post} = *Post-improvement duct leakage at 25 Pa (cu. ft./min)*

V_S = *Summer Demand Savings Coefficient in* Table 45

Table 45: Summer Demand Savings V_S per CFM_{25} Reduction

Region	Summer kW Impact per CFM_{25} Reduction	
	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	9.28E-04	2.29E-04
Climate Zone 2: North	8.47E-04	N/A
Climate Zone 3: South	1.06E-03	N/A
Climate Zone 4: Valley	6.72E-04	N/A
Climate Zone 5: West	7.66E-04	1.86E-04

Deemed Winter Demand Savings Tables

Table 46 presents the winter peak demand savings per CFM_{25} reduction for a residential duct sealing project. The following formula shall be used to calculate deemed winter demand savings for duct leakage reduction:

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

Equation 36

Where:

DL_{pre} = *Pre-improvement duct leakage at 25 Pa (cu. ft./min)*

DL_{post} = *Post-improvement duct leakage at 25 Pa (cu. ft./min)*

V_W = *Winter Demand Savings Coefficient in Table 46*

Table 46: Winter Demand Savings V_W per CFM_{25} Reduction

Region	kWh Impact per CFM_{25} Reduction		
	Gas	Resistance	Heat Pump
Climate Zone 1: Panhandle	4.38E-06	8.49E-04	1.46E-04
Climate Zone 2: North	1.22E-06	9.96E-04	6.98E-04
Climate Zone 3: South	8.60E-06	8.61E-04	5.02E-04
Climate Zone 4: Valley	1.18E-05	6.71E-04	4.06E-04
Climate Zone 5: West	6.68E-06	2.81E-04	6.69E-05

Alternate Approach (No Duct Leakage Testing)

The following savings tables are provided for projects implemented without performing leakage testing, accounting for the application of pre-retrofit leakage caps to not hard-to-reach (HTR) projects. The annual energy and summer and winter peak demand savings to be claimed according to the alternate approach for this measure shall be taken from Table 44 through Table 46 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

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

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

Hard-to-reach (HTR) and Targeted Low-income Programs

Deemed Energy Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 47: Climate Zone 1: Panhandle Region—Deemed Annual Energy Savings for Duct Efficiency, HTR Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	204	52	17	685	177
2	Average	323	83	28	1,083	280
3	High	514	132	44	1,725	445

Climate Zone 2: North Region

Table 48: Climate Zone 2: North Region—Deemed Annual Energy Savings for Duct Efficiency, HTR Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	262	N/A	7	297	77
2	Average	413	N/A	12	468	122
3	High	659	N/A	19	746	194

Climate Zone 3: South Region

Table 49: Climate Zone 3: South Region—Deemed Annual Energy Savings for Duct Efficiency, HTR Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	307	N/A	5	212	65
2	Average	484	N/A	8	335	102
3	High	771	N/A	13	533	163

Climate Zone 4: Valley Region

Table 50: Climate Zone 4: Valley Region—Deemed Annual Energy Savings for Duct Efficiency, HTR Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	364	N/A	2	152	47
2	Average	575	N/A	4	240	75
3	High	916	N/A	6	383	119

Climate Zone 5: West Region

Table 51: Climate Zone 5: West Region—Deemed Annual Energy Savings for Duct Efficiency, HTR Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	299	95	7	359	92
2	Average	472	150	12	567	146
3	High	753	238	19	903	232

Deemed Summer Demand Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 52: Climate Zone 1: Panhandle Region—Deemed Summer Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

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

Climate Zone 2: North Region

Table 53: Climate Zone 2: North Region—Deemed Summer Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.21	N/A
Average	0.33	N/A
High	0.53	N/A

Climate Zone 3: South Region

Table 54: Climate Zone 3: South Region—Deemed Summer Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.26	N/A
Average	0.42	N/A
High	0.66	N/A

Climate Zone 4: Valley Region

Table 55: Climate Zone 4: Valley Region—Deemed Summer Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.17	N/A
Average	0.26	N/A
High	0.42	N/A

Climate Zone 5: West Region

Table 56: Climate Zone 5: West Region—Deemed Summer Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

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

Deemed Winter Demand Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 57: Climate Zone 1: Panhandle Region—Deemed Winter Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.21	0.04
Average	0.00	0.33	0.06
High	0.00	0.53	0.09

Climate Zone 2: North Region

Table 58: Climate Zone 2: North Region—Deemed Winter Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.25	0.17
Average	0.00	0.39	0.27
High	0.00	0.62	0.44

Climate Zone 3: South Region

Table 59: Climate Zone 3: South Region—Deemed Winter Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.21	0.13
Average	0.00	0.34	0.20
High	0.01	0.54	0.31

Climate Zone 4: Valley Region

Table 60: Climate Zone 4: Valley Region—Deemed Winter Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.17	0.10
Average	0.00	0.26	0.16
High	0.01	0.42	0.25

Climate Zone 5: West Region

Table 61: Climate Zone 5: West Region—Deemed Winter Demand Savings for Duct Efficiency, HTR Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.07	0.02
Average	0.00	0.11	0.03
High	0.00	0.18	0.04

All Other Programs

Deemed Energy Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 62: Climate Zone 1: Panhandle Region—Deemed Annual Energy Savings for Duct Efficiency, Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	187	48	16	628	162
2	Average	300	77	26	1,005	259
3	High	428	110	37	1,437	371

Climate Zone 2: North Region

Table 63: Climate Zone 2: North Region—Deemed Annual Energy Savings for Duct Efficiency, Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	240	N/A	7	272	71
2	Average	384	N/A	11	435	113
3	High	549	N/A	16	622	162

Climate Zone 3: South Region

Table 64: Climate Zone 3: South Region—Deemed Annual Energy Savings for Duct Efficiency, Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	281	N/A	5	194	59
2	Average	449	N/A	7	310	95
3	High	643	N/A	10	444	136

Climate Zone 4: Valley Region

Table 65: Climate Zone 4: Valley Region—Deemed Annual Energy Savings for Duct Efficiency, Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	333	N/A	2	139	43
2	Average	533	N/A	4	223	69
3	High	763	N/A	5	319	99

Climate Zone 5: West Region

Table 66: Climate Zone 5: West Region—Deemed Annual Energy Savings for Duct Efficiency, Alternate Approach (kWh)

Category	Assessed Leakiness	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	Low	274	87	7	329	84
2	Average	438	139	11	526	135
3	High	627	199	16	752	193

Deemed Summer Demand Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 67: Climate Zone 1: Panhandle Region—Deemed Summer Demand Savings for Duct Efficiency, Alternate Approach (kW)

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

Climate Zone 2: North Region

Table 68: Climate Zone 2: North Region—Deemed Summer Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.19	N/A
Average	0.31	N/A
High	0.44	N/A

Climate Zone 3: South Region

Table 69: Climate Zone 3: South Region—Deemed Summer Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.24	N/A
Average	0.39	N/A
High	0.55	N/A

Climate Zone 4: Valley Region

Table 70: Climate Zone 4: Valley Region—Deemed Summer Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Refrigerated Air	Evaporative Cooling
Low	0.15	N/A
Average	0.25	N/A
High	0.35	N/A

Climate Zone 5: West Region

Table 71: Climate Zone 5: West Region—Deemed Summer Demand Savings for Duct Efficiency, Alternate Approach (kW)

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

Deemed Winter Demand Savings Tables (Alternate Approach)

Climate Zone 1: Panhandle Region

Table 72: Climate Zone 1: Panhandle Region—Deemed Winter Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.19	0.03
Average	0.00	0.31	0.05
High	0.00	0.44	0.08

Climate Zone 2: North Region

Table 73: Climate Zone 2: North Region—Deemed Winter Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.23	0.16
Average	0.00	0.36	0.25
High	0.00	0.52	0.36

Climate Zone 3: South Region

Table 74: Climate Zone 3: South Region—Deemed Winter Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.20	0.11
Average	0.00	0.31	0.18
High	0.00	0.45	0.26

Climate Zone 4: Valley Region

Table 75: Climate Zone 4: Valley Region—Deemed Winter Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.15	0.09
Average	0.00	0.25	0.15
High	0.01	0.35	0.21

Climate Zone 5: West Region

Table 76: Climate Zone 5: West Region—Deemed Winter Demand Savings for Duct Efficiency, Alternate Approach (kW)

Category	Heating System Type		
	Gas	Electric Resistance	Heat Pump
Low	0.00	0.06	0.02
Average	0.00	0.10	0.02
High	0.00	0.15	0.03

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Example Deemed Savings Calculation

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

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

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

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

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

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

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

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

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

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

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

Additional Calculators and Tools

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a duct sealing measure is 18.0 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[112]

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
- Heating type (gas, resistance heat, heat pump)
- Cooling capacity of home HVAC units (tons)
- EESPs claiming savings according to duct leakage testing:
    - Pre-improvement duct leakage at 25 Pa (cu. ft./min)
    - Post-improvement duct leakage at 25 Pa (cu. ft./min)
- EESPs claiming savings without performing leakage testing should provide:
    - Description of the leakage severity in the home (low, average, or high)
    - Description of location and condition of ducts:
        - Duct location (>90% conditioned, 50-90% conditioned, <50% conditioned)
        - Existing duct insulation value (>R7, R4-R7, <R4)
    - Leakage characteristics (some observable leaks, substantial leaks, catastrophic leaks)
    - Other relevant details that may assist with validating claimed leakage category (recommended)
    - Description and photos of interventions taken (both pre and post condition), such as newly sealed joints, supply vents, and other relevant leaks sealed
    - Incentive rate structure: incentive should be paid per home and should not vary by leakage category to avoid providing an incentive to overstate the

[112] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/23-deer-versions/27-deer-2014

existing leakage category.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 77: Residential Duct Efficiency Improvements Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor formatting changes, and language introduced to provide further direction for low-income customers and testing procedure. Contractors now required to track cooling capacity of HVAC equipment. Language added to reflect updates to federal standards for central heat pumps and central air conditioners.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Update of reference sources for air temperatures and densities, heating degree-days. Cooling demand savings required to be claimed.
v4.0	10/10/2016	TRM v4.0 update. Approach changed from algorithm-based to deemed savings coefficients estimated using building simulation models. Updated energy and demand savings. Added separate savings for homes with evaporative cooling. Updated measure description to eliminate eligibility for homes without a central AC, but with a ducted heating system.
v5.0	10/2017	TRM v5.0 update. Remove PY 2017 option to use energy and demand adjustment factors in combination with algorithm methodology from TRM v3.1. Added alternative approach to bypass the need to complete leakage testing in guidance memo to follow.
v6.0	11/2018	TRM v6.0 update. Added alternative approach to bypass the need to complete leakage testing in guidance memo to follow.
v7.0	10/2019	TRM v7.0 update. Added clarifying language on incentive rate per home.

2.2.3 Ground Source Heat Pumps Measure Overview

TRM Measure ID: R-HV-GH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex, and triplex; multifamily; manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) meeting the minimum requirements of ENERGY STAR® Tier 3 geothermal heat pump key product criteria. The deemed savings are dependent upon the energy efficiency rating (EER) and coefficient of performance (COP) of the installed equipment. Savings calculations are presented for systems both with and without desuperheaters.

Eligibility Criteria

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

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

Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard,[113] effective January 1, 2015.

[113] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www.energy.gov/eere/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal

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.[114] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 78: Ground Source Heat Pump Baseline Efficiencies

Project Type	Cooling Mode[115]	Heating Mode[116]
New Construction	11.8 EER (14 SEER)	2.4 COP (8.2 HSPF)
ROB—Air Source Heat Pump Baseline	11.4 EER (13.08 SEER)	2.4 COP (8.2 HSPF)
ROB—Electric Resistance Baseline	11.4 EER (13.08 SEER)	1 COP (3.41 HSPF)

High-efficiency Condition

Table 79 displays the ENERGY STAR® requirements for eligible Tier 3 geothermal heat pumps as of January 1, 2012. Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 79: Ground Source Heat Pump ENERGY STAR® Tier 3 Requirements

Product Type	Cooling Mode (EER)	Heating Mode (COP)
Closed Loop Water-to-Air	17.1	3.6
Open Loop Water-to-Air	21.1	4.1
Closed Loop Water-to-Water	16.1	3.1
Open Loop Water-to-Water	20.1	3.5
Direct Geoexchange (DGX)	16.0	3.6

[114] Frontier Associates on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780." Public Utility Commission of Texas. Approved August 27, 2009. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

[115] Code specified EER value converted to SEER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

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

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[117]

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

Equation 37

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

Equation 38

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on ground source heat pumps in Texas.[118] Desuperheater savings were calculated for each climate zone by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high-efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to the replacement of air source heat pumps with ground source heat pumps. These estimates were found to be within 5 percent of actual post-retrofit savings. Building models were developed using TRNSYS.[119]

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

[117] Geothermal Heat Pumps Key Product Criteria, https://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps. Accessed February 2014.

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

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

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

These models were used to derive the energy and demand savings associated with installation of a desuperheater along with a ground source heat pump, as shown in Table 82 and Table 83, respectively.

Energy Savings Algorithms

$$kWh_{Savings} = kWh_{Savings,Summer} + kWh_{Savings,Winter} + kWh_{desuperheater}$$

Equation 39

$$kWh_{Savings,C} = CAP_C \times \frac{1\,kW}{1{,}000\,W} \times EFLH_C \times \left(\frac{1}{SEER_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

Equation 40

$$kWh_{Savings,H} = CAP_H \times \frac{1\,kWh}{1{,}000\,Wh} \times EFLH_H \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{3.412 \times COP_{GSHP}}\right)$$

Equation 41

Where:

$kWh_{desuperheater}$	=	*Energy savings (kWh) associated with installation of a desuperheater (see Table 82). These savings should only be added if a desuperheater is installed.*
CAP_C	=	*Rated equipment cooling capacity of the installed GSHP (Btu/hr)*
CAP_H	=	*Rated equipment heating capacity of the installed GSHP (Btu/hr)*
$EFLH_C$	=	*Equivalent full load hours for cooling)*
$EFLH_H$	=	*Equivalent full load hours for heating (Table 80)*
$SEER_{Base}$	=	*Seasonal Energy Efficiency Ratio of the baseline cooling equipment (Table 78)*
EER_{GSHP}	=	*Energy Efficiency Ratio of the installed GSHP*
$HSPF_{Base}$	=	*Heating Seasonal Performance Factor of the baseline heating equipment (Table 78)*
COP_{GSHP}	=	*Coefficient of Performance of the installed GSHP*

Table 80: Equivalent Full Load Cooling/Heating Hours[120]

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

Demand Savings Algorithms

$$kW_{Savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right) \times CF_C + kW_{desuperheater}$$

Equation 42

$$kW_{Savings,H} = CAP_H \times \frac{1\ kWh}{3{,}412\ Btu} \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right) \times CF_H$$

Equation 43

Where:

CAP_C = *Rated equipment cooling capacity of the installed GSHP (Btu/hr)*

CAP_H = *Rated equipment heating capacity of the installed GSHP (Btu/hr)*

EER_{Base} = *Energy Efficiency Ratio of the baseline cooling equipment (Table 78)*

EER_{GSHP} = *Energy Efficiency Ratio of the installed GSHP*

COP_{Base} = *Coefficient of Performance of the baseline heating equipment (Table 78)*

COP_{GSHP} = *Coefficient of Performance of the installed GSHP*

CF_C = *Coincidence Factor = (*Table 81*)*

CF_H = *Coincidence Factor = (*Table 81*)*

$kW_{desuperheater}$ = *Summer demand savings (kW) associated with installation of a desuperheater (see Table 83). These savings should only be added if a desuperheater is installed.*

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

Table 81: Ground Source Heat Pumps—Coincidence Factors for GSHPs[121]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.634	0.677	0.626	0.583	0.725
Winter	0.549	0.478	0.515	0.453	0.437

Deemed Energy Savings Tables

Table 82: Energy Savings for Desuperheaters

Climate Zone	kWh/ton
Climate Zone 1: Panhandle	612
Climate Zone 2: North	791
Climate Zone 3: South	802
Climate Zone 4: Valley	847
Climate Zone 5: West	791

Deemed Summer Demand Savings Tables

Table 83: Summer Peak Demand Savings for Desuperheaters

Climate Zone	kW/ton
Climate Zone 1: Panhandle	0.440
Climate Zone 2: North	0.405
Climate Zone 3: South	0.405
Climate Zone 4: Valley	0.410
Climate Zone 5: West	0.405

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

[121] See Volume 1, Appendix B.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a high-efficiency ground source heat pump unit is 20 years.

This value is consistent with the EUL reported in the Department of Energy GSHP guide.[122]

Program Tracking Data and Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Climate zone
- Decision/action type (new construction, replace-on-burnout)
- Replaced unit type (heat pump, electric resistance)
- Cooling and heating capacity (Btu/hr)
- Energy Efficiency Ratio (EER) of the unit installed
- Coefficient of Performance (COP) of the unit installed
- Whether a desuperheater was also installed or present
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Manufacturer, model, and serial number
    - AHRI certificate matching model number

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ISO/AHRI 13256-1
- Shonder, J. A., Hughes, P., and Thornton, J. Development of Deemed Energy and Demand Savings for Residential Ground Source Heat Pump Retrofits in the State of Texas. Transactions-American Society of Heating, Refrigerating, and Air Conditioning Engineers. 108, no. 1: 953-961, 2001.
- The applicable version of ENERGY STAR®'s specifications and requirements addressing residential ground source heat pumps.

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

Document Revision History

Table 84: Residential Ground Source Heat Pumps Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Updated by Frontier Associates, March 2014, based on new federal standards and alternative methodology.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updates to tracking requirements.

2.2.4 Central Air Conditioner and Heat Pumps Measure Overview

TRM Measure ID: R-HV-CT

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex, and triplex; multifamily; manufactured

Fuels Affected: Electricity

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

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 air conditioner or heat pump in an existing building, or the installation of a new central air conditioner or heat pump 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 heat pumps that meet all existing measure eligibility criteria.

Eligibility Criteria

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

Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer datasheets for installed equipment or AHRI reference numbers must be provided. Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI 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.

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

For early retirement projects, in order 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.

The replacement of an evaporative cooler with a central 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.[123] For system upsizing, savings should generally be claimed against the new construction baseline. However, when upsizing while going from a single larger capacity system to multiple smaller capacity systems, savings may be claimed against the applicable replace-on-burnout or early retirement baseline if the total pre and post tonnage are within ½ ton.[124] For this scenario, savings must be looked up using the lower pre-tonnage. If the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

Additionally, low-income or hard-to-reach programs may use the electric resistance baseline for systems upsized by no more than a half-ton 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 requirements outlined in this measure.

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 Air Conditioner or Heat Pump

New construction baseline efficiency values for air conditioners or heat pumps are compliant with the current federal minimum standard,[125] effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to central heat pump installations replacing air conditioners with central gas heat,

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[123] For projects using a custom baseline see TRMv6.0 Volume 4.

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

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

evaporative coolers with central, space, or no heating, or room/window air conditioners 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.[126]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER.

For ROB projects, heating baseline efficiency values for heat pumps 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).[127] 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.[128] 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

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.41.[129] 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.

[126] Frontier Associates on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780." Public Utility Commission of Texas. Approved August 27, 2009. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

[127] *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. Accessed February 2014.

[128] Ibid.

[129] 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 85: Central System Baseline Efficiencies

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

High-efficiency Condition

Table 86 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 1 heat pumps as of January 1, 2009. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 1 requirements.

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

Table 86: Central System CEE Tier 1 Requirements

SEER	EER	HSPF
14.5	12.0	8.5

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Replace-on-burnout or New Construction

Energy, summer demand, and winter demand savings were estimated using air conditioner and heat pump performance curves developed by the National Renewable Energy Laboratory[130] for typical units in each of the following SEER ranges:

- Baseline units
- 14.5–14.9
- 15.0–15.9

[130] 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

- 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 the heat pump 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 heat pump 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 heat pump capacity. Heat pump system output was then compared to its loading under design conditions.

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 44

Table 87: Air Conditioner and Heat Pump Capacity Curve Coefficients[131]

Coeff.	Cooling			Heating		
	Single Stage	Multi-stage/Speed Low	Multi-stage/Speed High	Single Stage	Multi-stage/Speed Low	Multi-stage/Speed 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

131 Using air conditioner capacity curve coefficients for heat pump cooling savings.

Coeff.	Cooling			Heating		
	Single Stage	Multi-stage/Speed		Single Stage	Multi-stage/Speed	
		Low	High		Low	High
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

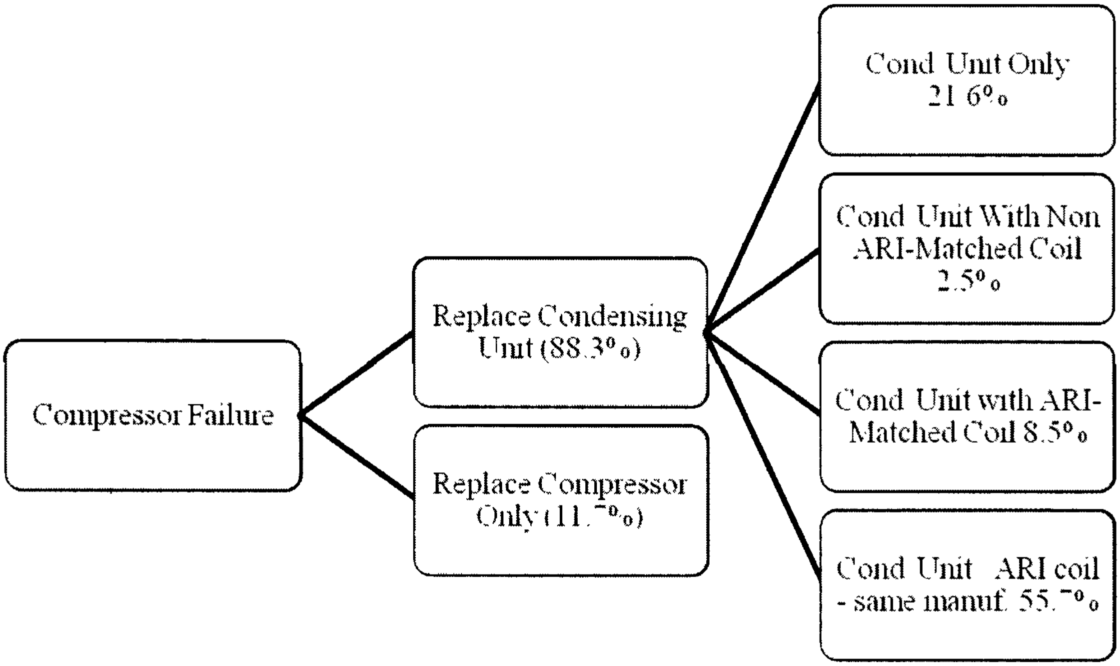
Table 88: Air Conditioner and Heat Pump EIR Curve Coefficients[132]

Coeff.	Cooling			Heating		
	Single Stage	Multi-stage/Speed		Single Stage	Multi-stage/Speed	
		Low	High		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:

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

Figure 1: 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:

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

Equation 45

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 (15—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 89 *or* Table 90*) or if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 7.0 (ACs) or 6.0 years (HPs). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. For heat pumps replacing an air conditioner with an electric resistance furnace, use the RUL table from the Central Air conditioner measure instead.*

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

Table 89: Remaining Useful Life of Replaced Air Conditioner

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

Age of Replaced Unit (Years)	Remaining Useful Life (Years)	Age of Replaced Unit (Years)	Remaining Useful Life (Years)
12	9.4	25[133,134]	0.0
13	9.0		

Table 90: Remaining Useful Life of Replaced Heat Pump

Age of Replaced Unit (years)	Remaining Useful Life (years)	Age of Replaced Unit (years)	Remaining Useful Life (years)
1	13.7	12	7.9
2	12.7	13	7.6
3	12.0	14	7.0
4	11.3	15	6.0
5	10.7	16	5.0
6	10.2	17	4.0
7	9.7	18	3.0
8	9.3	19	2.0
9	8.9	20	1.0
10	8.5	21[135,136]	0.0
11	8.2		

Derivation of RULs

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

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

[134] 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.

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

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

Figure 2: Survival Function for Central Air Conditioners[137]

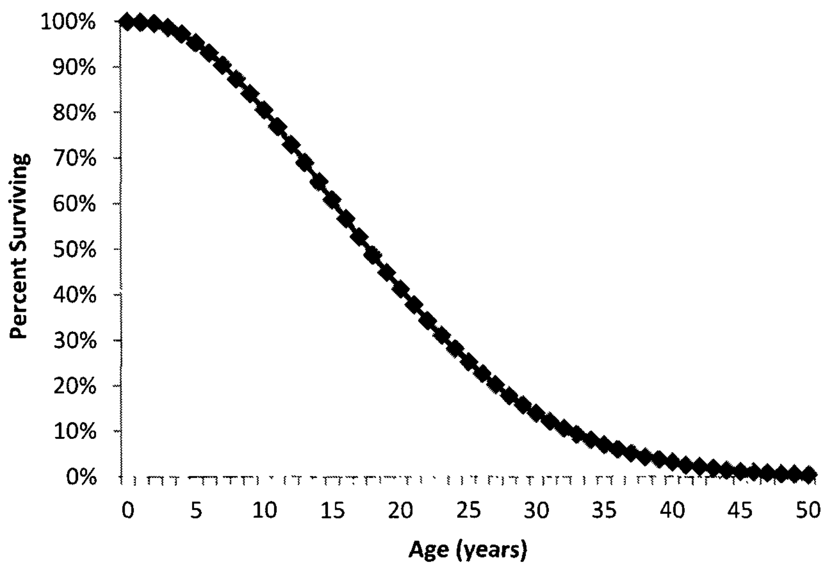
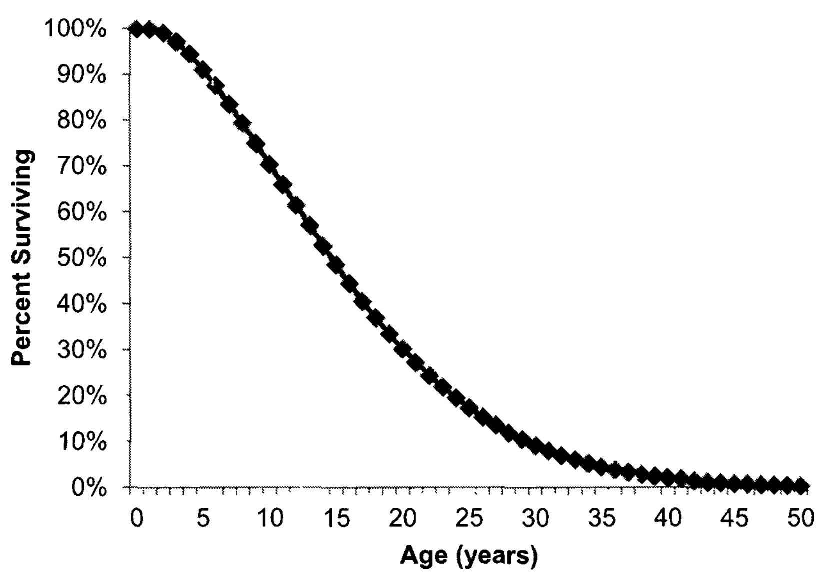


Figure 3: Survival Function for Central Heat Pumps[138]



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[137] 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.

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

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 3. The age of the central 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[139]

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.[140]

Deemed Summer Demand Savings Tables[141]

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.[142]

Deemed Winter Demand Savings Tables[143]

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.[144]

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

[139] 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).

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

[141] 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).

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

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

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